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HOW TO MEASURE AND MODEL SOCIAL AND EMPLOYMENT OUTCOMES OF CLIMATE AND SUSTAINABLE DEVELOPMENT POLICIES

TRAINING GUIDEBOOK

Green Jobs Assessment Institutions Network (GAIN)

Greening with jobs

THE GREEN JOBS PROGRAMME

GAIN Training Guidebook

How to measure and model social and employment outcomes of climate and sustainable development policies

Green Jobs Assessment Institutions Network

2017

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Introduction

All around the world climate change, policies to respond to it, and the related economic restructuring have deep implications for jobs. In fact, the social and employment outcomes of climate-related policies are vitally important to people around the world and can have far reaching implications for elections, international climate agreements and sustainable development strategies.

Thus, understanding the social and employment outcomes of the response to climate change is essential for policy-makers. Policy-makers want to know about potential job outcomes in order to design strategies that maximize job creation, minimize job losses and ensure a just transition for all in the process of restructuring.

Tools such as statistical databases and economic models are needed to quantify, qualify and project social and employment outcomes of policy alternatives. Input–output and social accounting matrix based models are planning tools well suited to analysing the impacts on jobs and income distribution. They make possible the analysis of direct, indirect and induced job effects at the sector level. They are based on national accounts and data collected at the country level. They are transparent, accessible and relatively easy to build.

The ILO initiated the Green Jobs Assessment Institutions Network (GAIN) in 2012 to support development of training tools that enhance the capacity of national institutions to build county-specific green employment projection models. Members of GAIN are international and national public and private policy research institutions, universities, and policy research oriented entities within government and in employers' and workers' organizations. By enhancing the capacity of their institutions, countries will acquire the ability to develop the statistical database, the economic model and the knowledge to use their own employment projections for national development planning centred on promoting decent work.

This training guidebook has been produced to serve that purpose. The main intended audiences of the training guidebook are policy-makers (Module 1) and statisticians, analysts and researchers (Modules 2–4) in ministries of finance, planning, labour and environment, national statistics offices, employers' and workers' organizations, research institutions and universities, and international organizations. Through the GAIN network and this training guidebook, countries, in partnership with ILO, can establish national technical working groups able to guide the building of the models and the analysis of alternative policy scenarios. Module 1 (Policy) is geared to policy-makers and social partners. Module 2 (Statistics) is geared to statisticians but also to researchers and economic modellers, who are the also the intended audiences of Module 3 (Input–output) and Module 4 (Social accounting matrixes).

After reading Module 1, policy-makers will understand what green employment projection models are and how they will help with designing and refining policies. Module 2 enables statisticians to use labour force and establishment surveys to provide statistics on the structure of green industries (with a focus on intermediate consumption and value added) and on employment in green industries. Module 3 will teach researchers about the basics of input–output tables, the technique of expanding input–output tables to feature green industries, and how to build a static comparative employment projection model. Module 4 expands the capacity of learners to assess income distribution effects using supply and use tables and social accounting matrixes.

In terms of training roll-out, this training guidebook can be introduced into national teaching institutions that would serve as regional-hubs supported by ILO and GAIN trainers. Ideally, over time institutions would formalize such training in national curricula or as an elective in a university programme. It could become an economics course or elective for bachelor- or masters-level students. Otherwise, recurrent standalone summer courses may be offered to students and researchers. In addition, based on country requests and needs, training using the training guidebook may be offered on a short-term basis.

Acknowledgements

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Green Jobs Assessment Institutions Network (GAIN)

Training module 1:

Introduction to Green Economy and Labour Market Assessments

Contents

1. Concepts and definitions

Key questions

- What is meant by a transition to greener economies?
- What are other concepts pertaining to employment in the transition to greener economies?

Important observations

- A green economy is one of the tools for achieving sustainable social, economic and environmental development.
- In addition to “green economy”, many other concepts are used in the literature and policy debates – for example, “green growth”, “low-carbon economy”, “low-emissions development”, sometimes with qualifiers such as “inclusive”, “pro-poor” or similar notions.
- Green jobs not only contribute to preserving or restoring environmental quality but also must be decent jobs.

What is a green economy? The United Nations Environment Programme (UNEP) has defined it as **an economy that improves human wellbeing and social equity while significantly reducing environmental risks and ecological scarcities**. In a green economy growth in income and employment are driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services (UNEP, 2011). A green economy can therefore be thought of as one which is low carbon, resource efficient and socially inclusive.

The 2012 Rio+20 Conference concluded that a green economy is one of the tools for achieving sustainable social, economic and environmental development. Rio+20 noted that this approach can be tailored to local and regional development needs while contributing to meeting broader international obligations and targets. The Rio+20 outcome document “encourage[d] each country to consider the implementation of green economy policies in the context of sustainable development and poverty eradication, in a manner that endeavours to drive sustained, inclusive and equitable economic growth and job creation, particularly for women, youth and the poor” (United Nations, 2012). It noted the importance of ensuring that workers are equipped with the necessary skills, including through education and capacity-building, and are provided with the necessary social and health protections. It encouraged all stakeholders, including business and industry, to contribute as appropriate. It invited “governments to improve knowledge and statistical capacity on job trends, developments and constraints and integrate relevant data into national statistics, with the support of relevant United Nations agencies within their mandates”.

> Well over a billion jobs are at risk in the sectors most threatened by environmental degradation, such as agriculture, forestry and fisheries.

A greener economy, as a way to achieve sustainable development, is not just good for sustainable enterprises and labour markets; it has become necessary. Continuing depletion of natural resources and pollution of the environment will increase the scarcity of fresh water and fertile land and accelerate climate change and the loss of biodiversity beyond manageable levels. The damage to economies and to society caused by environmental degradation could undo many of the gains in development and poverty reduction achieved over the past decades. Wasteful production and consumption patterns, along with continued soil degradation, deforestation, overfishing and climate change, will result in increasing water shortages and increasing prices for food, energy and other

Policy definition of green jobs

A report by the International Labour Office (ILO) and the United Nations Environment Programme (UNEP), *Green jobs: Towards decent work in a sustainable, low-carbon world* (2008), defined green jobs as:

> ...work in agricultural, manufacturing, research and development (R&D), administrative and service activities that contribute substantially to preserving or restoring environmental quality. ... Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity, reduce energy, materials and water consumption through high efficiency strategies, de-carbonize the economy and minimize or altogether avoid generation of all forms of waste and pollution.

More precisely, green jobs are decent jobs that:

1. reduce consumption of energy and raw materials;
2. limit greenhouse gas emissions;
3. minimize waste and pollution;
4. protect and restore ecosystems; or
5. contribute to adapting to climate change.

According to the ILO, green jobs must be not only green but also decent, i.e., jobs that are productive, provide adequate incomes and social protection, respect the rights of workers and give them a say in decisions that will affect their lives. The broader definition of green jobs currently used by the ILO Green Jobs Programme reflects this perspective:

Jobs are green when they help reduce negative environmental impact, ultimately leading to environmentally, economically and socially sustainable enterprises and economies.

Module 2 provides a statistical definition of green jobs.

commodities. And, crucially, well over a billion jobs are at risk in the sectors that are most threatened by environmental degradation, such as agriculture, forestry and fisheries (ILO, 2012).

Continuation of “business as usual” will impede economic growth and job creation. In contrast, a well-executed transition to a green economy will enhance economic growth. A green economy will grow faster than an economy in the “business-as-usual” scenario (UNEP, 2011).

Underlying concepts

A key question underpinning the rationale for moving to greener economies is the question of resource pricing. Conventionally, economics has considered financial and human capital as the factors of production, ignoring natural capital and its contribution to production. Natural capital refers to natural resources, such as forests, agricultural land, fisheries and water. It can be understood as the stock of ecosystems that supply economically useful services to society (ten Brink, 2012). While the use of such resources in the production of economic goods and services entails costs, such costs typically fall outside the market mechanism and are, therefore, termed negative environmental externalities. Because these costs are external to the market mechanism, the private costs of production tend to be lower than its social cost. The fact that market prices do not reflect environmental (and social) costs is often referred to as a “market failure”. To try to correct for this failure, some economic and environmental policies apply a “polluter (or user) pays” principle to incorporate these costs into the

Definition of “externality”: An externality exists when a person makes a choice that affects other people in a way that is not accounted for in the market price.

price of goods and, thus, prompt households and enterprises to internalize them in their plans and budgets (United Nations, 1997).

The size of externalities can be significant. Trucost (2013) reviewed the top 100 externalities for business, including pollution, water and land use, and waste. This report found that greenhouse gas emissions account for a significant part of unpriced natural capital costs (38 per cent), followed by water use (25 per cent), land use (24 per cent), air pollution (7 per cent), land and water pollution (5 per cent) and waste (1 per cent).

An important related concept is that of the "tragedy of the commons", popularized by the ecologist Garrett Hardin (1968). The tragedy of the commons is an economic theory that describes the situation of a shared-resource system in which individual users act independently, according to their own self-interest and, thus, collectively deplete that resource, contrary to the common good of all users.

An entire field of economic theory has grown up around concepts such as "natural capital", the "economics of ecosystems" and "ecological footprint". These theories focus attention on the economic and intrinsic values of natural capital in economics, business management and policy making.

Intended users for this module

This module is intended for policy-makers and for other decision-makers involved in the planning, formulation and implementation of policy. The users are not expected to be technical experts in modelling and not necessarily those who undertake the assessment work. Rather, they are those likely to commission or mandate assessments and to receive the results of assessments.

Learning objectives of this module

- understand the rationale, in terms of employment, for a transition to greener economies;
- learn the nature and scale of the major structural transformation, macro-economic and labour market implications of the greening of economies;
- understand the importance of quantitative assessment prior to, in the process of, and following the formulation and implementation of policies for a transition to a green economy;
- become familiar with assessment tools and methods that are useful for purposes of policy and planning for a transition to a green economy, what each method can and cannot do, and how to interpret the results of assessments.

Structure of this module

This module consists of six chapters:

Chapter 1 introduces concepts and definitions.

Chapter 2 explains the rationale and drivers for a transition to greener economies.

Chapter 3 discusses countries strategies and policies to promote greener economies.

Chapter 4 considers the implications for employment of greener economy policies.

Chapter 5 discusses the use of assessment to inform policy decisions.

Chapter 6 presents a review of assessment tools and methods.

2. Transition to greener economies – economic, social and environmental drivers

Key questions

- What are the main drivers of a shift to greener economies?
- Why are these drivers important for employment?

Important observations

- A number of economic, social and environmental factors act as drivers in the shift to greener economies.
- The impact of each driver – environmental factors, policies and regulations or market-related factor including consumer preferences depends on country contexts.

A set of economic, social and environmental factors operating through interrelated cause-and-effect mechanisms are increasingly creating the necessity for individual countries, and the international community as a whole, to seek a transition to economies and societies that produce fewer carbon emissions, are more resilient to the impacts of climate change, and are more efficient in the use of energy and other natural resources. These factors and circumstances, or drivers, can be grouped into five categories:

- degradation of the environment and ecosystems, and the public goods functions they provide, such as clean air, fresh water and carbon sequestration, with adverse effects on economic activity and human health;
- important and rapid changes in public and private investments, consisting of a growth of investments in clean energy, on one hand, and a trend of disinvestment in fossil fuels, on the other;
- shifts in public policies aiming to accelerate the transition towards more sustainable economies;
- changing consumer preferences that reflect growing awareness about environmental protection and sustainability considerations; and
- innovation and technological developments leading to gains in energy and material efficiency.

The following pages explore each of these categories.

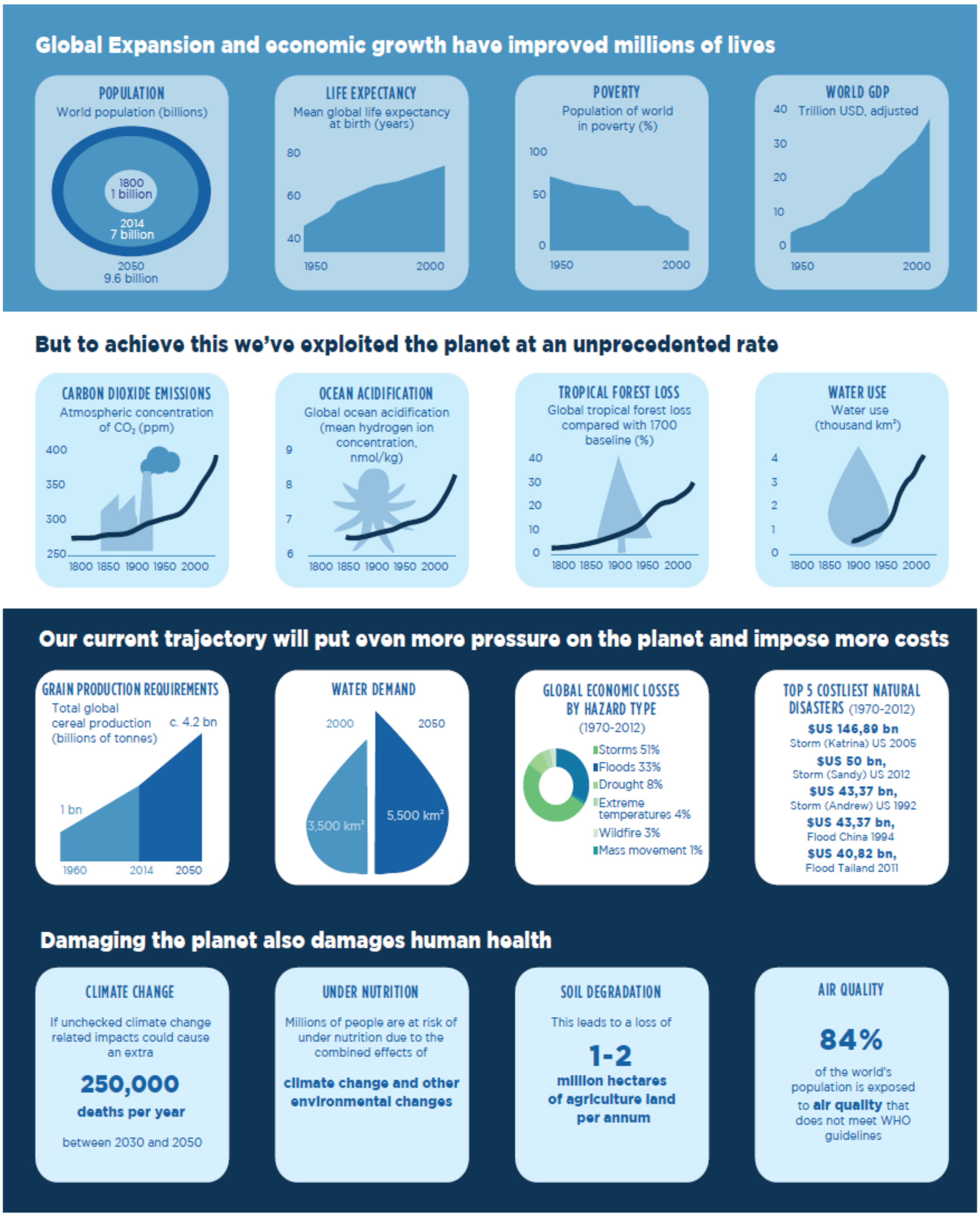
2.1 Resource scarcity, climate impacts and pollution

> Humanity is simply using more than the planet can provide.

Resource scarcity. If current patterns of resource consumption remain unchanged, water, fossil fuels, wood and agricultural products are likely to become too scarce by 2050 to ensure productive work and life for a projected world population of 10 billion people. Beginning in the mid-1970s, human consumption of resources began outstripping the pace at which the planet can replenish water, fauna and flora (Global Footprint Network, 2017). Humanity is simply using more than the planet can provide (Figure 2.1).

The concept of ecological footprint is an ecological accounting system to measure how much biologically productive area people use for their consumption (of fruits and vegetables, fish, wood, fibres, etc.) relative to how much biologically productive area is available. The Global Footprint Network, founded in 2003 as an independent think tank, calculates the global ecological footprint. It uses the concept of Earth Overshoot Day, marking the date when humanity has exhausted nature's budget for the year.[1] In 2014 Earth Overshoot Day was 19 August. The date moves earlier every year, signalling increasing overpressure on natural resources. In 2017 it was 2 August.

Figure 2.1 Economic growth and environmental sustainability



Source: Adapted from sharegraphic at http://www.thelancet.com/infographics/planetary-health. Additional data from World Bank, 2015. The Little Green Data Book, 2015. Washington, D.C., World Bank, and UNEP, The coming financial climate – the inquiry's 4th progress report, 2015.

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[1] http://www.overshootday.org/

Climate change disasters, job destruction and forced migration. Natural disasters have been growing in both frequency and severity. In 2007 cyclone Sidr disrupted several hundred thousand small businesses and adversely affected 567,000 jobs in Bangladesh. Similarly, typhoon Hagupit, which hit the Philippines in December 2014, affected approximately 800,000 workers. The economy of the United States of America lost 33,000 jobs in the aftermath of Hurricanes Harvey and Irma, which hit the country in September 2017 – the first job decline in seven years (Washington Post, 2017).

In addition, so-called “slow climate change onset” events are affecting large areas of land and productive assets, causing massive migration and disrupting formal and informal jobs and enterprises in rural and urban areas, including those of vulnerable groups – notably, women, children, youth, indigenous people and disabled people. Globally, in 2008 alone 20 million people were forced from their homes by extreme weather events, compared with 4.6 million internally displaced by conflict and violence. Forecasts predict a total of 25 million to 1 billion people will migrate between 2010 and 2050 due to environmental conditions, making these the single most important cause of migration (IOM, 2009).

In several parts of the world, the stress of excessive heat is reducing workers’ productivity and causing ill health and even deaths. In developing countries with high heat exposure, a productivity decline of up to half of normal levels has been reported for certain categories of working people, particularly those in outdoor work such as construction and agriculture (Climate Vulnerable Forum, 2016).

The true cost of pollution. Air pollution in industrial China is estimated to reduce life expectancy by as much as 5 years and to cause significant reductions in workers’ productivity (Council on Foreign Relations, 2016). An estimated 10 per cent of Chinese agricultural soil is considered too polluted to farm. According to 2016 estimates from the World Health Organization, an estimated 12.6 million people died in 2012 as a result of living or working in an unhealthy environment – nearly one of every four deaths globally. Air pollution, in particular, killed 8 million (WHO, 2016).

2.2 Changing patterns of investment

Growing green investment. An unprecedented growth in green investments is underway**.** In 2015 investments in renewable energy reached US$285 billion – for the first time more than in oil, gas and coal. China accounted for US$102 billion of this. Developing countries’ investments are greater than those of countries of the Organisation for Economic Co-operation and Development (OECD) (Frankfurt School–UNEP Centre, 2016). In a similar vein energy efficiency investments in 2011 were USD 300 billion. In Europe every 1 million Euros invested in renewable energy create net 8 to 27 jobs**.**

Less investment in fossil fuels. In contrast, there is a growing wave of pulling investments out of fossil fuels. In 2015 Norway’s parliament confirmed the divestment of 900bn sovereigns from the country’s wealth fund, the largest fossil fuel divestment to that date, affecting 122 companies across the world (The Guardian, 5 June 2015). Other major global initiatives are making significant shifts away from fossil fuel investments. Under the aegis of UNEP-Finance Initiative’s Portfolio Decarbonization Coalition, 25 institutional investors have committed to fighting climate change by decarbonizing US$600 billion of assets.[1] Increasingly, investors, including institutional investors, realize and fear that fossil fuel investments might become stranded assets. Even oil and gas majors have started to diversify their energy investments into renewables.

[1] UNEP–FI Portfolio Decarbonization Coalition, http://unepfi.org/pdc/

In the field of development finance, the World Bank announced in September 2015 a new "carbon pricing leadership coalition" that would rally 73 countries (representing almost half of the world's population and 52 per cent of global Gross Domestic Product (GDP)) and more than 1,000 companies and investors that support a price on carbon.[1] In 2014, for the first time in 40 years in the absence of recession, carbon emissions from the energy sector did not increase. This was the combined effect of the growth of investment and installed capacity in renewable energy, policies limiting carbon emissions and promotion of energy efficiency (International Energy Agency, 2014).

Businesses change production. Driven by productivity gains and market opportunities, businesses are changing production. Global companies such as Renault, Veolia, Unilever, Kingfisher, Philips, Deutsche Post and many others are moving towards circular production systems such as "product-service systems". Such product-service systems aim to move away from a cycle of produce-use-discard towards a cycle of produce-use-reuse. Such a shift will increase employment. For example, McKinsey estimates that in Europe adopting currently available technology for a circular production system in food, mobility and housing alone would increase GDP growth by 7 percentage points by 2030 over a business-as-usual scenario (McKinsey, 2016).

2.3 Policy, innovation, prices and consumer choices

A third category of driving factors relates to public policies, accelerating innovation and technological development. These are bringing the price of clean energy down and so change consumer preferences to favour more environmentally sustainable products and services.

Major policy changes. Important global policy frameworks were adopted in 2015, in particular the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change. These agreements have profound implications for the world of work. In the Paris Agreement, reached at the 21st session of the conference of the Parties to the United Nations Framework Convention on Climate Change (COP21), 195 countries committed to mitigation and adaptation to climate change, with a goal of keeping global average temperature rise below 2 degrees Celsius and striving for no more than 1.5 degrees above pre-industrial levels. This is considered necessary to avoid irreversible human interference with the climate system. To achieve these goals, renewable energy needs to grow to 80 per cent of the total energy mix by 2050, with a nearly total phase-out of fossil fuels by 2100 (Intergovernmental Panel on Climate Change, 2014). In addition, the Parties to the Agreement committed to contributing a minimum of US$100 billion by 2020 to a Green Climate Fund. The Fund is meant to finance programmes that can lead to transformation in economic and social systems to mitigate and adapt to the effect of climate change. The 2030 Agenda includes the Sustainable Development Goals (SDGs). The SDGs include several goals related to sustainable energy, natural resource use, resource efficiency and responsible consumption. These goals and their targets will affect employment in many ways, including through changes of supply and demand of goods and services.

The energy sector is illustrative of the wave of policy changes taking place around the world. As of early 2015, at least 164 countries had renewable energy targets, and an estimated 145 countries had renewable energy support policies (REN21, 2015). In addition, important targets are being set for energy efficiency. For example, China's 13th Five-Year Plan, for 2016–2020, seeks a 15 per cent cut in energy consumption per unit of GDP and an 18 per cent reduction by 2020 in carbon intensity compared with 2015 levels (Climate Home, 2016). These measures point to a growing realization that decoupling economic growth from pollution is possible and necessary.

Green technological innovation and price changes. The combined effects of the falling cost of renewable energy and of green technological innovation are changing the landscape of energy

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[1] http://www.carbonpricingleadership.org/

supply. Across the world renewable energy, notably wind, solar, biomass and geothermal, has become cost-competitive with fossil fuels and in many instances cheaper. In Australia, the country with the world's fourth largest coal reserves, in 2013 producing electricity from onshore wind energy was 14 per cent cheaper than new coal and 18 per cent cheaper than new gas. In Egypt a recent tender for onshore wind-generated electricity resulted in bids as low as US$.04 per kilowatt hour, compared with US$.07–.19 for fossil power plants, including externalities. Solar module prices worldwide have dropped 75 per cent since 2009. For example, a German solar photovoltaic (solar PV) rooftop system cost roughly €14,000/kW in 1990. At the end of 2015 the price was less than one-tenth that amount, at €1,300/kW (IRENA, 2015). According to Bloomberg New Energy Finance, in the Americas nuclear power costs more than three times as much to produce, on average, as wind, solar PV and small hydro power.

Consumers' changing taste for green. Driven by health and sustainability concerns, consumers are changing their consumption patterns towards more green products and services. This trend is more pronounced in high-income countries. A European enterprise survey asking, "What is the reason for offering Green products and services?" found that 48 per cent of managers first cited customers' changing taste and their increasing demand for green products as a reason for going green.

3. Country strategies for green growth

Key questions

- How are governments formulating strategies and policies for greener economies that feature employment and social dimensions?
- What are examples of economy-wide strategies or sector-specific initiatives, and what lessons have been learned from such policies?

Important observations

- Countries follow various approaches and strategies with different appellations, e.g., green economy, green growth, low-carbon strategies.
- Policies for greener economies to do not produce job gains by default. Positive employment outcomes can be achieved by design as part and parcel of green economy strategies and policies.

A number of countries have formulated and adopted strategies and policies to transform their economies and societies in a sustainable manner, achieve economic growth, create jobs and reduce poverty without undermining the environment and depleting the natural resource base.

3.1 Comprehensive country strategies

The report titled *Uncovering pathways towards an inclusive green economy*, provides a framework of possible elements in a strategy for creating an inclusive green economy (UNEP, 2015). An inclusive green economy is based on sharing, circularity, collaboration, solidarity, resilience, opportunity and inter-dependence. The design principles for an inclusive green economy speak to these elements of a socio-ecological and economy-wide transition. They call for economic and fiscal policy reforms, legislative changes, new technologies, changes in financing and strong institutions that are specifically geared to safeguarding social protection floors and the ecological resource base. These design principles include the following:

Summary: Ten guidelines for a strategy to create an inclusive green economy

1. Focus on jobs and the economy.
2. Focus on public wealth.
3. Invest in ecological infrastructure.
4. Operationalize the precautionary principle.
5. Innovate for sustainability.
6. Conserve natural resources.
7. Develop human resources.
8. Build institutions.
9. Focus on both the long term and the short term.
10. Make micro-policy reforms.

Source: UNEP, 2015

Focus on jobs and the economy: Seek economy-wide, cross-sectoral transformation by addressing all dimensions of sustainability – economic, social and environmental – hence "promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all".

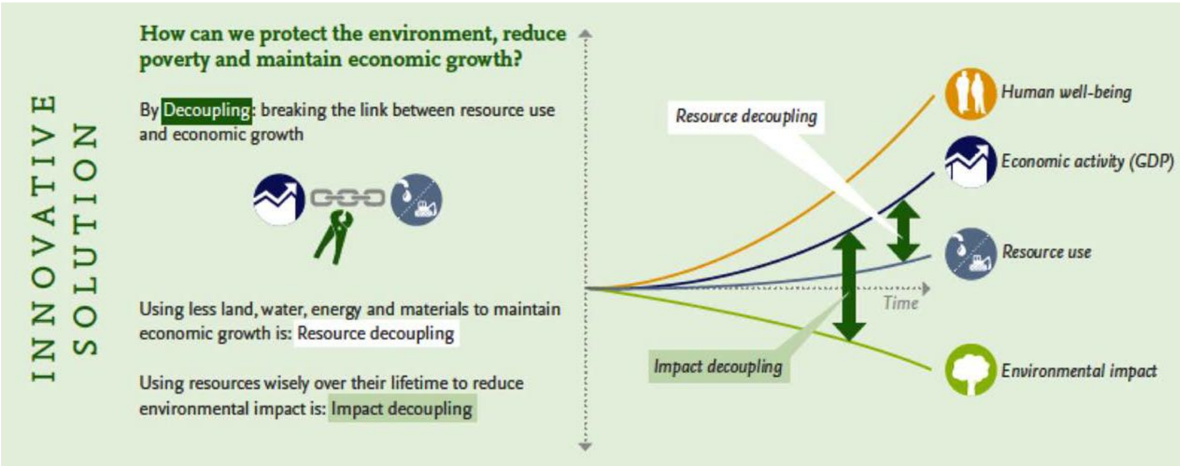
Focus on public institutions and structures: Develop, maintain and invest in public wealth – i.e., physical and ecological infrastructure, constitutions, laws (e.g., property rights and environmental legislation) and corporate governance standards.

Invest in ecological infrastructure: Among public assets, recognize the central role of healthy ecosystems to secure long-term human wellbeing, economic opportunity and improved social outcomes. Recognize, measure and respond to the economic significance of ecosystem services as a large fraction of the “GDP of the poor” in rural contexts in the developing world.

Operationalize the precautionary principle: Recognizing today’s risks as tomorrow’s costs to wellbeing, legislate protective action or precautions even in the absence of complete scientific proof of major ecological risks and health risks arising from an economic activity.

Innovate for sustainability: Recognize economic, social and environmental opportunities in all forms of innovation – social, institutional, financial and technological. Incentivize and invest in an innovation-based inclusive green economy that will produce with less, remanufacture more, reuse, recycle and restore and so set the stage for evolution towards a truly “circular economy”, an economy of permanence (Figures 3.1 and 3.2).

Figure 3.1 Decoupling resource use and economic growth requires innovative solutions



Source: Secretariat of the International Resource Panel, cited in UNEP, 2015

Conserve natural resources: Promote resource efficiency, sustainable natural resource management and sustainable consumption and production to address concerns of resource security.

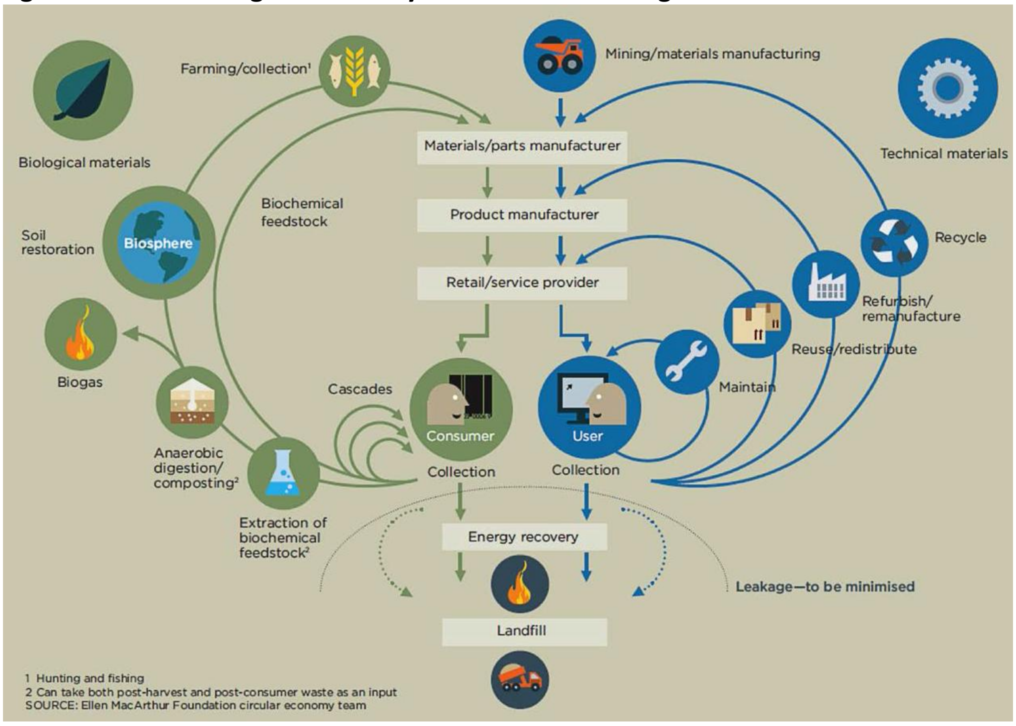
Develop human resources: Invest in human capabilities to enable people to determine outcomes and live their lives with dignity. Missing capabilities misaligns the economy, environment and society and leads to unsustainable development.

Build institutions: Invest in effective legislation and strong institutions for governance at local, regional and national levels, while ensuring transfers of knowledge and finance between these levels; ensure buy-in to green reform by providing clear fiscal stakes at different levels of government; encourage collaboration among ministries.

Focus on both the long term and the short term: Broaden the focus of policy reforms, incentives, subsidies and market regulations from short-term stability to long-term resilience to address the real horizons of most sustainability challenges and to align financial markets and the real economy with the long-term interests of humanity.

Make micro-policy reforms: Today, private sector choices largely determine resource use and economic direction, but regulations influence and incentives motivate firms to make choices. Identify and implement effective “micro-policy” reforms in key areas (such as corporate taxation, financial reporting, advertising standards, limits to leverage, etc.) so that the private sector can be generating gains, not losses, in public wealth.

Figure 3.2 Envisioning an economy that is circular and green



Job creation is a central element in most strategies for moving towards greener economies. As a result the constituents of the ILO, who are representatives of governments, employers and workers' organizations, have produced, through a tripartite process, the *Guidelines for a just transition towards environmentally sustainable economies and societies for all* (ILO, 2015). These guidelines suggest a set of actions for governments and social partners to ensure effective policy formulation, implementation and monitoring that address the employment and social dimensions of the transition to green economies. The main points suggested are summarized below.

Alignment of economic growth and environmental objectives

The incorporation of job-rich and environmentally sustainable macroeconomic policies into national action plans helps to signal long-term commitments and to articulate targets. This includes establishing long-term financing requirements under different scenarios to ensure that adequate funding and commitments are in place to mitigate the risk that austerity measures will divert these funds to other purposes.

Setting social and employment goals

Setting social and employment goals, targets and indicators, as many countries have done, is essential (Tables 2.1 and 2.2). Still, outcomes will often depend on the process of policy design and implementation as well as on the policy's content. A review of green growth best practices (GGBP, 2013) suggests that inclusive processes that involve not only governments but also the private sector, employers, workers, local communities and civil society can lead to better outcomes.

Using market based instruments

The use of taxes, permits, subsidies, guaranteed prices and loans on favourable terms are examples of market-based instruments at the disposal of governments. Market-based instruments require sufficient funding allocations for effective and efficient monitoring and evaluation, with an eye to revenue management and enforcement.

Using regulations

Regulations are required to enforce guidelines and targets. These can take the form of quotas, standards or norms. All of these require monitoring and enforcement. Such regulations can also help to establish enabling environments for the private sector through, for instance, protective trade policies for infant green industries and to encourage and facilitate green innovation and job creation.

Table 3.1 presents examples of various countries' green growth strategies and their employment goals.

Table 3.1 Examples of green growth strategies including employment goals

Country	Examples of comprehensive green economy or green growth initiatives
Barbados	The National Strategic Plan 2006–25 includes "Building a green economy – Strengthening the physical infrastructure and preserving the environment" and "Building social capital" as two of six strategic goals. The plan includes strategies to create new businesses and expand existing enterprises on a sustainable basis, supported by a modern, synergistic manpower planning framework for decent work and the creation of quality jobs.
Chile	Chile launched the National Green Growth Strategy in December 2013, outlining a set of actions over the short, medium and long term (2014–22). Actions include implementing environmental management instruments, promoting the market for environmental goods and services and monitoring and measuring progress.
China	The 12th Five-Year Plan (2011–15) set as key themes the rebalancing of the economy, reducing social inequality and protecting the environment. There are plans to invest US$468 billion in greening key economic sectors, in particular waste recycling and reutilization, clean technologies, and renewable energy. An estimated 35,000 enterprises and institutions in environment protection and its related industries employ 3 million workers. Employment and skills policies for green jobs are in preparation.
European Union	Europe 2020 (2010–20), a European strategy for smart, sustainable and inclusive growth, sets key targets covering employment, education, research and innovation, social inclusion, poverty reduction and climate/energy. Employment targets include the following: 75 per cent of the population ages 20–64 should be employed while meeting the EU's objective of 20 per cent of energy generation from renewable sources. Meeting the target of 20 per cent higher energy efficiency by 2020 would create over one million new jobs.
Ethiopia	Climate Resilient Green Economy (CRGE) Initiative (2011–2025): Seeking to achieve middle-income status by 2025 in a climate-resilient green economy, the CRGE Initiative promotes socio-economic targets such as rural development; health; the creation of employment in high value-added production; local production of efficient stoves; and afforestation/reforestation as well as forest management; livestock development, in particular poultry production; and rural employment.
Indonesia	Through its National Action Plan Addressing Climate Change (2007), based on a triple-track strategy that is pro-poor, pro-job and pro-growth, Indonesia has voluntarily committed to reducing its greenhouse gas emissions by 26 per cent, and up to 41 per cent by 2020 with international support. A Climate Change Sectoral Roadmap that includes green jobs and skills was developed to mainstream climate change in the

Country	Examples of comprehensive green economy or green growth initiatives
	Indonesian national mid-term development plan (2010–14), while a National Action Plan on Mitigation and Adaptation to Climate Change on Public Works consists of policies, strategies and programmes to lower impacts of climate change.
South Africa	The Green Economy Accord (2011), adopted as one of the accords under South Africa's New Growth Path, was signed by representatives of the South African Government, business representatives, organized labour and the community constituency at the Parliament of South Africa in November 2011. The Accord sets the goal of creating at least 300,000 jobs by 2020 in the green economy and activities that green the economy, including in manufacturing, energy efficiency, recycling, transport and energy generation.
United Arab Emirates	A long-term national initiative, A Green Economy for Sustainable Development (2012–21), seeks to position the country as a centre for the export and re-export of green products and technologies through programmes and policies in the areas of energy, agriculture, investment, sustainable transport and construction.
United Kingdom	The Low Carbon Transition Plan: National Strategy for Climate and Energy (2009–20) seeks to make a necessary transition to a low-carbon economy through the creation of new business and employment opportunities in renewable energy and building, among others, and to cut emissions by 34 per cent from 1990 levels by 2020.

3.2 Sectoral initiatives

The sectoral composition of a national economy is one important determinant of the social and employment outcomes of a shift towards a greener economy.

Many countries have put in place specific sector strategies that concentrate efforts on economic sectors and industries that play a key role in the structural transformation of the economy owing to their upward and backward linkages with the rest of the economy. Several strategies have focused on the energy sector. Others have focused on buildings. In general, governments have given particular attention to strategies significantly raising investment in infrastructure, as a way to stimulate economic recovery and growth and job creation in the aftermath of economic crises. A review of recovery plans following the 2009 global economic crisis indicates that about US$450 billion of emergency fiscal packages went to rail transportation, water infrastructure, electricity grid expansion and improved building efficiency (Robins et al, 2009). In fact, the Global Green New Deal report, published by UNEP in 2009, called for such investments (UNEP, 2009).

Eight sectors are particularly important due to their dependence on natural resources, their vulnerability to climate change, their large consumption of resources and their role as significant polluters. These are agriculture, forestry, fisheries, energy, resource-intensive manufacturing, recycling, building and transport. Between them they employ half the global workforce (ILO, 2012) (Table 3.2).

Table 3.2 Global direct employment in selected sectors critical to climate stability

Sector	Employment (millions of people)
Agriculture	1 000
Forestry	44
Energy[1]	30
Manufacturing (resource-intensive)	200
Buildings	110
Transport	88
Total	**1 472**

[1] *Energy revolution: A sustainable world energy outlook 2015* puts global energy employment at 28.4 million jobs in 2015 (Greenpeace International, Global Wind Energy Council and SolarPowerEurope, 2016. Available at: http://www.greenpeace.org/international/en/campaigns/climate-change/energyrevolution/).

Source: Adapted from Poschen, 2015.

Agriculture provides livelihoods for many people who are among the most vulnerable to climate change. In the context of climate change, agriculture is at the centre of efforts and policies for adaptation, making interventions in this sector a pillar of the national programmes of developing countries to respond to climate change.

The **energy** sector, which weighs in at far less than agriculture in terms of employment, is nonetheless central to the way that virtually every other part of the economy functions. A new path to a sustainable energy future is central to the mitigation of climate change and the shift to a low-carbon economy.

The rest of this section will discuss these two sectors as key priorities for most countries in the move towards environmentally sustainable economies with high employment.

Finally, the **building** sector plays an important role for both greenhouse gas emissions and employment, and where energy efficiency is a critical aspect of rendering employment more sustainable.

The most polluting economic activities tend to contribute relatively little to employment. Among OECD countries, just seven industries account for over 80 per cent of total carbon dioxide (CO_2) emissions from fossil fuel burning, but they employ only about 10 per cent of the workforce (albeit in mostly well-paid jobs) (ILO and OECD, 2012). This picture tends to hold true also for countries beyond those in the OECD.

> The most polluting economic activities contribute relatively little to employment.

3.2.1 Agriculture

Although its share of employment has fallen over the last two decades, agriculture remains the sector with by far the largest workforce in the world – about one in every three workers. But it is also the sector that has the highest concentration of poor people, with agricultural incomes growing more slowly than GDP (ILO, 2013). Agriculture is a significant contributor to environmental degradation – land degradation, water pollution, loss of biodiversity – and one of the largest emitters of greenhouse gases. Demand for food production is likely to continue rising, although a reduction in food waste would help relieve this pressure. At the same time, agriculture is perhaps the sector most vulnerable to climate change (Poschen, 2015).

> Agriculture is perhaps the sector most vulnerable to climate change.

UNEP (2011) suggests that these challenges can be met by a strong commitment to disseminate farming methods with a low environmental impact. Evidence from various countries strongly suggests that low-impact (organic) methods tend to be more labour-intensive than conventional farming, therefore opening an opportunity for new workers to be absorbed into agricultural jobs, at least in the short to medium term. Training farmers in organic agriculture methods will require an appropriate investment in extension services.

Solutions should be adapted to specific situations, built on the local farming system and developed in cooperation with the farming communities themselves. The organization of farmers and workers is an important stepping stone to giving rural communities a voice in policy-making for rural development and greening agriculture. The inclusion of women farmers is especially important. Organization will also be critical for developing the capability to implement more productive, low environmental impact farming methods. The formation of cooperatives can help with access to know-how, inputs, finance and markets at fair prices, as illustrated by the experience of large cooperatives such as the Oromia Coffee Growers in Ethiopia,[1] which is bringing substantial benefits to over 200,000 producers of organically grown coffee, and the cocoa farmer cooperative Kuapa Kokoo in Ghana.[2] In Costa Rica and India, cooperatives have become leaders in the production of carbon-neutral coffee and in using agricultural residues for power generation. In industrialized countries upgrading of skills, coupled with reforms of agricultural subsidies to favour remuneration of environmental services, would make a major contribution to the transition of workers and also improve incomes and export prospects in developing countries (ILO, 2013).

Assessment of job creation through sustainable agriculture

As part of a global assessment, Herren et al. (2011) ran a macroeconomic model simulating green investments in the agriculture sector. They concluded that the transition to sustainable agriculture could create over 200 million full-time jobs across the entire food production system by 2050.

However, this overall positive finding should not obscure the fact that mitigation policies will have adverse impacts. Therefore, there is a need to design and implement policies to smooth the transition towards a sustainable agricultural system. Additional work needs to be undertaken to improve the understanding of likely impacts and to develop adequate transition measures.

3.2.2 Energy

The bulk of the world's energy system still relies on fossil fuels, accounting for 78 per cent of global final energy consumption in 2014. But renewable energy is beginning to make inroads. Traditional biomass has an 8.9 per cent share in final energy consumption, while modern forms of renewables such as wind and solar energy account for 10.3 per cent, and nuclear power accounts for the remaining 2.5 per cent (REN21, 2016). Still, global fossil fuel production remains at a historic peak, with only coal output dipping, by 5 per cent since 2013 (BP, 2016).

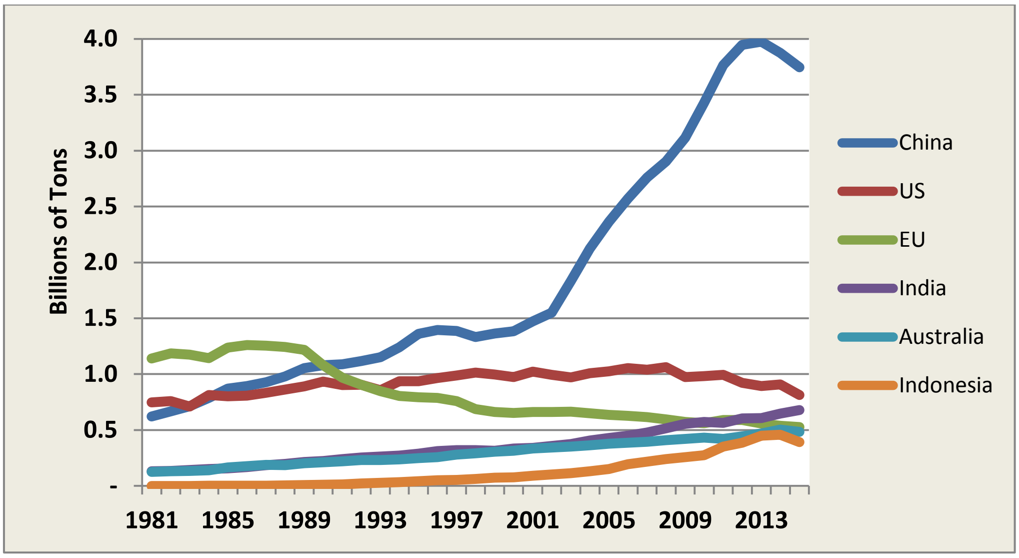
To date, employment losses in the fossil fuels sector have been the result of industry restructuring and consolidation and of increasing mechanization. Climate policies will need to bring about a fundamental change in the global energy mix in coming years and decades. The result will be further job losses in the fossil fuel sector – in coal mining, in exploration and production of oil and gas, and at fossil fuel power plants. Coal, as the dirtiest and most carbon-intensive fuel, will bear the brunt of the changes that will result from implementation of the Paris Agreement.

The trajectories of production of leading coal-producing countries have diverged considerably (Figure 3.3). European Union (EU) member states have seen their combined coal production fall since the mid-1980s, with more than proportionate job loss. Output in the United States of America

[1] See http://www.oromiacoffeeunion.org/.
[2] See http://www.kuapakokoo.com/.

started to decline in 2008, but rising automation had driven employment down even when output was expanding. China is by far the largest coal producer. China's production rose steeply in the decade to 2013, but it has since fallen by 6 per cent. In contrast, India, Australia and Indonesia, although producing much less than China, have seen a strong rise in their output.

Figure 3.3 Coal production trends in leading coal-producing countries, 1981–2015



Source: BP, 2016 .

Global data on coal mining employment are sparse. A decade ago the World Coal Institute put employment in the sector at about seven million jobs. Output has risen by close to 30 per cent since then, but growing automation has likely tempered a concomitant rise in employment. Still, the latest *Energy revolution* report (Greenpeace International, Global Wind Energy Council and SolarPowerEurope, 2016) estimates employment in energy at 9.7 million in 2015. China, which produces nearly half the world's coal, is alone estimated to employ some 6.5 million coal miners today.[1] As is the case in India and Indonesia, labour productivity in China is much lower than that of the United States or Australia, so that its share of global output is not indicative of its share of employment. It is unclear how many people work in coal-fired power plants globally. In 2011 ILO (2011c) estimated the utility sector as a whole to employ some 11 million people worldwide, but this figure includes not just all power plants but also water utilities, and it is certainly dated.

The renewable energy industry has seen strong growth in recent years, and this expansion is likely to continue. It is important to note, however, that to date this growth has supplemented jobs in the fossil fuel sector rather than replaced them. This may well change if greenhouse gas emissions are cut to the extent that climate science calls for – in other words, if there is a comprehensive transition from fossil fuels to renewables and increased energy efficiency.

Along with energy efficiency, clean energy is one of the key ways in which the energy system can be transformed in line with climate goals. Rising investment and falling costs have been the drivers behind an expansion of renewables, with wind power and solar PV the most dynamic sectors. Global employment in renewable energy has grown substantially in recent years, reaching an estimated

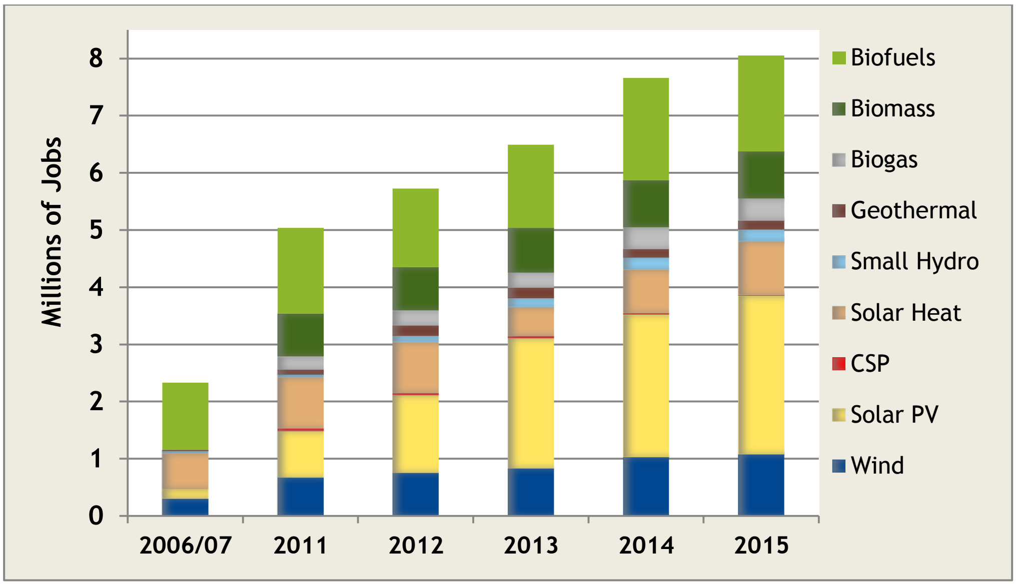
[1] This is a calculation based on figures reported by Yan (2016).

8.1 million jobs in 2015[1] (Figure 3.4). Employment relating to installation of solar PV has mushroomed in recent years because PV panels are becoming cheaper.

Most renewable energy employment is found in Brazil, China, EU member states, India and the United States. These countries are home to the key equipment manufacturers and account for the bulk of generating capacity installed to date. However, many other countries are now developing and expanding their domestic markets, with the largest – and rising – employment primarily in sales and distribution, installation, and operations and maintenance. The installation and maintenance of energy systems account for the most jobs created.

Table 3.3 presents examples of sectoral strategies in several countries.

Figure 3.4 Estimates of global employment in renewable energy, 2006/07–2015



Note: These estimates exclude large hydropower.
Sources: UNEP, ILO, IOE and ITUC, 2008; ILO, IILS, 2012; IRENA, 2014; IRENA, 2015; IRENA, 2016.

Job creation potential through building renovation

In the EU an assessment of the potential impacts of the 2010 Energy Performance of Buildings directive for the period 2011–2050 concluded that an accelerated pace of renovation could generate 0.5–1.1 million jobs annually (Buildings Performance Institute Europe, 2011). A study in the United States found that energy efficiency retrofits of pre-1980 building stock could reduce electricity use by 30 per cent and create more than 3.3 million cumulative job-years of employment (Deutsche Bank Climate Change Advisors and Rockefeller Foundation, 2012).

[1] The estimates reflect annual data collection based on a wide range of sources, including government agencies, industry and NGO studies, academic reports and interviews with experts. Inevitably, the underlying methodologies vary, however, and data gaps remain.

Table 3.3 Examples of sectoral strategies

Country	Examples of sectoral green economy or green growth initiatives
Brazil	The national poverty eradication strategy (2011) reflects green opportunities, including social housing, green protection grants (*Bolsa verde*) and the formalization of employment for 250,000 recycling workers linked to the National Solid Waste Policy established by law in 2010.
Germany	The objectives of the energy policy (*Energiewende*) 2011 are to phase out nuclear energy by 2020 and increase energy efficiency and to increase the share of renewable energy sources in gross electricity consumption from 17 per cent in 2010 to at least 35 per cent by 2020.
Morocco	The Solar Plan (2009–20) aims to reduce Morocco's energy imports by installing 2,000 megawatts of solar generation by 2020 while supporting economic growth and creating employment and to integrate concentrated solar power technologies into industry.
United States of America	The American Recovery and Reinvestment Act (2009) has allocated up to US$100 billion to green investments, while the Green Jobs Act (2013) provides training for workers and entrepreneurs in green sectors such as energy efficiency, renewable energy and sustainable construction.

3.3 Financing and fiscal reforms for greener economies

> A transition to green growth depends on large-scale shifts in capital mobilization.

Investment is central to a transition to greener economies. A key message from the Green Economy Report, published by UNEP in 2011, was the notion of "misallocation of capital". In order to foster a green economic transformation, governments are encouraged to reallocate investments from sectors that damage the environment and lead to resource use to more resource-efficient and environmentally sustainable sectors (UNEP, 2011). A transition to green growth depends on large-scale shifts in capital mobilization (GGBP, 2013). Successful financing strategies for green growth create the market conditions for these mostly private-sector investments to take place and overcome barriers such as investment risks, insufficient rates of return for some green technologies and practices, competing subsidies and policies, insufficient capacity, information gaps and regulatory and institutional barriers.

Effective green growth financing strategies combine three primary roles in mobilizing private green growth investment:

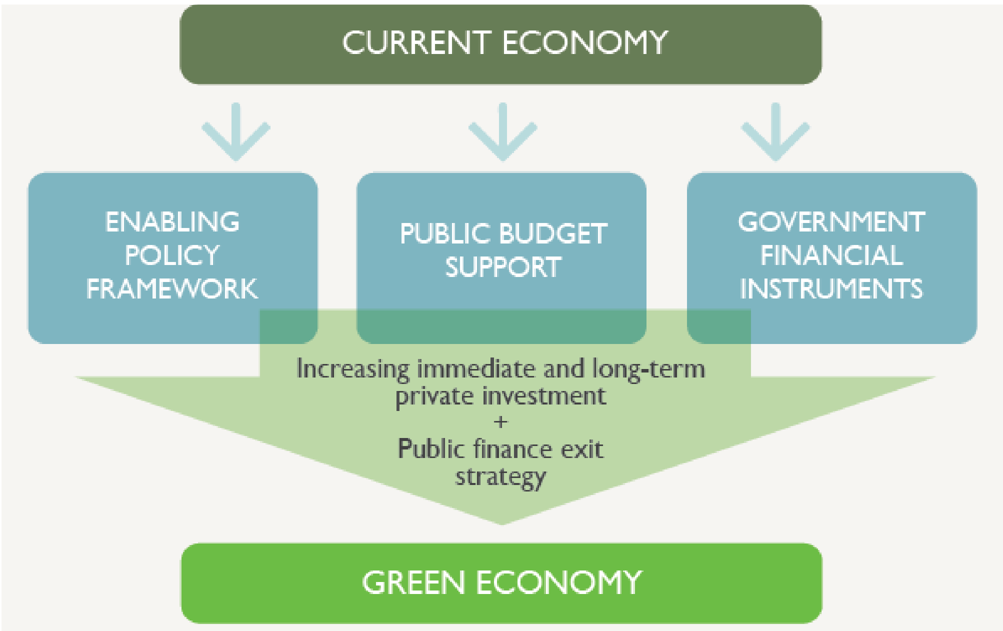
1. creation of an effective enabling environment for long-term green investment;
2. allocation of public budgets and investments, including through dedicated funds and/or financial intermediaries, to encourage green growth; and
3. tailored application of financial instruments to mitigate risks and increase returns on investment to mobilize private green investment (GGBP, 2013).

Fiscal policy is one of the key tools for advancing the transition to a green economy. In broad terms, it consists of the most fundamental functions of government: generating revenues – such as taxes, charges and fees – to serve low-carbon and socially inclusive purposes; public expenditure in support of the environment; and fiscal incentives that shift consumption and investment patterns in favour of clean goods, services and technologies.

Fiscal policy for the green economy seeks to ensure that environmental externalities, such as air and water pollution, congestion and greenhouse gas emissions, are included in the prices of goods in order to reflect the cost in terms of environmental damage and human health of the use of natural resources and services. Moreover, fiscal policy aims to redress perverse incentives for the excessive consumption and production of energy and water and for generation of solid waste. Finally, fiscal reforms can be used to shift and ease taxation away from labour towards resource consumption and pollution. Through environmental fiscal reform, additional fiscal revenues can be generated to invest in environmental protection and to stimulate innovation and research into clean technologies. In addition, public investment can contribute to attracting private investment in green sectors that ultimately leads to economic growth, job creation and environmental protection (Figure 3.5).

Fiscal policy for the green economy seeks to ensure that environmental externalities are included in the prices of goods.

Figure 3.5 The role of public policy and finance in unlocking private investment in green growth



At a global scale there is growing push to use the tools of fiscal policy to benefit the environment while ensuring economic growth and human wellbeing. Policies have addressed investment, subsidies and fiscal reform. As for investment, the financial crisis of 2007 provided an opportunity for governments to stimulate their economies by injecting public funds into environmental sectors. Between September 2008 and December 2009, governments spent US$3.3 trillion, of which US$522 billion, or 16 per cent, was directed to green activities such as energy-efficient buildings and water infrastructure through tax breaks and direct budget expenditure. While the financial crisis proved to be a catalyst for investment in low-carbon segments of the economy, more investment is needed to ensure broader and sustained support for green economies across the world.

The use of subsidies is also common; they can help lower the cost of capital and induce private investment in clean and efficient technologies such as solar panels, water recycling and electric vehicles. There is also a growing trend of environmental fiscal reform around the world, motivated by interests such as job creation, economic growth, environmental protection and energy security. Moreover, the reform of fossil fuel subsidies is increasing, spurred by both the need to reduce fiscal deficits and the need to protect the environment.

Despite the positive reform efforts, there can be drawbacks to implementing measures such as eliminating fossil fuel subsidies or imposing a carbon tax or levies on motor fuels. These reform efforts can ramp up the costs of businesses and reduce the purchasing power of households, leading to resistance from labour unions, industry and the public. Also, enforcing tax measures can be daunting for administrations with weak capacity, and using the revenues generated from environmental fiscal reform can be a delicate exercise in resource allocation. To induce the intended behaviour change and achieve the desired impact, getting the price right also matters.

However, two key lessons from successful reforms and ILO's core argument are: (2) There should be no subsidy reform without social protection for population groups disproportionately affected (poor households). Countries need to design social protection and compensation schemes first, communicate widely to build trust and public support, and only then undertake the reforms. (2) There are economic, social and welfare gains (in addition to environmental ones) through successful reforms that benefit the poor (IMF, 2015). Environmental fiscal reform should be undertaken with the costs and benefits in mind and with appropriate compensatory measures to balance out winners and losers. For example, strengthened social safety nets can help mitigate the effects on vulnerable households. Moreover, to have full effect, fiscal policy for the green economy should be complemented by appropriate regulations, tripartite dialogue and consultations, communication strategies and evaluation mechanisms.

> There should be no subsidy reform without social protection for groups disproportionately affected.

4. Implications for employment

Key questions

- How is employment affected by climate change and environmental degradation and by policy responses for sustainability and greener economies? What other parameters need to be taken into consideration to fully understand the nature and scale of labour market changes?
- What policies and tools exist to manage the transition in labour markets arising from greening policies?

Important observations

- Greening policies are just one category of factors leading to changes in labour markets. Other factors can include the economic conditions of the moment, technology development and industry restructuring.
- The impact of greening on employment can be direct, indirect or induced. Labour market changes can be both quantitative and qualitative.

Decent work provides the income that a person needs for daily living, a meaning to life, social inclusion and self-respect. This explains why job creation has been a central consideration in green economy strategies and policies in all countries.

Overall, the extent of the creation of "green and decent jobs" in a country can be seen as an indicator of competitiveness: The higher it is, the better poised the country is to compete in a foreseeable future in which economies are designed to produce wealth and income without creating environmental risks and ecological scarcities (UNEP, 2015).

> The more that jobs are "green and decent" jobs, the better poised a country is to compete in the green economies of the foreseeable future.

Such jobs are not emerging by default, however. Rather, they result from carefully designed policies that set green employment as a goal in itself within the articulation of green economy policies (ILO, 2012). While a number of country studies and global reports suggest that new job opportunities in a green economy are significant, there is a crucial need to identify such job opportunities in order to develop the education and skills training needed to fill them.

> Green jobs are not emerging by default. There is a crucial need to identify such job opportunities.

4.1 Job creation

The transition to low-carbon, greener economies can be a net creator of jobs. The ILO has estimated the potential to be up to 60 million new jobs by 2030 (ILO, 2012). In 2015 alone, about 8.1 million jobs were created in the renewable energy sector, excluding large hydropower; this was an 18 per cent increase over the previous year. Countries with the largest number of new jobs in renewable energy were China, Brazil, India, Japan, Germany and the United States of America. Asia accounted for 60 per cent of the new employment globally (IRENA, 2016). Worldwide, doubling the share of renewable energy in the total energy supply by 2030 could lead to 24 million new jobs net in the energy sector. In Europe every percentage point reduction in resource use leads to 100,000 to 200,000 new jobs (GWS, 2011).

> The move to greener economies can create 60 million new jobs by 2030.

The potential for new green jobs is great. However, realizing this potential requires building the needed workforce with vocational education and training systems, entrepreneurship promotion and ensuring retraining and reconversion options for those likely to lose jobs. These are critical issues for the world of work to address. The guidelines for a just transition to environmentally sustainable economies and societies for all, adopted by ILO constituents in November 2015, provide a menu of policy options to ensure a fair transition that leaves no one behind (ILO, 2015a).

4.2 Job losses

Climate change has severe consequences for jobs and global income. The Stern Review of the Economics of Climate Change projected that climate change impacts could impose a cost of up to 20 per cent of GDP if no action is taken to prevent it (Nicolas Stern, 2006). There are one billion people living and working in low-lying areas, according to the U.S. Geological Survey (USGS), who are directly affected by sea level rise and floods.[1] The World Bank projects global losses of property value due to flooding to increase from $6 billion in 2005 to $52 billion a year by 2050. In addition, risks from sinking land and global flood damage for large coastal cities could cost $1 trillion a year in the absence of adequate adaptation in cities to climate change (World Bank, 2013b).

The ILO's own research points to a possible decline in productivity of up to 7 per cent by 2030 if no action is taken to address climate change. Over one billion people, amounting to one-third of all workers, are employed in agriculture, which depends on natural resources, particularly water. Thus, their jobs are potentially affected by climate change (ILO, 2012). The 2015 UN report *Water and jobs* shows that almost half of the world's workers – 1.5 billion people – work in water-related sectors, which are facing the increasing stress of climate change. All these factors explain why trade unions have been rallying around the slogan of "no jobs on a dead planet" as a way to advocate action against climate change.

Changes due to climate and environmental policies are only one among several factors leading to job losses. In fact, greening has to date been a minor factor (ILO, 2012). The principal causes of declining employment in industries such as mining, fossil energy, and iron and steel have been the relative and absolute price changes, increasing automation and rising labour productivity that have been occurring over several decades.

4.3 Job transformation

Most jobs will neither be lost nor newly created but instead will be redefined in terms of their occupational qualifications and profiles. Many existing jobs, such as plumbers, electricians, metal workers and construction workers, will simply be transformed and redefined as day-to-day workplace practices, skill sets, work methods and job profiles are greened. For instance, plumbers and electricians working in the brown economy can in principle be reoriented to carry out similar work in the green economy. Automobile workers will produce more fuel-efficient (or electric) cars. Farmers will apply more climate-appropriate growing methods.

The same argument applies to enterprises. For leading global employers, "climate change and the transition to a greener economy" is the second most important driver of change for the future of jobs. So reports the 2016 World Economic Forum survey on the future of jobs, which surveyed leading global employers representing more than 13 million employees across nine industry sectors (World Economic Forum, 2016). Moving from linear economies, which are driven by manufacturing, towards circular systems, which are driven by services, will alter the sectoral distribution of employment. Because services tend to be more labour-intensive than manufacturing, more jobs can be created.

[1] http://www.worldwatch.org/node/5056

4.4 The quality of jobs

The quality of employment is a dimension as important as the number of jobs created, lost, or transformed. Jobs that are not decent today may or may not become more decent or greener with the structural transformation. Again, policies are critical in this respect. For instance, construction workers generally face poor working conditions, and their jobs are among the most hazardous in terms of both work accidents and occupational diseases, even in the formal sector. Constructions jobs also are often temporary rather than permanent, and frequently they are filled by migrant workers who lack social protection. There are often complex subcontracting arrangements. Particularly among informal workers, this makes for extremely hazardous employment conditions (Poschen, 2015). As construction of green buildings and retrofitting of the existing building stock creates jobs, it is essential to address these deficits in decent work and not to focus only on technical solutions that improve energy and material efficiency in the construction industry.

With greening, jobs will change in the way that they provide – or do not provide – adequate incomes and social protection, respect for the rights of all workers, a meaningful voice for workers in decision-making and safe working conditions. Research indicates that occupational risks tend to be less with a move towards a low-carbon economy (Poschen, 2015). For example, a shift to renewable energy will avoid many of the severe health risks associated with coal mining, even though some new hazards need particular attention (workers producing solar PV panels, for example, deal with a number of toxic substances and electrical hazards; thin-film and emerging nanotech-based solar technologies may prompt additional concerns).

5. The use of assessments to inform policy decisions

Key questions to answer

- Why are assessments useful for policy-making?
- How can assessments be used at different stages in the process of policy design, implementation and review?

Important observations

- Assessment tools should follow, not drive, the questions to be asked by the analysis.
- Assessment tools should clearly indicate their data requirements, assumptions used and limitations.
- Quantitative assessments can be informed and completed by direct feedback from social partners.

Greening the economy and creating more sustainable enterprises can potentially create tens of millions of green jobs. Still, the transition to a green economy implies both gains and losses in employment. Additional jobs will be created, some employment will be substituted, some jobs may be eliminated without direct replacement, and many jobs may be redefined and transformed as work methods are greened (ILO, 2012).

A lack of knowledge regarding the employment effects of the transition to a green economy makes decision-makers reluctant to implement new policies. Therefore, it is crucial to estimate the implications of a green economy policy for the labour market. Such assessments comprehend the scale and nature of changes across sectors and the economy at large, identify and quantify the job creation potential, and point to challenges that the structural transformations of the economy and markets will pose.

Central to the policy and political interests of many decision-makers is the opportunity to create new jobs and improve the quality of employment, thus securing income for people and enhancing human welfare. Green economy policies seek to do this. Their premise is that implementation will achieve transformational change by stimulating economic growth while reducing environmental risks, thus improving human wellbeing.

A net gain in employment will hinge on the right policies and on the capability of the institutions implementing them.

An increasing number of assessments are showing that net gains in employment due to a transition to a green economy are possible. Net gains stem from new markets being created (such as waste management and recycling) and often longer and more diversified value chains in green sectors than in conventional sectors (e.g., renewable energy versus fossil fuels). However, while considerable potential exists, a net gain in employment is, unfortunately, not inherent in the transition to a green economy. It will hinge on the right policies and on the capability of the institutions implementing them.

Decision-makers want quantitative measurements of production and employment in the green economy at various stages of policy design, formulation, implementation and review. Such measurements can assist in (1) gaining a better understanding of the impacts (both costs and benefits) of greening the economy, including the effects on the labour market, and (2) ensuring that effective policy measures are formulated to seize opportunities while addressing challenges in the shift to a greener economy.

5.1 What to measure – policy and methodological questions and boundaries

Assessments can help answer questions that arise when designing and implementing policies for greener economies (see box, next page). These assessments outline the potential implications for labour markets of shifts in public and private investments along with policy reforms to drive a transition to greener economies. Typically, these changes can be classified into three types, as discussed in the sections that follow:

- the volume and composition of jobs (direct, indirect and induced jobs) across economic sectors;
- the quality of jobs; and
- the level and distribution of income.

5.1.1 Measuring employment effects: direct, indirect and induced job creation

The first dimension of a green jobs assessment concerns the **quantitative impact** of green policies on employment. This measurement assesses three effects – *direct*, *indirect* and *induced* effects – which together translate into the gross and net impacts on employment.

> Quantitative jobs assessment looks at three types of job creation – direct, indirect and induced.

Direct job creation. Increased demand and investment in greener products and services, as well as in the equipment and infrastructure to produce them, will lead to the expansion of production in certain industries and enterprises. This will translate into higher labour demand and job creation – *direct jobs* – primarily in green sectors.

Indirect job creation. In addition, due to inter-industry relationships of the expanding industries, other parts of the economy that supply inputs to the expanding green sectors also benefit, creating additional employment – *indirect jobs*. Such additional job creation is not confined to the green sectors and can occur in non-green sectors such as high-insulation glass and cement needed as inputs for green buildings or steel and carbon fibre that are inputs to the production of the blades and towers of wind turbines.

Induced job creation. The income generated by this additional economic activity is redistributed by spending on additional consumption and investment across the economy, creating further employment – *induced effects* – in addition to the direct and indirect creation of jobs.

The number of jobs created at all stages of the greening process is a function of the size of demand and investment and of trade (imported products and inputs subtract from domestic demand or export), thereby increasing domestic demand and related employment, and of the elasticity of employment (jobs created or maintained per unit of demand).

Gross and net employment effects

In gauging the labour market effects of green economy policies, it is important to consider whether *gross* or *net* employment effects will be calculated. A study that measures the potential new jobs resulting from a policy or project calculates the *gross employment effects*.

Specific policy issues requiring assessments

Job creation and loss

- What is the net employment-creation effect arising from a particular type of investment, climate change policy or environmentally motivated economic stimulus?
- What is the overall impact of environmental and economic policies on the labour market?
- What is the potential for green employment growth?
- What is or will be the employment shifts across and within sectors? Which industries and types of workers are adversely affected?

Changes in occupation and skills needs

- What are or will be the transitions in employment patterns across occupations? For which occupations will there be increasing or decreasing demand?
- What new occupations are being created? What existing occupations are becoming greener?
- What new work skills need to be developed? What are the consequences for education and training systems if they are to adapt to the development of new areas of growth and new technologies?
- Are there bottlenecks caused by lack of needed skills? If so, in which sectors and occupations? What are the skills gaps? How many people need to be trained in what skills in the transition to a green economy?

Organizational restructuring

- How many establishments will restructure their organization and production processes to use less energy, to reduce emissions, to use cleaner technologies and/or to produce green products and services?
- What are the consequences for workers of such restructuring?

Decent work

- Are newly created green jobs good and decent? Is the transition to the low-carbon green economy socially just? Which groups are affected in a positive way, and which groups may be disadvantaged?
- Are newly created green jobs accessible to all?
- Do particular green initiatives have a negative impact on particular social groups, on food security for specific populations or on employment in existing environmentally sustainable economic activities?

However, while green economy policies (and other sustainable development policies) may create new direct, indirect and induced jobs, they may also lead to some job losses. For example, a government policy that invests in the renewable energy sector is likely to generate new jobs in that sector, but it may have an adverse effect on employment in the fossil fuel energy sector. Analysis that takes into account both the new jobs generated and the potential job losses calculates the *net* employment effect.

Data availability and the methodology or methodologies chosen for the study determine whether net or only gross employment effects can be measured. Some methodologies can measure only gross employment in green sectors, but some macroeconomic analyses can take into account the potential negative effects and so gauge net employment effects. The more complex models outlined in this handbook can project future employment impacts and calculate the change in net employment that is likely to occur as a result.

Budget effects and investment

A further conditional factor is *budget effects.* If green products and services are more expensive than their substitutes, enterprises and households will have fewer resources left to spend on other goods and services. For example, a negative budget effect can be associated with the introduction of renewable energy. Although the cost of power generation using renewables has been falling fast and has become increasingly competitive, it has initially (and temporarily) resulted in higher costs to consumers (ILO, 2013).

Conversely, positive budget effects do occur due, for example, to cost-effective investments in energy efficiency and broader resource efficiency (Rosenfeld et al., 2009). The resulting gains shift demand away from energy consumption, which has low employment elasticity, to goods and services with higher elasticities. Importantly, these gains are cumulative over time. Thus, the potential for job creation is not limited to certain industries but can occur throughout the economy, with some significant spillover effects. Together, these add up to the gross gains in employment.

Unfortunately, this mechanism works in both directions. When a green product replaces a less green one, employment (and income) will be adversely affected in other parts of the economy. An increase in renewable energy, for example, may reduce demand for conventional fossil power and thus for fossil power plants, as well as having an adverse impact on related supply sectors such as coal mining. The direct, indirect and reduced losses add up to a gross loss in employment in fossil fuel and related industries.

5.1.2 Measuring employment effects: Are green jobs also decent jobs?

> Despite the increasing importance of green jobs, the working conditions they provide remain largely unexplored.

The second dimension of green job that assessments seek to consider is the **quality** of green jobs. There is a real lack of concern for this second dimension; despite the increasing importance of green jobs, the working conditions they provide remain largely unexplored. The ILO has defined decent work as productive work for women and men in conditions of freedom, equity, security and human dignity. Decent work involves opportunities for work that is productive and delivers a fair income; provides security in the workplace and social protection for workers and their families; offers prospects for personal development and encourages social integration; gives people the freedom to express their concerns, to organize and to participate in decisions that affect their lives; and guarantees equal opportunities and equal treatment for all. Translating these qualitative qualifications of decent work into quantitative indicators remains a challenge for researchers and requires further work.[1]

5.1.3. Who will be affected by the implementation of this green policy?

Beyond the quantity and quality of employment, a third dimension of green job assessments is the **distributional impacts** by *income groups*, *category* of *workers*, *gender* or *age groups* as well as geographic regions. It is important to consider what groups stand to benefit or lose from job creation and loses and changes in wages. The disaggregation of employment effects can be used to explore equity considerations (such as gender equality) when assessing employment impacts of a green economy policy. The feasibility of such a disaggregation depends on data availability. Nonetheless, this disaggregation is fundamental for a precise understanding of impacts at a national, sectoral or household level and to devise the appropriate policy responses.

[1] Some guidelines can be found in: *Guidelines for producers and users of statistical and legal framework indicators,* ILO manual, Sept. 2013, available at: http://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/publication/wcms_223121.pdf.

5.2 Policy design and implementation

Assessments can be developed both *ex ante* and *ex post* the implementation of green economy policies. *Ex ante* assessments, or projection models, are conducted prior to the implementation of policies, in order to decide among different policy and investment scenarios among sectors and activities and to project potential outcomes. Projection models help to design, formulate and assess the coherence and adequacy of policies in relation to stated goals.

The ILO, in particular, has seen a growing demand for assessments at the international and country levels of the quantity and quality of green jobs (in terms of the number of people employed directly or indirectly, their level of skills and the specialist skills required, and composition and contribution of specific groups of workers and economic units to the green economy) and of their potential for growth.

Assessment of green jobs will help to answer a number of questions concerning environmental, economic and labour market policy. It provides governments with a tool for monitoring the transition to a greener economy, for designing and evaluating environmental and labour market policies and for assessing both their positive impacts (such as job creation in specific industries, uptake of innovation, market development, export growth) and their negative impacts (such as job loss in conventional “brown” industries and in the regions where these industries are located).

Another potential use of assessment on green jobs is the creation of labour market projections that take account of anticipated green growth and of contraction in less sustainable activities. Such projections could help to minimize risk and uncertainty for providers of training and to enable businesses and governments to plan and invest strategically in innovative areas. The resulting information would also be useful for evaluating policy initiatives and the labour market impact of activities related to environmental protection and conservation of natural resources.

A greener economy could lead to net gains of up to 60 million jobs

A review of nearly 30 studies covering a range of advanced and emerging economies and using a variety of analytical approaches and scenarios, from economy-wide emissions reductions to increased recycling and rehabilitation of natural resources, indicates net gains in employment of 0.5–2 per cent. This would translate into 15 to 60 million additional jobs by 2030, based on today’s labour force. These findings are in line with the double-dividend hypothesis – that policy measures can achieve economic benefits (in particular employment gains) and environmental improvements at the same time (ILO, 2012).

Economy-wide assessment in South Africa

The government of South Africa commissioned a quantitative green economy assessment in 2011. The assessment considered scenarios on the basis of policy targets in the National Development Plan for 2030 and compared them with scenarios involving more ambitious goals and targets on clean energy and resource efficiency. Results show that investment in a green economy can contribute to 46 per cent more restored land and greater water availability by 2030 without reducing the availability of land required for the agriculture sector. In addition, it could create jobs for an additional 169,000 people over a business-as-usual scenario. Moreover, targeted investments in organic agriculture could increase crop yields by as much as 23.9 per cent by 2030 while avoiding further CO_2 emissions. The study also showed that current green investment in the transport sector were not enough to meet the national goal of improving energy efficiency by 9 per cent by 2015 (UNEP, 2015).

5.3 Policy review and monitoring

Ex post assessments demonstrate how existing policies and investments or programmes that have already been implemented and for which data are available have affected the volume and quality of green jobs. In an *ex-post* analysis, an estimate can be made of jobs created through a measure of the development of an economic sector. The results of *ex post* assessments help measure and monitor the effectiveness of existing policies and programmes against indicators of progress. Eventually, the assessment can support further policy refinement or revision. Certain green job assessment models are applicable both for *ex ante* and *ex post* assessments, whereas others can work only for *ex ante* or *ex post* analyses.

6. A review of assessments tools

Key questions to answer

- What assessments tools and methods are available to measure labour market impacts?
- What are strengths and limitations of the various assessments tools and methods?

Important observations

- Assessment tools can complement one another or even be substitutable.
- Each assessment method has specific systemic strengths and limitations.
- Quantitative assessments can be informed and completed by direct feedback from social partners.

Various methodologies exist for assessing green jobs on a regional, national or global basis. A fundamental difference exists between sector-based assessments, which measure the employment effect in specific green economic sectors and activities, and macroeconomic studies, which examine the broader and net employment effects of greener economy policies and investments across the economy. The following section presents and discusses five approaches. (Table 6.3, following this chapter, compares the characteristics of these approaches.) In practice studies often employ a combination of several methodologies and approaches.

These methodologies offer a means both for the identification and quantification of existing jobs and for projecting how effective policies and investment programmes can be in creating green employment. The selection of the most appropriate tools for carrying out an assessment depends largely on the questions that it sets out to answer. For example, will the study estimate current or potential jobs? Will it take only a "snapshot", or is it intended to take a more dynamic or longer-term view? Should it also analyse occupational and skills needs and income distribution? Not only are different methodologies suited to answering different questions, but their selection also depends on factors such as the resources available and, most importantly, the quality of the available data. It is important to note that economic modelling can be informed and complemented – or even replaced – by direct feedback from the social partners who are involved in restructuring processes.

Assessment methods

1. Inventories
2. Statistical surveys
3. Input–output models
4. Social accounting matrices
5. Macroeconomic models
   - Optimization models
   - Econometric models
   - System dynamics models

6.1 Inventories

Inventories can provide a simple and effective way to assess how many green jobs exist in specific sectors, regions or countries, providing the inventories are kept up to date consistently over a prolonged period. The inventories commonly contain data on the economic units that produce environmental goods and services and, occasionally, on environmental technologies and processes. They may also contain lists of environmental goods and services that are being produced.

Inventories are usually established and maintained by employers' organizations, specialized associations and/or government departments. They may take a form of business registers or various types of administrative records.

Business registers may contain the information required, but keeping this information up to date is not an easy process. Industry and business associations that bring together businesses working in a common field or using similar technologies can often be a useful source of information. As specialists in their field, they have an insider's knowledge of the most common processes used, and they may even be willing to survey their members at regular intervals to assess the penetration of new processes, goods and services. Patent registers and registers of recipients of venture capital for clean technology may also provide some information, at least on formal-sector establishments engaged in environmental activities. Some studies based on inventories are more comprehensive, covering multiple activities or a whole country, while others offer a more limited estimate of green jobs in a sector or region. Assessments based on inventories, if repeated consistently over a prolonged period, can also indicate the extent of new employment generated by policies seeking to develop employment in sustainable sectors.

6.2 Statistical surveys

Surveys, both household-based and establishment-based, and economic censuses are the main sources of information for assessing how many green jobs currently exist in specific sectors and the economy as a whole. They are usually carried out in the form of questionnaires designed by national statistical institutes and sent to relevant observation units.

To optimize resource use, and depending on national priorities, data collection in establishment surveys could focus on key economic activities and industries (e.g., the largest in terms of their contribution to the production of environmental goods and services) and/or on those that have the greatest potential to change. A pragmatic approach could be to focus on some resource management subsectors (e.g., renewable energy, organic agriculture, ecotourism, sustainable forestry) where clear benchmarks exist (e.g., specific "green" labelling). In order to estimate employment in the production of environmental output, the questionnaire should include, at a minimum, questions on the type of environmental goods and services produced in the establishments surveyed, the value of, or sales revenues from, these goods and services and the number of people employed in the establishment.

Information that would allow estimation of employment by each type of environmental output can be obtained by asking respondents in establishments to indicate whether the production of environmental goods or services is their principal or secondary activity. They can list the environmental goods and services produced, indicating the percentage of total turnover associated with each environmental good or service.

In countries with large informal sectors and/or where agriculture, forestry and fishing are widespread activities, conventional establishment surveys based on business registers are unlikely to be the best option; these sectors are not normally covered by such registers, or they are not up to date. More useful sources include household surveys, agricultural censuses and area-based establishment surveys designed specifically to collect data from small or unregistered economic units, including those in agriculture and the informal sector.

Module 2 explores the use of inventories and surveys in depth.

6.3 Input–output models

Input–output (IO) analyses are empirical tools that rely on the construction of a matrix or table. This matrix lists all subsectors in an economy and details how outputs from one sector are used as inputs in others. These models draw on information from the national accounts, budget data, flows of funds and labour force data as well as environmental data (CO_2 emission, water, land use, etc.). Based on assumptions regarding the relationship between economic and environmental variables, employment multipliers can be calculated to estimate direct and indirect employment. A large number of studies have used the IO method. IO tables disaggregate the system of production and value chains and can illustrate the interactions within it.

IO analysis can be used to estimate the effects on employment of the increase in final demand for the product or service in a given industry by estimating direct, indirect and induced jobs. Thus, the model can answer questions such as, "How many jobs may result from a given programme of investment in sustainable economic areas?" or "For a given level of investment, which sector or sectors would yield the greatest number of jobs?".

Input–output tables are used to estimate direct, indirect and induced employment effects that are triggered by additional demand for goods and services in production sectors.

Table 6.1 Simplified input–output table – row: sector total output; column: inputs from other sectors

	Agriculture	Food & beverages	Land transport	Final demand	Total output
Agriculture	1 323	2 290	6	1 911	6 467
Food & beverages	333	1 390	17	8 074	11 670
Land transport	34	261	480	5 794	10 775

Source: Adapted from: Exploring the links between the environment, economy and employment in developing countries: a practitioner's guide (forthcoming).

In Table 6.1 the rows show the total output of an industry that is consumed by either other sectors or through final demand (e.g., household consumption). The columns show the share of inputs that each sector uses in order to reach its final output. The basic IO model measures how much additional output is needed from each sector to meet an increase in final demand. If information on the labour intensity of the different sectors in an economy can be obtained, then the matrix can be used to estimate the effect on employment of an increase in demand for a green service or product.

IO calculations are relevant for the analysis of green jobs in a country because they show the relationship between green outputs (which need to be clearly defined) and the sector-specific production structure of the country. An example of this is additional demand for organic agricultural products due to a campaign or a subsidy. This additional demand translates directly into additional produce, assuming that the additional amount will not be entirely imported. Additional produce requires additional workers – for sowing, watering and harvesting in the case of crops. This employment effect is often called direct employment (see section 3.1.1). From the IO table we can further deduce the additional demand for intermediary inputs. All sectors affected will also have additional demand for labour and thus create additional employment. This effect is often called the indirect employment effect. In the agriculture example this effect could extend to the machinery sector, the construction sector and transport and trade.

Module 3 explores IO assessment methods in detail.

An example of the findings of an IO assessment of green jobs creation comes from South Africa.

6.3.1 South Africa's green jobs potential (2012)

The New Growth Path of South Africa, spelled out in 2011, highlights the green economy as one of the ten "job drivers". The South African Industrial Development Corporation (IDC) was requested to assess the potential for net direct job creation in key sectors of the formal economy. Based on the constructed input–output model, IDC estimated that by 2025 nearly half a million new and additional jobs can be created (Table 6.2). The analysed sectors include energy generation and efficiency as well as pollution control. Management of natural resources had the highest potential for job creation.

Table 6.2 Net direct job creation in South Africa's green economy as projected in 2011

	Short term (2012)	Medium term (2017)	Long term (2025)
Total	**98 000**	**255 000**	**462 000**
Energy generation	13 565	57 142	130 023
Energy efficiency	31 569	70 193	67 979
Pollution control	8 434	13 189	31 641
Natural resources	44 512	114 842	232 926

6.4 Social accounting matrices

> A social accounting matrix (SAM) brings together data on income creation and production with information on the incomes of government, enterprises and households.

A social accounting matrix (SAM) can be considered an extension of IO tables. The ILO has used SAMs extensively in recent decades to measure the direct and indirect employment effects of public investment through a multiplier analysis. The major drawback of IO tables is that they do not include detailed data about the distributional aspects of economic processes. That is, they do not contain data on the expenditure patterns of the economic actors (government, enterprises and households). A SAM brings together, in a coherent way, data on income creation and production, as national accounts and IO tables do, and also includes information on the incomes of the different economic actors and their related spending.

The ILO began with the use of a static SAM to analyse the impact of trade on employment in countries such as Costa Rica, India and South Africa. An employment satellite account was introduced, using real employment data that were disaggregated by sector. This made possible a detailed analysis of the employment impact of trade strategies and policies. Thus, a SAM can reveal the actual effects of a greening policy on employment in every part of the economy.

The SAM methodology has been used frequently for green jobs assessments. However, SAM also can have its drawbacks. The four main shortcomings of the static SAM methodology are:

- a SAM model is static, with fixed coefficients;
- data in the SAM refer to a single period (usually a year);
- the year of the SAM is usually not the current year; and
- a SAM lacks any explanation of behaviour.

6.5 Macroeconomic models

Macroeconomic models help calculate the employment effects of specific policies and investments or predefined scenarios, showing processes of change in the economy at large. These models can be categorized into three broad types: optimization models (e.g., sectoral and computable general equilibrium models), econometric models and system dynamics models.

6.5.1 Optimization models

Optimization models seek to find the best state of the system under specific conditions and assumptions. These models can be used to determine what needs to be done to reach a stated target or to assess the likely outcome of a policy intervention (which is seen as a shock to the system, which then finds a new equilibrium).

There are several types of optimization models. Two main types are highlighted here: sectoral, engineering optimization models (e.g., for energy sector analysis) and macroeconomic computable general equilibrium (CGE) models (e.g., for fiscal policy assessments). An example of the former is the energy supply model called MARKAL (Loulou et al., 2005). This model optimizes energy supply to minimize production costs. More specifically, MARKAL is a “partial equilibrium bottom-up energy system technology optimization model employing perfect foresight and solved using linear programming” (Loulou et al., 2004). Concerning employment, engineering optimization models such as MARKAL estimate the physical stock of infrastructure (e.g., the number and size of power plants). Employment multipliers can then be used to estimate job creation in the construction and use of infrastructure.

In contrast, computable general equilibrium (CGE) are models of the economy that take the work of IO analysis and SAMs a step further by simulating the full economy’s responses to exogenous changes. Typically, they combine empirical data, usually in the form of IO tables, with a series of economic equations designed to comprehensively capture the complexity of the economy (i.e., assessing demand and supply effects through changes in price and quantity). By accounting for changes in a multitude of variables, policy-makers can use these models to analyse the short- to medium-term employment impacts of policies.

CGE models are widely used to analyse the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets or that involve menus of different tax, subsidy, quota or transfer instruments. They are capable of exploring the relationships between sectors, consumers and the government and of modelling the more complex dynamic effects of policies on a variety of macroeconomic parameters, including employment.

However, many of the classical CGE studies work with the simplest possible set of assumptions about the labour market: labour supply is fixed, and a uniform, flexible, market-clearing wage balances labour supply and demand (Boeters and Savard, 2011). Two options exist to better represent the labour market in CGE models: (1) explicitly modelling labour supply (e.g., separating the low-skilled from other groups) and (2) disaggregating labour demand (e.g., by household group and sector, with substitution possibilities between different types of labour in production).

6.5.2 Econometric models

Econometric models use historical data to estimate the relationships among the key drivers of the economy or, more generally, of the indicators analysed. A set of equations describes the structure of the system analysed. Both physical relationships and behaviour are defined by estimating the correlation among variables using historical data in the form of elasticities, or coefficients relating changes in one variable to changes in another. Forecasts are obtained by simulating changes in exogenous input parameters. These are then run through the equations, forming the model (e.g., of economic growth and employment).

An example is the global energy–environment–economy model (E3ME), created by Cambridge Econometrics.[1] E3ME is a model of the economy, energy systems and environmental emissions that consists of 22 sets of equations (each disaggregated by sector and by country). These equations cover the components of GDP, prices, the labour market and energy demand. The estimation method utilises developments in time-series econometrics, in which dynamic relationships are specified in terms of error correction models (ECM) that make possible dynamic convergence to a long-term outcome. E3ME is made up of several modules, including an economic module, an energy module and an emissions module. The economic module in E3ME contains a full representation of

[1] For more information see: http://www.e3me.com.

the National Accounts and includes a sectoral disaggregation with 42 economic sectors that are linked by input–output relationships.

During the past decade, to complement available data and expand data coverage, the Trends Unit of the ILO has developed a number of econometric models to produce estimates of labour market indicators and fill data gaps. These include the Global Employment Trends (GET) model (ILO Employment Trends Unit, 2010), which was developed to provide estimates – disaggregated by age and gender – of unemployment, employment, status in employment and employment by sector. The output of the model is a complete set of data for 178 countries. The country-level data are then aggregated to produce regional and global estimates of key labour market indicators, including the unemployment rate, the employment-to-population rate, sectoral employment shares, status in employment shares and the share of workers in vulnerable employment.

6.5.3 System dynamics models

System dynamics is a methodology used to create descriptive models. It focuses on the identification of causal relationships that influence the creation and evolution of the issues being investigated (Sterman, 2000). System dynamics models are most commonly used as “what if” tools that provide information on what would happen if a certain policy is implemented at a specific date and in a specific context.

The pillars of system dynamics are feedback loops, nonlinearity and delays, represented with stocks and flows and identified via the selection and representation of causal relationships existing within the system analysed (Barlas, 1996). System dynamics is, therefore, a flexible methodology that allows full incorporation of biophysical variables into monetary models and vice versa. Making use of this strength of the methodology, sectoral and integrated models can integrate various methodologies (e.g., optimization and econometrics) and represent key causal relationships (i.e., the main drivers of change) within and across sectors.

Several models have been created using this methodology, covering energy, agriculture, waste and water management. All these are fully tailored to the problem to be analysed and the local context (for instance, in South Africa (UNEP, 2013), Serbia (UNEP, 2013a) and the United States (Bassi et al., 2009). Employment and green jobs have been estimated in UNEP’s Green Economy Report (UNEP, 2011) and in the context of several green economy country assessments. Employment in these cases is estimated using various methodologies: using multipliers for sectoral assessments (e.g., for the manufacturing and installation of infrastructure as well as for operation and maintenance) and adopting econometrics when it comes to macroeconomic employment creation, which is affected in direct, indirect and induced ways by the policies and investments simulated.

Long-term projections of employment creation within a green economy transition

System dynamics models such as T21-World (UNEP, 2011), the South Africa Green Economy Model (SAGEM) (UNEP, 2013) and the Green Economy Model (GEM)[1] reflect the dependence of economic production on the “traditional” inputs of labour and physical capital as well as stocks of natural capital in the form of resources such as energy, forest land, soil, fish and water. Growth in these models is driven by the accumulation of capital – whether physical, human or natural – through investment, also taking into account depreciation or depletion of capital stocks. As a result, employment is affected both by economic performance (e.g., GDP, through capital and productivity) and by the state of the environment (e.g., considering that the fishery sector and fish catch are affected by the fish stock). Employment is calculated using multipliers, which vary depending on the sector analysed (e.g., employment per megawatt of power capacity built or per output of industrial

[1] To date applied in Belarus, Bosnia Herzegovina, Indonesia, Mauritius, Moldova, Mozambique, Serbia and Ukraine. See http://www.ke-srl.com/KnowlEdge_Srl/Models.html.

production and employment per hectare of agriculture land). Depending on the sectors, employment can be either a driver of production or a result of physical and economic activity.

UNEP's Green Economy Report (2011) indicated that a shift to a green economy also means a shift in employment, which will create at least as many jobs as continuing business as usual. UNEP's global modelling of the economy and the labour market found no significant differences in overall employment between business as usual and a green investment scenario. However, if we consider indirect and induced job creation as well as direct job creation, several sectors were found to benefit. These include agriculture, buildings, forestry and transport sectors, which would see job growth in the short, medium, and long term exceeding their comparable business-as-usual scenarios. Over the next decade, it was estimated, global employment in agriculture could increase by as much as 4 per cent. Investing in forest conservation and reforestation could boost formal employment alone in this sector by 20 per cent by 2050. As far as transport is concerned, improving energy efficiency across all transport modes and shifting from private transport to public or non-motorized transport would increase employment in this sector by about 10 per cent above business as usual. Finally, investments in improved energy efficiency in buildings could generate an additional 2 to 3.5 million jobs in Europe and the United States alone.

> Economic development in a green economy could push total employment up 3 to 5 per cent above business as usual.

Overall, UNEP estimated that economic development in a green economy could push total employment up by 3 to 5 per cent above business as usual. In addition, since system dynamics models can show developments over time, the assessment found that, depending on the investment simulated and its timing, the total net direct employment in green sectors would decline in the short-term (primarily due to a decline in fishery and forestry sector employment) but then converge or rise above business-as-usual employment in the medium to long run.

Table 6.3 A comparative review of assessment methods

	Inventories, surveys and employment factors	Input–output (IO) analysis	Social accounting matrices	Optimization (CGE)	Econometrics	System dynamics
Implemen-tation	Fast implementation; can be customized to the local context.	Relatively fast to construct; both flexible and practical.	Labour-intensive; relies on existing macroeconomic data that often are not up to date.	Labour-intensive; relies on existing macroeconomic data that often are not up to date.	Quick analysis of trends; more laborious process to create a model.	Fast for high-level models, time-consuming for cross-sectoral and detailed ones. Lack of technical skills is a concern.
Core strength	Provides a useful snapshot of the current employment situation and a basis for further assessment using more complex models.	Makes possible the assessment of employment impacts within and across value chains.	Brings together data on income creation and production, such as national accounts and IO tables.	Models full economic responses to exogenous shocks (i.e., policies). Projects economy-wide impacts through changes in quantity and prices.	Uses data and existing relationships to project trends. Accurate for short-term assessments and for systems that do not change dramatically.	Captures feedback loops and accounts for delays. Makes it possible to link social, economic and environmental indicators explicitly and dynamically.
Main weaknesses	Static; effective design and data quality are essential.	Generally static; estimates potential employment effects over the short term and does not estimate distributional impacts.	Comparatively static simulation, largely limited to economic indicators (drivers).	Most models use very simple assumptions: Labour supply is fixed and a uniform, flexible, market-clearing wage balances labour supply and demand.	Cannot be used with confidence to test interventions that have never been implemented. Historical correlation may not hold true in the future.	Often lacks the level of detail offered by IO and by other macroeconomic models.
Fit with the green economy approach	Povides the basis (or backbone) for any other more complex modelling effort.	Supports value chain analysis, which is often missing from macro assessments.	Makes possible analysis of trends over time but retains the level of detail of IO tables.	Models economic responses to policy implementation, including distributional impacts.	Makes possible estimation of impacts for several indicators across sectors and dimensions.	Fully incorporates the main characteristics of a CGE analysis; simulates policy change over time through causal relations.
Support to the policy cycle	Makes possible estimation of short-term employment effects of increased activity in a sector. Generally useful for issue identification and policy formulation.	Makes it possible to test changes in economic activity. Generally useful for issue identification and policy formulation.	Useful for policy formulation and evaluation due to its socioeconomic coverage.	Useful for policy assessment; particularly indicated for fiscal policy analysis.	Useful primarily for issue identification and policy assessment as well as for monitoring and evaluation.	Makes possible the projection of the outcome of policies across sectors. Informs issue identification, policy formulation and assessment, and M&E.

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Green Jobs Assessment Institutions Network (GAIN)

Training module 2:

Assessment Tools: Inventories and Surveys as Sources of Data on Employment in the Environmental Sector and Green Jobs

Contents

1. Introduction

Key questions to answer

- What criteria can countries use to choose suitable data sources?
- What existing sources are the likely to provide data on the green economy?
- What measurements can and cannot be found in existing sources?
- What kind of data can specialized statistical surveys provide?

Important observations

- Each source of data has systemic strengths and limitations.
- Existing data plus modelling usually provide sufficient information at low cost, without new surveys.

This module provides guidelines to help countries estimate employment in the environmental sector and green jobs by using data from:

1. inventories;
2. regular statistical surveys and censuses; and
3. specialized statistical surveys and censuses, including subsample surveys.

The module describes and analyses these sources of data, indicating their advantages and disadvantages, so that users of this module can choose the sources that best suit their purposes.

Countries can evaluate and choose methods of data collection on the basis of:

- size and importance of the environmental sector, or parts of this sector;
- efficiency of data collection (extent and level of detail needed for the analysis and relative cost in terms of resources and time to collect these data); and
- data quality (in terms of coverage, comprehensiveness and comparability).

In practice, different approaches may complement each other. Some parts of employment and economic activity in the environmental sector may be gauged by using data derived from existing regular statistical surveys (e.g., labour force surveys (LFS)) or administrative records (e.g., records maintained by industry associations or by government ministries or agencies), while others may require new data collection. Where the data compiled are incomplete, statistical modelling techniques[1] may be needed – e.g., input–output analysis and social accounting matrices, dynamic macroeconomic models and other computable general equilibrium models (see modules 3 and 4). Section 3.2 of this module provides practical steps for using existing statistical data to estimate the number of jobs in the environmental sector.

Best use of existing data combined with modelling techniques can yield sufficiently exhaustive estimates at relatively low compilation cost without increasing the burden for data providers.

> Best use of existing data combined with modelling techniques can yield sufficiently exhaustive estimates without increasing the burden for data providers.

The methods and approaches described in this module have been used and assessed by statisticians, researchers and consultants. Annex 1 provides model questionnaires that could be attached to existing ongoing establishment surveys and censuses and/or labour force surveys. They could be easily adapted to specific national situations to suit policy interests, research budgets and the structure of the environmental sector.

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[1] See ILO. Methodologies for assessing green jobs: Policy brief. Available at www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_176462.pdf.

Intended users for this module

This module is intended for statisticians and analysts seeking to estimate total direct employment in the environmental sector, and in each of its green sub-industries, and green jobs. It describes how data from inventories and surveys can be used for this purpose.

Learning objectives of this module

- understand the potential sources of data on jobs in the environmental good and service industries based on the System of Environmental and Economic Accounting (SEEA) guidelines; understand how to classify certain jobs as green;
- be able to choose the appropriate data source for an assessment based on data availability and the purpose of the assessment;
- to understand the basics of estimating numbers of green jobs from inventory and survey data.

Structure of this module

Chapter 1 offers an overview of the use of data from inventories and surveys in estimating employment.

Chapter 2 describes the use of data from inventories of producers of environmental goods and services.

Chapter 3 discusses how existing statistical surveys and censuses of establishment and of households can provide data for employment estimates.

Chapter 4 explains how specialized environmental sector surveys can be undertaken if existing data sources are not sufficient.

Chapter 5 lists the various indicators that can be derived from survey data.

Chapter 6 presents case studies of green jobs assessments in Mongolia and Albania.

Annexes 1 and 2 provide green jobs modules for inclusion in establishment surveys or labour force surveys.

2. Inventories of producers of environmental goods and services

Key questions to answer

- What are the likely sources for creating inventories of producers?
- What are the advantages and disadvantages of using inventories to identify producers in the green economy and employment in these units?

Important observations

- Business registers are the usual starting point for collecting information on environmental activities.
- Secondary activities are likely to be harder to identify than primary activities.
- Industry and business associations in the environmental sector often can provide information on their members.

Inventories can provide a simple and effective way to assess how many green jobs exist in specific sectors or regions, provided the inventories are kept up-to-date consistently over a prolonged period. These inventories should contain data on the economic units that produce environmental goods and services and, wherever possible, on environmental technologies and processes. They may also contain lists of environmental goods and services that are being produced as well as cost estimates of the production structure of those goods and services.

Inventories might be established and maintained by employers' organizations, specialized industry associations (e.g., environmental business organizations) and/or government departments. They may make use of data contained in business registers or various types of administrative records as well as information obtained through direct requests to the producers of environmental goods and services.

Assessments based on inventories can provide a useful measure of the effectiveness of various policies aimed at developing employment in the environmental sector.

2.1 Business registers

The usual starting point in establishing inventories is the business registers that contain information about the main economic activity[1] of each economic unit.[2] In principle, each unit in the national statistical business registers is assigned one ISIC[3] code according to the main economic activity in which it engages.

From these business registers it is possible to identify economic units that are entirely environmental (e.g., ISIC Rev.4 Division 37 – *Sewerage*; Division 38 – *Waste collection, treatment and disposal activities; materials recovery*; Division 39 – *Remediation activities and other waste management services*). Depending on the information and level of detail available, business registers may also lead to the identification of units carrying out several activities, some within the environmental sector and others outside it (e.g., ISIC Rev.4 Division 72 – *Scientific research and*

[1] The main activity of a unit is the activity that contributes most to the gross value added of the unit.
[2] Other registers may classify establishments by product codes (e.g., Central Product Classification (CPC) codes).
[3] International Standard Industrial Classification of All Economic Activities (ISIC)

development; Division 71 – *Architectural and engineering activities; technical testing and analysis,* Class 4669 – *Wholesale of waste and scrap and other products n.e.c.*).

Economic units that produce environmental goods and services as a secondary activity may not be as easily identifiable as units whose main activity is production of environmental goods and services. For example, ISIC Rev.4 Division 36 – Water collection, treatment and supply is not a typical environmental activity, as a major part of it consists of collecting, treating and distributing water. However, producers classified under ISIC Rev.4 Division 36 may, as a significant secondary activity, process sewage, which is an environmental activity. Similarly, this ISIC category could include units which carry out environmental activities, such as management of water resources, as secondary activities (e.g., the reduction of water losses in waterworks).

Compilers of data must make sure that environmental activities carried out as secondary activity are captured in the total estimates of employment in the environmental sector and green jobs. The usual procedure for estimating the environmental portion of employment in these units is to make some assumption of the portions of employment in environmental and non-environmental activities.

Economic units that execute environmental activities as ancillary activities cannot be identified using the ISIC description of economic activity in the business registers. Ancillary activities are those undertaken to support the main productive activities of a unit by providing goods or services entirely or primarily for the use within that unit.

2.2 Other administrative records

In addition to business registers, administrative sources such as databases of the **tax board** and the **social security** and **labour market administrations** may provide useful information on the activities or products of individual producers (whether part of the environmental sector or not). This administrative information can be particularly useful when it can be linked, through common identification codes, to statistical surveys that contain employment data. It may be possible to supplement this information by research in the media (e.g., Internet, professional journals) or from trade fairs.

Industry and business associations that bring together businesses working in a common environment-related field or using similar technologies can often be a useful source of information about these activities. All establishments that are members of such an association are usually considered to belong to the environmental sector. As specialists in their field, these associations have an insider’s knowledge of the most common processes used and the cost structure of those processes (e.g., the average expenditure on intermediate goods, capital, wages, taxes and imports) and may even be willing to survey their members at regular intervals to assess the penetration of new processes, goods and services. Usually, they regularly publish data on their members. Either turnover and employment data or else physical parameters (e.g., cubic meters of wastewater treated, number of waste collection trucks), and in some cases value added, are usually reported. However, trade association data usually cover a particular class or sub-class of the industry – for example, private or municipal waste management, urban wastewater collection and treatment, recycling firms, equipment providers, etc. In general, these detailed data may complement other available data on the environment industry, but they cannot provide a wider picture of the whole industry.

Another example is producers of organic food, who may be registered with specialized business associations or certification bodies as well as with government agencies managing subsidies and/or government grants for organic agriculture. Where producers are involved in both environmental and non-environmental agricultural activities, employment in environment-related activities could be estimated on the basis of the proportion of land area under organic production, the volume of production of organic products or the income generated from the sale of organic products.

Other possible sources of information are organizations that routinely collect environmental information as part of their usual activities. For example, government environmental protection agencies usually collect data as part of their monitoring and regulatory programmes. Government organizations responsible for employment and training policy may obtain data from businesses through various environmental employment-generation programmes. Further information may be obtained from databases on research and from development projects for waste management and pollution control. Patent registers and registers of recipients of clean-technology venture capital may also provide some information, at least on formal-sector establishments engaged in environmental activities.

Depending on its type, the information in administrative records may be supplemented with data obtained through direct requests to the producers of environmental goods and services.

2.3 Advantages and disadvantages of inventories (administrative records)

Inventories have several **advantages** over survey data:

1. **Low costs of data collection** for the statistics-producing agency: Since the data have already been collected as part of an administrative function, there are few costs for accessing the data for statistical compilation.
2. **No additional burden to respond** for the respondents: Data that were already provided as part of an administrative process (e.g., registration, application, inspection, notification) may be used for statistical compilation without involving the reporting units in a separate statistical enquiry on the same or closely related topics.
3. **The data represent a complete (full) count** of the all economic units that are within the scope of the administrative system. This means that statistics can be produced for small areas (e.g., districts, towns and provinces) without the problems of sampling precision and estimation error.

Possible **disadvantages** of inventories are linked to:

1. **Types of units described** in the records: The units used in some administrative systems may not be the most appropriate to satisfy statistical needs (for example, jobs versus persons, establishments versus enterprises), or they may not use definitions that are compatible with definitions used in other statistical sources.
2. **Scope** of the registrations or applications: The scope of some administrative systems may be either too narrow, because certain categories of economic units are excluded by design (legal exemptions) or otherwise (illegal non-registration, avoidance), or they may be too broad, including groups that are not of direct interest for analysis of environmental activities and green jobs. For example, a register of organic food producers omits producers who have not registered but may include former producers.
3. **Processing costs**: Since administrative record are designed for administrative rather than statistical purposes, the data may require considerable attention to detecting and correcting errors and to coding information that the administrative system did not need but is needed for statistical analysis. This processing may require expensive follow-up and file amendment.

Inventories may provide very useful information, but keeping them up to date is not easy.

Inventories may provide very useful information, but keeping this information up to date is not an easy process. To facilitate the maintenance of inventories, it may be useful to establish lists of environmental goods, services and technologies, based on the SEEA classifications of environmental activities and environmental goods and services. These lists would need to be updated regularly to take account of the development of new products, services and technologies. Lists of establishments engaged in these activities would need to be updated regularly for the same reason.

Many studies have used inventories to quantify employment in the environmental sector and the impact of the environmental sector on economic growth and job creation. Some of these studies are more comprehensive, while others offer a more limited estimate of green jobs in a country or region (see examples following). This approach is reasonable for a quick, low-cost investigation of part of the environment sector. However, it does not provide a comprehensive picture of the whole economy in a common framework and common reference period.

2.4 Examples of green job assessments based on inventories

2.4.1 Green jobs in Spain, 2009

The Spanish government estimated the number of green jobs in Spain to be 530,947 in 2009, equivalent to 2.6 per cent of Spain's working population. This extensive research employed a combination of interviews and survey techniques to identify and quantify green jobs and to calculate totals by sector (Table 2.1). The approach chosen meant that only direct green employment was included, although the depth of analysis was also able to provide some information on the potential in each sector for the generation of new employment.

Table 2.1 Green jobs in Spain, 2009

Sector	**No. of jobs**
Waste water treatment and purification	58 264
Management and treatment of waste	140 343
Renewable energy	109 368
Forest management	32 400
Environmental services to business	26 354
Environmental education	7 871
Organic agriculture and stock breeding	49 867
Management of green spaces	10 935
Industry and services	20 004
Public sector	53 072
Environmental research and development	21 929
Services	540
Total	530 947

Source: SustainLabour. 2012. Green jobs for sustainable development: a case study of Spain. www.ilo.org/global/topics/green-jobs/publications/WCMS_186715/lang--en/index.htm.

2.4.2 *Brazilian inventory of green jobs, 2006–2008*

The Brazilian government has made green jobs a central part of its national development policy, with the ILO providing technical support for the implementation of green jobs strategy at both federal and state levels. Many of Brazil's green jobs have been created by the extensive development of its renewable energy sector, with many jobs in wind, solar thermal power and solar photovoltaic power supply. Brazil has also invested in innovative projects such as the "My House, My Life" housing programme, which orchestrated the construction of 300,000 new homes with solar heating systems installed, creating 30,000 new green jobs.

The inventory was undertaken using data from the Annual Inventory of Social Statistics compiled by the Ministry of Work and Jobs. The original inventory compiled statistics for formal employment in Brazil, and the ILO study then disaggregated these figures so that a specific total for green jobs could be reached (Table 2.2).

Table 2.2 Inventory of green jobs in Brazil, 2006–2009

	2006	2007	2008
Total green jobs	2 293 505	2 484 799	2 653 059
Total formal jobs	35 155 249	37 607 430	39 411 566

Source: Adapted from the ILO study, Green jobs in Brazil: How many are there? Where are they? How will they evolve over the coming years?[1]

2.4.3 *Estimating green jobs in Bangladesh, 2010*

In an ILO study undertaken in Bangladesh,[2] core environment-related jobs were identified on the basis of the environmental performance of the sector or activity measured against standards, benchmarks, codes and, where possible, compliance with regulations. The numbers of jobs were estimated through literature review, interviews with experts, sector-specific studies and investment-to-job ratios within individual sectors. These core environment-related jobs formed the subject for subsequent analysis. To assess whether the jobs were decent work, jobs were screened to determine whether they provided acceptable working conditions. Published sources and interviews with stakeholders provided the data on decent work.

[1] Original publication: Empregos verdes no Brasil: Quantos são, onde estão e como evoluirão nos próximos anos? Available at: http://www.ilo.org/brasilia/publicacoes/WCMS_229625/lang--pt/index.htm.
[2] Estimating green jobs in Bangladesh: A GHK report for the ILO, June 2010. Available at www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_159433.pdf.

3. Existing statistical surveys: establishment and household surveys and censuses

Key questions to answer

- What are the strengths and weaknesses of using existing periodic surveys as a source of information on green jobs?
- What are the two main environmental activities in the SEEA classifications?
- How can one determine which outputs and processes are green?
- Why is it important to understand differences in the production structures of green and corresponding conventional industries?

Important observations

- Existing statistical surveys can be used to identify economic units whose main activity is environmental. In order to identify units whose environmental activities are secondary or ancillary (for own consumption), further investigation and analysis are necessary. The first step in estimating green jobs from existing statistical data is to identify economic units in the environmental sector.
- The difference in structure between green and conventional industries drives the results of the employment projection model.

Many studies have attempted to quantify employment in the environmental sector and the impact of the environmental sector on economic and employment growth by using data from existing periodic establishment- and household-based surveys and censuses that provide some information for some parts of the environmental sector. Existing survey data can be used to estimate employment in the environmental sector, but doing so requires several steps in classification of the data and analysis and some assumptions about the proportion of environmental activities in total activities.

3.1 What can existing surveys provide?

Existing periodic establishment- and household-based surveys and censuses can provide comprehensive data on employment by economic activity and by occupation for ISIC industries that are entirely environmental (e.g., ISIC Rev.4 divisions 37 – *Sewerage*; 38 – W*aste collection, treatment and disposal activities; materials recover*y; and 39 – *Remediation activities and other waste management services*).

Also, the ISIC allows identification of some environmental activities but only as parts of divisions or classes containing other activities. For example, parts of employment in ISIC Rev.4 Division 72 – *Scientific research and development*; Division 71 – *Architectural and engineering activities; technical testing and analysis*, Class 4669 – *Wholesale of waste and scrap and other products n.e.c.*, Class 8412 – *Regulation of the activities of providing health care, education, cultural services and other social services*, *excluding social security* may be considered environmental but not separately identifiable.

> ISIC classification cannot identify economic units that engage in environmental activities as a secondary activity or that produce environmental goods and services for their own use.

Existing statistical surveys based entirely on classifications such as ISIC (and also ISCO) do not separately identify all the economic units engaged in environmental activities. This is because establishments or enterprises are classified according to their *output* and main economic activity and not according to the *purpose* of their output or the type of *production process* used. For example, all establishments and farmers that produce corn are classified under one code. However, there may be organic producers, using no chemical inputs, and there may be conventional producers, importing and applying chemical fertilizers. The cost structure, wages and employment content may be very different in the two production systems. Another example is energy utilities. The ISIC guide does not discriminate between coal and solar electricity providers because both produce the same output, electricity. However, the economic, social and environmental impacts of coal producers are very different from those of solar producers. The challenge is to disentangle the two and distinguish activities and jobs that have an *environmental purpose* from those that do not, following the SEEA guidelines. In addition, establishments or enterprises are classified in ISIC according to their main activity. Thus, it is not possible to identify units that produce environmental goods and services as secondary activities (e.g., large establishments with a low degree of specialization in production of environmental goods and services) or units that produce environmental goods and services for their own use.

An additional issue is that even establishments that are specialized in environmental activities such as environmental engineering, architectural or land survey services may engage not only in environmental but also in non-environmental activities.

Furthermore, some producers may be difficult to identify. For example, in the manufacturing sector establishments producing filters for environmental purposes may not be identifiable as part of the environment sector since filters have other uses beyond protecting the environment. Similarly, establishments in the trucking industries that provide waste collection and hazardous material transportation may be classified along with establishments that transport non-waste material. Establishment in the construction sector (ISIC Rev. 4 Division F) may be involved in any combination of environmental and non-environmental projects. Furthermore, the proportion of environmental projects and the number of persons engaged in these projects may change from year to year.

As ISIC separately covers only parts of environmental activities, a more detailed breakdown of ISIC categories may need to be developed in the future to allow deeper analysis of industry structure and provide a reasonably comprehensive picture of environmental sector and the employment that it provides. Where expertise exists, national adaptations of ISIC may introduce an additional level (below ISIC class-level) to distinguish between environmental and non-environmental activities.

National adaptations of ISIC may introduce an additional level of classification to distinguish between environmental and non-environmental activities.

To estimate employment in the environmental sector and green jobs on the basis of existing data, some assumption and coefficients need to be used to split employment in economic activities that are not wholly environmental. Regrouping the data collected in each of these divisions would enable a large part of the environmental goods and services industry to be identified and measured.

The ILO's International Standard Classification of Occupations (ISCO) provides a tool for organizing all jobs in an establishment, an industry or a country into a clearly defined set of groups according to the tasks and duties undertaken in the job. It is intended for use in statistical applications and in a variety of client-oriented applications. Unfortunately, ISCO, too, is not sufficiently developed to measure employment in the environmental sector and green jobs. Although a small number of workers employed in occupations such as environmental engineering or refuse sorting may be easily identified because their occupation is entirely environmental, the majority have occupations that are not directly identifiable as environmental, such as maintenance work on renewable energy and energy-efficient equipment, or occupations that typically involve both environmental and non-environmental activities.

For the majority of occupations, some tasks and duties involve environmental processes and technologies, while the rest of the work involves non-environmental processes and technologies. For example, a planning engineer may spend part of his/her time on work associated with installing recycling equipment in the establishment and part on commercial premises with no distinguishing environmental characteristics. Likewise, there are many other occupations for which some work can be green and the rest not – for example, insulator workers, plumbers and pipe fitters, building and related electricians, steam engine and boiler operators, survey and market research interviewers, social work associated professionals, legal and associated professionals, civil engineering technicians, training and staff development professionals, some teaching professionals, building architects, civil engineers and senior government officials.

Finding the dividing line between green and brown occupations is not simple.

The current schemes of occupational classification are not sufficient to separately identify green from non-green occupations. Finding the dividing line between green and brown occupations is not simple, as majority of occupations may involve tasks that can be considered green and some that cannot.

3.2 Practical steps in using existing statistical data

3.2.1 Identifying economic units in the environmental sector

The first step in estimating green jobs from existing statistical data, including input–output (IO) tables, is to identify economic units in the environmental sector. SEEA and ILO guidelines (see box, “SEEA and ILO guidelines on classification”, next page) can be used to identify green industries**.** Based on these guidelines, Table 3.1 provides a list of indicators that could be used to identify and distinguish green from conventional units in some industries.

Indicators to identify green industries

It is important to define indicators for identifying green industries at the national level. This is because industries with the same ISIC code can be very different across countries – for example, modern recycling plants in Germany cannot be compared with recycling activities in Zambia. Despite national differences in terms of the “greenness” of their industries, the definitions of “green” should be consistent with the definition of environmental protection and resource efficiency activities stated in Module 1.

Various indicators can be used to identify green industries. For example, the indicator used to identify green units in forestry and fishing is rather simple – a sustainable green industry in this sector of the economy is defined as one that respects the natural renewal rate of the resource. Determining this requires assessing the total stock of the renewable natural resource, such as timber, fish or groundwater, and establishing whether the activities lead to a stable, growing or decreasing stock. If total stock is growing or stable, overall the industry is sustainable and, hence, green. However, if only part of the industry is operating in a sustainable way, then the sustainable part must be split from the conventional part (see Section 3.2.2).

In renewable resource activities a green industry can be defined as one that respects the natural renewal rate of the resource.

For agriculture to be considered green, an agricultural production system must satisfy several conditions related to soil fertility and crop protection, for example. Agriculture could be considered sustainable when soil fertility is maintained or increased by using organic fertilizer rather than continually adding chemical fertilizer. This information should be combined with an indicator regarding the use of chemical pesticides.

SEEA and ILO guidelines on classification

The United Nations System of Environmental and Economic Accounting (SEEA)[1] provides guidelines on classification of environmental activities, environmental products and environmental expenditures and other transactions needed to identify economic units in the environmental sector (see Module 1, Annex 1). It defines green industries as all industries that perform:

- **Environmental protection activities.** The primary purpose is the prevention, reduction and elimination of pollution and other forms of degradation of the environment.
- **Resource management activities.** The primary purpose is preserving and maintaining the stock of natural resources and, hence, safeguarding against depletion; this includes renewable energy generation and resource efficiency.

ILO guidelines[2] concerning employment in the environmental sector and green jobs, described in Module 1, Ch. 4, make an important distinction between (A) activities that relate to the *production* of goods and services for consumption outside of the producing establishment (output concept) and (B) activities that relate to the *use* of those activities inside the production unit (process concept). It follows that there are four different types of green industries:

1. **Industries *using* technology in their process to protect the environment from pollution** (Protection – Process activities)
Example: Sulphur dioxide and soot filters used in the production unit of a coal-fired electricity generating station would make its production process greener. Such activity falls under the category of processes and environmental protection.

2. **Industries *producing* technology or services for environmental protection for other industries** (Protection – Output activities)
Example: The industry that produces and manufactures the sulphur dioxide and soot filters would sell that technology outside the establishment that produces the filters – in fact, to the coal-fired power stations. Such activity falls under the category of output and environmental protection.

3. **Industries *using* technology in a process that improves resource management** (Resource management – Process activities)
Example: A car manufacturer that uses recycled steel and renewable energy as inputs in the production process. This manufacturer reduces the pressure on raw materials such as iron ore and fossil fuel energy and, thereby, improves resource management.

4. **Industries *producing* products or services that improve resource management** (Resource management – Output activities)

Example: The recycling industry that produces recycled steel and the renewable energy manufacturer producing clean technology for sale to the car manufacturer would qualify as resource management activities under the output concept.

The SEEA guidelines also distinguish between natural resource-based industries (primary sector) and manufacturing and service industries (secondary and tertiary sectors). This is helpful because, when it comes to greening, the primary sectors and, notably, Agriculture, Husbandry, Fishery and Forestry (those under ISIC Rev. 4 code A) are quite distinct from services and manufacturing. In addition, mining and water supply activities are also quite different and so warrant a different set of indicators. In the next section this becomes clearer.

Eurostat provides comprehensive guidance on the classification of environmental goods and services industries that encompass both pollution control and resource management categories.[3]

[1] UN System of Environmental Economic Accounting (SEEA). Central framework 2014. Available at: https://unstats.un.org/unsd/envaccounting/seea.asp.

[2] Guidelines concerning employment in the environmental sector, 19th International Conference of Labour Statisticians, 2013. Available at: http://ilo.org/global/statistics-and-databases/standards-and-guidelines/guidelines-adopted-by-international-conferences-of-labour-statisticians/WCMS_230736/lang--en/index.htm.

[3] EUROSTAT, Environmental goods and services sector accounts HANDBOOK, 2016 edition. Available at http://ec.europa.eu/eurostat/documents/3859598/7700432/KS-GQ-16-008-EN-N.pdf/f4965221-2ef0-4926-b3de-28eb4a5faf47.

Sources of information needed to identify green industries

The most important sources of information are nationally representative establishment and household based surveys. Both should be reviewed to see if they contain direct or proxy information that could be used to identify green industries.

If this information is not available, the next best choice would be to undertake a representative establishment survey of the establishments with economic activities that are likely to be green. The last option would be to rely on expert knowledge and secondary literature to estimate the proportion of the economic activities that are green.

Expert knowledge includes experts in relevant industry associations, ministries, civil society organizations as well as other public stakeholders that can help to determine the most suitable indicators to identify the green industries.

Expert knowledge, as well as secondary sources of data, however, should always be used in combination with primary survey data. The information regarding intermediate demand, value added, imports and total output (see Section 3.2.2), would provide the basis for expanding IO tables (the column entries of the IO table).

Input–output tables as sources of information

Input–output tables are another source of information to identify green industries. They describe the relationships between producers and consumers within an economy and between different branches of a national economy. A few ISIC activities can be directly identified as green in the IO tables. For example, waste management and recycling are, by nature of their activities, green. Economic units active in forestry, fisheries and water, could be classified as green only if their overall sustainability is established (see section 3.2.1, concerning indicators).

As the ISIC classifies industries according to their main economic activity/output, (i) only the concept of green outputs can be applied, and not the concept of green processes, and (ii) only if this is their main activity. Thus, conceptually, the ISIC can be used to identify two of the four types of green industries (see box, "SEEA and ILO guidelines on classification", above) – i.e., those industries providing goods and services for "use outside the establishment" either in "pollution control" or in "resource management".

In order to identify all units active in green economy, including the ones without environmental output but using environmental processes, each ISIC activity in the existing IO table should be scrutinized. Table 3.1 illustrates how to identify part of the economic activities that have either green output or green processes.

Given the fact that very often input–output tables contain information referring to a period in the past, the review of the IO tables should include assessing whether new green industries have started after the establishment survey was conducted. If so, the new green industries should be added to the IO tables. For the green industries that existed at the period covered by the IO tables, it should be determined whether they are still active.

This updating differs from expansion, as additional values are added to the IO table. In the case of expansion, current values are split between conventional and green production structures; no additional values are added to the table.

Updating of IO table requires not only adding values for new green industries but also updating the data for existing industries to the current year. Updating should be based on more recent information on the supply and use of products, value added, taxes, subsidies, imports and exports, etc. Care should be taken to estimate the total values, as the IO table features national data based on all economic activities.

Table 3.1 Indicators to identify green industries (according to SEEA) and distinguish them from conventional industries

Industry	Conventional (ISIC)	Green (SEEA)	Indicator for outputs or processes
Secondary and tertiary sectors			
Transport	Individual car transport	Public train and rail transport	CO_2 emissions per km travelled per person/freight weight, or, as a proxy, separating industry by public versus private transport (green service)
Energy	Fossil fuel energy	Renewable energy	CO_2 emission per kilowatt-hour of electricity produced or, as a proxy, separating renewable from fossil fuel technology (green service)
Construction	Conventional buildings	Green buildings	Net energy consumption or CO_2 emission per m^2 of floor space or, as a proxy, using certification as a green building to separate from the conventional (green service)
Tourism	Conventional tourism	Sustainable and nature tourism	Energy and water consumed per unit of output of establishment or, as a proxy, using a green tourism label (green service)
Manufacturing (materials)	Steel, plastic, aluminium production from virgin commodities such as iron ore, oil, bauxite ore	Recycled steel, plastic and aluminium	Raw materials versus recycled materials or energy and material consumption per unit of output (green product)
Manufacturing (electronics)	Conventionally designed electronics using new raw materials	Electronics designed for high energy efficiency and made with recycled materials	High energy efficiency equipment versus conventional equipment, or energy and material input per unit of output (green product)
Manufacturing (chemicals)	Toxic chemicals and chemical fertilizer	Bio-degradable chemicals and organic fertilizer	Chemical versus organic fertilizer (green product)
Manufacturing (energy equipment)	Fossil fuel combustion equipment	Renewable energy equipment	Renewable versus fossil fuel technology (green product).

Industry	Conventional (ISIC)	Green (SEEA)	Indicator for outputs or processes
Manufacturing (textiles)	Using conventional energy, cotton, chemicals and conventional plant	Using energy-efficient processes, renewable energy, recycled water as well as green input such as organic cotton and organic dying colours	Share of renewable energy and water in total use and energy input per unit of output. As a proxy, sourcing of organic material in the supply chain and/or product certified as a green textile (green process)
Manufacturing (cars, trucks motorcycles)	Conventional fossil fuel combustion engines	Hybrid or electric vehicles	Combustion versus electric vehicles (green product, while the provision and use of transport services with cleaner fuel are greener processes)
Waste	Dumping	Collecting and sorting	Dumping versus sorting (green service)
Primary sector			
Agriculture	Conventional agriculture	Sustainable agriculture	Use of organic versus chemical pesticides and fertilizers or, as a proxy, labelling of product as organic
Forestry	Deforestation	Sustainable forestry	Assessing whether total forest land is decreasing or increasing, or using certified sustainable forest labelling (FSC label) versus non-certified forest
Fishing	Overexploitation	Sustainable fish stock management	Assessing whether total fish stock is decreasing or increasing, or using certified fishing (MSC label) versus non-certified fishing
Water	Overexploitation	Sustainable water management	Assessing whether there is a fresh water shortage and/or a management plan to distinguish from overexploitation
Mining	Causing environmental damage	Mitigating damage or undertaking environmental restoration of damaged area	Paying for or saving in an environmental trust fund to pay for environmental damage or for restoration after the end of the operations

Source: Authors’ compilation

3.2.2 Estimating the number of green jobs

Once green industries have been identified, estimating the number of green jobs involves finding the total green output of these industries and the production structure of green industries.

Finding total green output

As a starting point, for each industry the green output as a percentage of total output needs to be found.

Green outputs for use outside the establishment. When the industry in question is producing green outputs for use outside of the establishment, product labels can be good indicators. When a label certifies the environmental friendliness of the product or service, there is no further need to establish the physical impact or relationship of this activity to the environment. Globally used labels exist for – inter alia – organic agriculture (e.g., EU and US bio/organic labels), eco-friendly tourism (e.g., Green Globe) and green buildings (e.g., US LEED label). Labels may also exist at the national level, such as the Singapore Sustainable Manufacturing label. As indicators should be defined nationally, it is not important whether the label is a local or global label or even whether there is a label at all. What is important is that there is a clear indication at the national level that an output on an economic activity is green.

Following the IO logic, either total production or total consumption could be used to estimate the size of green output. For example, the percentage of electricity produced or consumed that is renewable could be used. In agriculture hectares under organic agricultural production or value of organic production in total agricultural production can be used as a proxy. From the consumption side one could estimate total organic sales in total agricultural sales. Total output is then estimated based on the share.

A threshold can be used to set a benchmark for the green processes – for example, the top 10 per cent most efficient enterprises.

Green production processes. In order to identify the economic units that are using greener production processes, the efficiency of energy, water or material use could be used as indicators. Efficiency is measured as input per unit of output. Calculating efficiency requires data on energy, water and material consumption at the enterprise level. The lower the energy, water and material use per unit of output produced the higher the efficiency and hence greener the process. Both, monetary and physical measures may be used. To produce a car of USD 10,000 of value, factory A may use 1MW of energy while factory B uses 2 MW of energy. Factory A is 100% more efficient that factory B. For identifying units that use greener processes a threshold could be set with respect to average energy, water or material consumption per person employed (or per unit of output), and used as a benchmark. For example, the top 10 per cent most energy-efficient textile enterprises could be defined as employing greener processes. If data needed for assessing efficiency are not available, green and conventional production cannot be separated.

It can be argued that this approach is too broad. It counts as green all output and all jobs in the 10 per cent of economic units with the most efficient use of energy, water or materials when, in fact, only jobs in occupations that make production more efficient should be considered green. The reason for suggesting a broader definition is not only its simplicity but also its interpretation within the context of a green economy. The green economy and green jobs concepts aim at an overall sustainable economy. Such an economy requires that all jobs, and not just those that are directly involved in green processes, be highly efficient in terms of production processes.

This treatment is similar with jobs in economic units producing environmentally friendly output: All jobs are counted as green if the output is green even if part of the output is conventional. Therefore, in IO analysis, the entire economic unit that has a lower environmental impact of its production process than the average economic unit within the same industry is classified as green. As this approach overestimates the number of jobs that are directly involved in environmentally friendly production processes at the economic unit level, surveys are required with detailed data on time spend on environmentally friendly processes. Green jobs modules attached to labour force surveys or establishment surveys could obtain this information.

Finding the input (production) structure of the green industries

Once the value or the share of green output is found, information on the production structure is needed in order to estimate numbers of green jobs. The input structure in the IO tables that includes intermediate demand, imports and value added as well as subsidies and taxes can be used for this purpose. The focus here is on the production structure (columns) rather than on the supply structure (rows) of industries, which includes exports, final demand, government demand and investment.

Determining the production structure of green industries is the most important and the most difficult part of the modelling of green IO tables. The difference in the structure between green and conventional industries drives the results of the employment projection model: differences in output and employment between conventional and green industries result from different production structures.[1]

> Determining the production structure of green industries is the most important part of the modelling of green IO tables – and the most difficult.

For example, it is unlikely that organic agriculture has the same production structure as conventional agriculture. Organic agriculture relies on organic fertilizer, which is produced by the agricultural unit itself or, by the manufacturing industry but with inputs from agriculture, notably animal manure and compost. Conventional agriculture relies on chemical fertilizer, which is purchased from the chemical manufacturing industry and made with inputs from mining. In most countries, however, mined minerals or fertilizer are imported, as only a very few countries in the world mine phosphate, a key ingredient.

For example, Mexico’s organic agriculture does not rely on imports at all, it consumes 20 per cent as much chemical fertilizer and purchases organic fertilizer from its own industry. A study in Mauritius, for example, found that the 10 per cent most energy-efficient textile factories consume 30 per cent less energy per unit of output than the average. Therefore, it would be wrong, from an environmental and technical perspective, to lump together green with conventional agricultural producers or textile factories. If both green and conventional textile factories were lumped together, the industry account in the IO table would overstate energy purchases by the subsumed green factories while understating purchases by the conventional ones.

In order to estimate the production structure of a green establishment, a simplified modelling approach would identify the total output of the green industries and assume that green units purchase only from other green units. This means that the cells where green industries intersect with conventional industries would be zero. A green jobs assessment in Tunisia applied this approach (ILO, 2017).

> The challenge is getting hard data on production structure. A representative establishment survey is the first and best option.

[1] A technical reason for determining the production structure of green and conventional industries is that if the entire column and row vectors of the parent industry are multiplied only by the total output share, then the production structure remains the same. It will result in the same output multipliers – hence, the need to identify the particular input structure to detect differences between conventional and the green industry.

Determining the production structure should comprise an analysis of the intermediate demand (industry by industry) and the value-added accounts – notably, profits and workers' compensation – and imports. It might be found, for example, that because of energy savings, profit margins are higher in one industry than another. At the same time, the energy saving technology may require more operation and maintenance workers, thus increasing workers' compensation relative to that in the conventional industry.

For example, the green textile factory in Mauritius employs 12 per cent of the total workforce in the textile industry but produces only 10 per cent of total textile output. However, it uses 30 per cent less energy per unit of output. Thus, its production structure is different from that of conventional establishments in the textile industry. If it is assumed that the wages in the green establishments and in the conventional establishments are the same, then the green establishments will have a higher share in terms of workers' compensation, as relatively more workers are employed. However, if there is evidence that the wages in the green establishments differ from the wages in the conventional establishments, this should be taken into account and reflected in the production structure.

To ascertain the difference in production structures between green and conventional economic units and identify the individual green industries' intermediate purchasing pattern, an establishment survey is the first and best option. Secondary sources and expert interviews should complement the survey findings. Because of the data intensity, the number of questions in the surveys should be limited to the most important variables and indicators. The following variables and indicators could be compiled and used to adjust the IO table and alter the production structure of the green industries:

Intermediate consumption industry-by-industry

- **Energy** (e.g., electricity and manufacture of petroleum products): Typically, green activities will use less energy per unit of output as well as more renewable sources.
- **Water:** Typically, green activities, and notably agriculture, will use less water per unit of output as well as relatively more renewable sources.
- **Materials** (e.g., manufacture of paper, chemicals, plastic): Typically, green activities will use less raw and more renewable and recycled materials.
- **Manufactured machinery and equipment:** Typically, green industries, such as green construction, renewable energy and transport, will purchase machinery from the green/environmental goods industries such as renewable energy technology or public transport vehicles.
- **Services:** In general, because of the circularity of products in a green economy, green industries will rely more on services than the linear conventional economy will. For example, operation and maintenance inputs of (typically smaller) renewable energy equipment are greater than in larger conventional power plants. That means maintenance costs are higher.

Imports

- **Energy imports:** Typically, green industries, and notably renewable energy industries, will not rely on energy imports but instead use local resources.
- **Fertilizer imports:** Typically, organic agriculture will rely on and purchase compost and organic fertilizer and not chemical fertilizer, which in many countries is imported.
- **Machine and equipment imports:** The trade and machine manufacturing pattern of countries is very diverse. Thus, for example, it needs to be determined where solar panels originate, wind turbines are manufactured, and eco-building equipment is produced.

Value added

- **Compensation of workers:** As green industries typically require a higher level of technology, they also require a higher level of skills and, hence, a higher share of value-added going to workers. In addition, a premium is often attached to a green product, making it more likely that workers receive a fair share – for example, when farmers using the fair trade label receive a premium income. Questions in the establishment survey should ask about workers' pay. If this information is not available, it should be assumed that workers in the green industry are paid the same as those in the conventional industry. In this case, however, it should be noted that total employment in the green industry may be higher (or lower). The proportional share allocated to the green industries' compensation of workers should be adjusted accordingly.
- **Profits:** As green industries are driven by the increasing demand of concerned consumers, they are likely to attract a premium price, making it likely that profits are higher than in conventional industries. At the same time, emerging industries may have lower profit margins when entering the market, and so total profits also may be lower.

The survey questionnaire should follow the IO logic to cover all inputs/purchases and outputs/sales of the green industry, with a focus on the above suggested adjustments and indicators (Table 3.2).

Full survey instruments, as introduced in Chapter 4, often can come from statistics offices. Examples of surveys that focus on ex-post adjustment of conventional IO tables can be found in Miernyk's work (1970) on West Virginia in the 1960s and Garrett-Peltier's analysis (2010) of the renewable energy industry in the United States of America.

Table 3.2 Model simplified data requirements for a green industry survey

Expenditures for products or services from:	Sales of products or services to:
Agriculture	Agriculture
Green agriculture	Green agriculture
Manufacturing	Manufacturing
Green manufacturing	Green manufacturing
Service	Service
Green service	Green service
Imports	Exports
Taxes	Government
Subsidies	Consumer
Wages & salaries	Other
Depreciation	
Profits	
Investments	
Number of employees	

Source: Author's compilation

4. Specialized environmental sector surveys

Key questions to answer

- What kind of data do specialized surveys provide?
- What are the advantages and disadvantages of establishment surveys/censuses?
- What is the unique advantage of household surveys?
- What are the measurement issues?

Important observations

- Specialized environmental surveys are needed to identify as precisely as possible the economic units that produce environmental output or use environmentally friendly processes.
- Detailed information on employment in the environmental sector can be obtained economically by adding specific modules or questions to ongoing statistical surveys or censuses.
- Employment in environmental output and in environmental processes should be estimated separately because these statistics may serve different purposes and may be used as different targets for policy-making.

Additional tools are required to collect comprehensive data regarding the employment in the environmental sector. There are several reasons for this. For example, the majority of the larger establishments producing environmental goods and services are not specialized, and many establishments are unable to specify whether their products are used for environmental or other purposes (e.g., filters and pumps). Also, as noted (section 3.1), on-going periodic statistical surveys based on existing classifications such as ISIC do not allow for exhaustive identification of all economic units carrying out environmental activities.

Estimating employment in the environmental sector requires specialized surveys.

Employment in the environmental sector can be estimated with some precision only if all environment-related activities can be identified, i.e., those carried out by specialist producers, by non-specialist producers in other industries and by economic units for their own internal use. Doing so requires special environmental surveys to identify as precisely as possible the economic units, activities and products involved in the environmental sector. These surveys also can produce comprehensive information on employment, turnover, wages, export/import, investment, innovation, research and development, fiscal schemes and subsidies, etc. in the environmental sector.[1]

These comprehensive surveys can be time-consuming, costly and resource intensive for both respondents and national statistical institutes. Such stand-alone full surveys may cost several hundred thousand dollars and may take one to two years to design, conduct and process.

When comprehensive surveys are not feasible because of time or resource constraints, information on employment in the environmental sector can be obtained by adding specific modules/questions

[1] One of the very few countries that have conducted specific surveys on employment in the environmental sector and green jobs is the United States of America. Two types of establishment-based surveys have been conducted (1) the Green Goods Survey, and (2) the Green Technologies and Practices (GTP) Survey. Comprehensive information about the approach of the US Bureau of Labor Statistics (BLS) to the measurement of green jobs can be found on the BLS website at http://www.bls.gov/green/.

to ongoing statistical surveys or censuses. The main advantage of the latter approach is that it uses an existing survey operation and process, which reduces the cost for the statistical institutes. Furthermore, it is usually simpler to add extra questions to an existing survey than to launch an entirely new survey. A representative subsample rather than all sample of the ongoing survey may be surveyed for this module.

The most important existing surveys that could be used to gather additional information regarding employment in the environmental sector are household and establishment surveys and censuses. These are usually carried out through questionnaires designed by national statistical institutes and sent out to relevant observation units. They provide data not only on employment but also on wages, hours of work, etc. by economic activity, occupation, status in employment, sex, age and other labour force characteristics. In the case of establishment-based surveys, information on intermediate demand, imports, taxes and value added are obtained, all of which are necessary for building economic models that estimate employment effects of environmental policies (see modules 3 and 4).

Annexes 1 and 2 to this module present model green jobs questionnaires that can be attached to existing establishment surveys and/or household surveys.

In line with the ICLS Guidelines on employment in the environmental sector and green jobs, the modules compile separate information on employment in production of environmental outputs and on employment in environmental processes. This distinction is important because the estimates of employment in environmental output and of employment in environmental processes may serve different purposes and may be used as different targets for policy-making. As a result separate statistics should be produced for each component of employment.

4.1 Module attached to establishment surveys and censuses

The module related to employment in the environmental sector can be sent to all units or to a representative subsample of units that are covered in the main establishment survey. The module can be integrated into the main survey or it can be a separate questionnaire.

For comprehensive statistics on employment in the environmental sector and green jobs, the survey should cover all economic activities and all sectors of the economy (public/private and formal/informal). However, to optimize resource use, but also depending on national priorities, data collection in establishment surveys could be limited to key economic activities and industries (e.g., the largest in terms of their contribution to the production of environmental goods and services) and/or those that have the greatest potential to change from conventional to green. A pragmatic approach could be to focus on some resource management sub-sectors (e.g., renewable energy, organic agriculture, ecotourism, sustainable forestry) where clear benchmarks exist (e.g., specific labels). Information available in the business register in combination with information on produced goods from production statistics can be used to identify the subsample of establishments to be surveyed. However, this approach, which limits survey coverage to only some sub-sectors, does not satisfy all the data requirements in the area of the environmental sector; it does not cover all units engaged in environmental activities. Furthermore, there is a general problem with delimitation of the producers of environmental goods and services, especially in the area of adapted goods (conventional goods modified to be more environmentally friendly or cleaner), and upfront exclusion of some units from the survey coverage.

To reduce the financial burden of statistical production as well as the burden for survey respondents and at the same time to maintain a high level of quality, the module on employment in the environmental sector may be surveyed only once every three to five years. In the intervening years survey data can be combined with data from other sources and aggregate statistics (e.g., aggregate data on capacity changes and investments in renewable energies and on the production of manufactured goods).

To estimate the ***employment and cost structure in the production of environmental output***, the module should include, as a minimum, questions on:

- the type of environmental goods and services produced in the establishments surveyed;
- the value of or sales revenues from these goods and services;
- intermediate demand;
- wages and value added; and
- the number of persons employed in the establishment.

Information that would allow estimation of employment by type of environmental output could be obtained by asking respondents to indicate whether the production of environmental goods or services is their main activity or a secondary activity. Further information to request would be the list of environmental goods and services produced, indicating the percentage of total turnover associated with each environmental good or service.

Data collected in this way will provide information on turnover by type of output (environmental or not) and by type of environmental output. For establishments reporting that their output is entirely environmental, 100 per cent of employment in the establishment is counted as employment in environmental output. For establishments that undertake both environmental and non-environmental activities, it will be possible to isolate the environmental outputs from the total output. Thus, an appropriate proportion of total employment in the establishment can be allocated to employment in environmental output.

In surveys that collect data on employment both in the production of environmental output and in environmental processes, the questionnaire could include questions on the share of environmental turnover in total turnover. It could also include questions that would make it possible to determine the proportion of employees who are directly involved in the production/provision of environmental technologies, goods and services or who carry out environment-related activities. To avoid double counting, a distinction should be made between the time spent on environmental activities for consumption within and for consumption outside the establishment.

Specific modules on employment in the environmental sector and green jobs, in combination with variables covered in the main establishment survey, can provide detailed information on the economic cost structure of the establishments and on employment in the environmental sector broken down by economic and environmental activities.

4.1.1 Advantages and disadvantages of an establishment module

The strength of establishment surveys lies in their greater specificity than household-based surveys, both in terms of coverage and content. Notably, these surveys can provide the information on intermediate demand, value added and imports that are needed when building economic models for green economy projections. When the interest is in specific industries, establishment surveys, given an adequate sampling frame, can achieve more efficient sample designs and procedures than household surveys covering the whole population. Establishment surveys can provide more reliable and more detailed information on certain topics. Establishment surveys also provide an opportunity to collect information on many other economic variables, such as output, costs, investment and technological and organizational factors, which can then be directly related to information on employment, wages and productivity. This larger sphere of information can form a much more comprehensive basis for analysis of economic activity and inform economic modelling such as the IO-based employment projection models introduced in the next module. Also, data on employment can be related more accurately to data on earnings, skills, occupation and industry. Establishment surveys may also be more economical and timely than household surveys. They are also more precise and less costly.

The main disadvantage of establishment surveys and censuses is that they can be limited in content and coverage of the labour force. Particularly in developing countries, establishment surveys and censuses are likely to cover only large private- and public-sector employers (employing more than a certain number of persons). Another disadvantage of a specific green jobs module in establishment surveys and censuses is that the questionnaire is generally filled by accounting clerks who are not specialists in the production processes and who may not have the necessary information or knowledge to answer the survey or to accurately report the information requested.

4.1.2 Measurement of employment in production of environmental outputs and in environmental processes

Employment in production of environmental outputs – measurement

For the purposes of measuring employment in production of environmental output, the environmental sector is defined as consisting of establishments where all or some goods or services produced belong to the environmental goods and services domain and are designated for consumption outside the establishment.

Employment in the production of environmental outputs is not, however, equal to total employment in the establishments producing environmental goods and services for consumption outside the producing unit. Many producers of environmental goods and services also produce other goods and services. For example, a producer of electric vehicles may also produce conventional vehicles that are less resource efficient; and employment in the production of electric vehicles may be only a relatively small part of the total employment in the unit. Unless the jobs are linked to the type of vehicles produced, the employment cannot be measured directly. Linkage of this kind are usually not available and would be costly and difficult to implement in data collection. In the absence of such information this type of employment can be approximated using, for example, the data on the value of environmental goods and services produced as a proportion of the value of the total production of the establishment. Consequently, employment in the production of environmental outputs can be measured directly only in specialist environmental establishments whose output is 100 per cent environmental.

Employment in production of environmental goods and services can be approximated based on their share of total sales.

Where direct estimates of employment in the production of environmental goods and services cannot be obtained, it can, nevertheless, be approximated, based on the share of output (sales) of environmental goods and services in total output (sales). To do this, it is necessary first to calculate the value of environmental goods and services produced as a proportion of the value of the total production of the establishment.[1] This proportion can then be applied to total employment in the establishment to estimate employment in production of environmental outputs. Thus, if 100 per cent of an establishment's outputs are environmental goods and services, then 100 per cent of employment in the establishment is included. If 50 per cent of the output is environmental, 50 per cent of employment is included. This method of estimation does not

[1] If data on environmental output are not available at the individual establishment level, the ratios at industry level may be applied. However, using industry-level data instead of establishment-level data may not accurately estimate the size of the green economy when establishments in an industry produce a mix of green and non-green products and services. Expert advice could also be helpful, particularly for industries where the relationship between patterns of employment and the output of environmental goods and services may vary considerably from the average.

deal with situations where production of some goods and services might be more or less labour intensive than others. However, it does ensure that the labour inputs of workers are counted in areas such as administration, accounts, information technology, cleaning services and so forth, who contribute indirectly to environmental production.

For establishments that do not generate revenue (e.g., non-profit organizations, government agencies, research organizations and new businesses that provide environmental goods and services without generating income), information about the proportion of their employment involved in production of environmental goods and services may have to be obtained through surveys.

Total employment in the production of environmental outputs in a sector is calculated by summing up the observed employment in establishments whose output is 100 per cent environmental, and the estimated employment in establishments whose output is partial environmental.

Employment in environmental processes – measurement

The other component, employment in environmental processes, is more difficult to measure, requiring questions about the number of workers employed in activities leading to the production of environmental goods and services for consumption *within* the establishment and/or making the production process more environmentally friendly. Difficulties in measurement arise because businesses do not usually keep records that would allow making a distinction between output for internal consumption and for the market at the individual job level. Although useful, the occupation on its own is not sufficient to accommodate the requirements of measuring employment in environmental processes**.** Only a small number of workers employed in occupations such as environmental engineering or refuse sorting may be easily identified because they spend 100 per cent of their working time on tasks that are entirely environmental. The majority of workers have occupations that involve both environmental and non-environmental activities. Some tasks and duties of these workers are divided in such a way that they are undertaken with environmental processes and technologies, while the rest of the work involves non-environmental processes and technologies. For example, a planning engineer may spend part of his or her time on work associated with installing recycling equipment in the establishment and part on obtaining permission for commercial premises with no distinguishing environmental characteristics.

In order to measure only the part that is related to production of environmental goods and services for consumption within the establishment, it is necessary to split the hours spent on each component in order to estimate the equivalent number of full-time jobs. An alternative would be to split the volume of employment, if possible, in proportion to the values of internal and external consumption.

The recommended approach is to make a distinction between workers who spend less than 20 per cent, those that spend between 20 and 50 per cent, and those that spend more than 50 per cent of their time on environmental processes. The data compilers may wish to consider using different thresholds or using the measure of volume of work expressed in terms of hours worked.

4.2 Module attached to labour force surveys

In countries with large informal sectors and/or where agriculture, forestry and fishing are widespread activities, conventional establishment surveys based on business registers are unlikely to be the best option. Registers do not normally cover these sectors, or they are not up-to-date. More useful and comprehensive sources include household-based surveys such as labour force surveys and other types of household surveys with a module on employment. Other sources are area-based establishment surveys designed specifically to

Household-based surveys have the unique advantage of obtaining information on the total labour force and its structure.

collect data from small or unregistered economic units, including those in agriculture and the informal sector.

Household surveys, especially labour force surveys, can measure the employed, unemployed and economically inactive populations at the same time. They can be designed to cover virtually the entire population of a country, all branches of economic activity, all sectors of the economy and all categories of workers, including own-account workers, unpaid contributing family workers and persons engaged in casual work or marginal economic activity. Thus, they have the unique advantage of obtaining information on the total labour force and its structure.

Compiling information on employment in the environmental sector through household surveys may be more difficult than in establishment-based surveys: Respondents and interviewers may have difficulty assessing the extent to which the activities performed or products produced fall within the scope of the environmental sector. Therefore, many examples may need to accompany the survey questions. For surveys addressing employment in environmental output in agriculture, forestry and fisheries, questions could be included on the use of sustainable agricultural and forestry practices and/or the use of chemical fertilizers and pesticides during the reference year. Where workers are involved in both environmental and non-environmental agricultural activities, employment could be estimated at the level of a farm run by a household on the basis of the surface area under organic production, the production of organic products or the income generated from the sale of organic products.

As in establishment surveys, information should be complied separately on employment in the production of environmental goods and services intended for consumption outside the production unit and on employment in production of environmental goods and services for consumption within the producing unit.

The recommended approach, as in establishment surveys, is to distinguish among workers who spend less than 20 per cent, between 20 and 50 per cent, and more than 50 per cent of their time on (1) production of environmental goods and services or (2) technologies and practices that reduce the environmental impact of the production process or training co-workers or employees/contractors in these technologies or practices. The data compilers may wish to consider using different thresholds or using the measure of volume of work expressed in terms of hours worked.

Households as producers of environmental goods and services

Household units may engage in many environmental protection and resource management activities. Where production is undertaken for sale or where the work is performed by employees of a household, these units can be treated in the same way as any other production unit. Where the production is undertaken by members of the household for the benefit of the household, the labour inputs would be considered as “own-production work”, according to the framework for work statistics proposed in the resolution on labour force and work statistics adopted by the 19th International Conference of Labour Statisticians (2013).[1] Although work by household members for the household’s benefit could be looked upon as work in environmental processes, it would not be counted as employment.

In practice, “own-production work” in environmental protection and resource management activities may be difficult to measure. Nevertheless, it may be of interest and of some significance

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[1] Guidelines concerning a statistical definition of employment in the environmental sector, 19th International Conference of Labor Statisticians, 2013. See http://ilo.org/global/statistics-and-databases/standards-and-guidelines/guidelines-adopted-by-international-conferences-of-labour-statisticians/WCMS_230736/lang--en/index.htm.

where households are commonly engaged in, for example, environmental remediation activities (e.g., cleaning up dumped waste). This could be particularly important in countries where large numbers of households are primarily engaged in agricultural production for their own consumption.

5. Statistical measures and indicators to be produced

Key question to answer

- What employment indicators are most useful for monitoring the progress towards a "greener economy"?

Important observations

- Employment in the environmental sector can be a leading indicator of progress towards a green economy.
- To adequately inform environmental and labour market policy-making, data on the quality of jobs in the environmental sector are needed.

The transition to a green economy implies progressive increases in the share of total output that is environmental and the share of employment that is in the environmental sector. To assess whether and how far the green transformation has progressed, information needs to be collected and analysed in a consistent manner on various aspects of the activities of institutions in the economy both within and outside the environmental sector. This includes information on employment, production, value added, exports, imports, innovation, research and development, and fiscal schemes and subsidies. Progress can be assessed using indicators such as the share of these sectors in total output, the share of green investment in total investment and the share of environmental employment in total employment.

> Progress towards a green economy can be assessed using such indicators as:
> - the share of green sectors in total output;
> - the share of total investment that is green; and
> - the share of total employment that is environmental.

The indicators presented below can serve as a starting point for discussion of the indicators and measures that will be most useful to inform public policy in a wide range of areas.

5.1 Employment in the environmental sector

Employment in the environmental sector (total and by economic activity), expressed in absolute numbers and as a percentage of total employment, can be a leading indicator of progress towards a green economy. Separate statistics for employment in production of environmental outputs and for employment in environmental processes would also be of interest. Although the whole economy needs to be involved in the green transformation, it is nonetheless important to focus on a core set of green industries that characterize a green economy. Their progress should be closely monitored. Disaggregation of data by economic activity will facilitate both identification of core industries and monitoring of progress in other industries.

5.1.1 Employment by environmental domain

Breaking down data on employment and turnover (or output) by the environmental domains specified in the SEEA's Classification of Environmental Activities (i.e., environmental protection and resource management activities) will help to identify the type of environmental initiatives that are likely to lead to create more jobs, as well as to assess relative levels of labour productivity.

5.1.2 Employment by occupation

For an assessment of type and level of skill required in the environmental goods and services sector, detailed data on employment by occupation are required, as is information on employment by level of education, field of study and qualifications. Analysing those employed in the environmental sector will also reveal the qualification profile of the environmental sector and its potential to provide jobs for workers with lower levels of education or the unemployed. Workers' level of actual education could also serve as an indicator of the knowledge content of the environmental sector and, hence, of the development potential of the environmental goods and services sector.

5.1.3 Employment by economic activity

The sectoral composition of a national economy very largely determines the challenges posed by – but also the potential for – economic development and environmental sustainability and their likely impact on enterprises and workers. Economic sectors that are directly dependent on natural resources and the climate, or that are major consumers of resources or significant polluters, or both, might be in a position to significantly reduce their environmental impact. The behaviour and practices of economic units engaged especially in agriculture, forestry, fisheries, energy, resource-intensive manufacturing, recycling, buildings and transport may be important to environmental sustainability. Many of the environmental policies adopted to date, and also many of the more comprehensive green economy or green growth strategies, focus on these sectors.

5.1.4 Percentage of establishments using green technologies

Statistics on the percentage of establishments using green technologies (total and by economic activity) would allow an assessment of general progress towards a greener economy.

5.1.5 Employment by type of green technology used (total and by economic activity)

Statistics on employment by type of technology, processes and methods used for restructuring organizational and production processes and for reducing the environmental impact of production will inform labour market planning and help to assess which technologies are likely to create employment opportunities. Disaggregation by economic activity can be used to evaluate how local labour markets are making the transition to greener activities.

5.1.6 Employment in the environmental sector by region

Where information can be obtained, environmental employment may also be analysed at a regional level. This will reveal whether employment in the environmental sector is concentrated in certain areas and whether this geographic distribution is directly linked to other economic activities or particular environmental characteristics of the area (e.g., sea, forest). Over time, such statistics monitor the shift in the structure of employment by economic activity and by geographic area.

5.1.7 Wages and hours of work

As part of data collection on employment in the environmental goods and services sector, it could be useful also to collect data on wages and hours of work. This information would provide further insight into the quality of employment in the environmental sector, and help to identify jobs that are decent.

5.1.8 Decent jobs

In order to generate statistics that will adequately inform environmental policies as well as labour market, social and economic policies, it is necessary to provide statistics that would reflect the decent work dimensions of the jobs in the environmental sector. The decent work dimension may be measured according to relevant indicators selected from the ILO manual on Decent Work Indicators[1]. Examples of variables that could be used to classify jobs as decent or not include (i) social security coverage, (ii) formality of jobs, (iii) average wage paid, (iv) hours of work and (v) social dialogue.

5.1.9 Specific vulnerable groups

Whenever possible, data on employment in the environmental sector should distinguish among age groups (especially between youth and adults) and among levels of education and/or training. A complementary analysis disaggregated by sex is essential for understanding the gender patterns of employment in the environmental goods and services sector and of the differential impact on males and females of particular environmental initiatives. Some results suggest that women are much less likely than men to work in the environmental sector and are particularly underrepresented in the green occupations that are predicted to grow most strongly.

Some results suggest that women are much less likely than men to work in the environmental sector and are particularly underrepresented in the green occupations that are predicted to grow most strongly.

[1] *Decent Work Indicators: Concepts and definitions*, ILO Manual. Available at http://www.ilo.org/wcmsp5/groups/public/---dgreports/---stat/documents/publication/wcms_183859.pdf.

6. Case studies: green jobs assessments in Mongolia and Albania

Key questions to answer

- In Mongolia how many people have green jobs?
- In Mongolia and Albania what percentages of all those employed work more than half of their time in environmental production? In environmental processes?
- In both Mongolia and Albania, how closely do the results of establishment surveys and household surveys compare?

Important observations

- In Mongolia those working in the environmental sector have less education than those working outside the environmental sector.
- In both Mongolia and Albania, many people produce environmental goods or services or use environmental processes, but very few do so more than half of their working time.

6.1 Green jobs in Mongolia, 2016

Mongolia, with technical assistance from the ILO, is one of the first countries to conduct pilot surveys and estimate the number of jobs in the environmental sector and green jobs in line with ICLS guidelines in this area of statistics.[1]

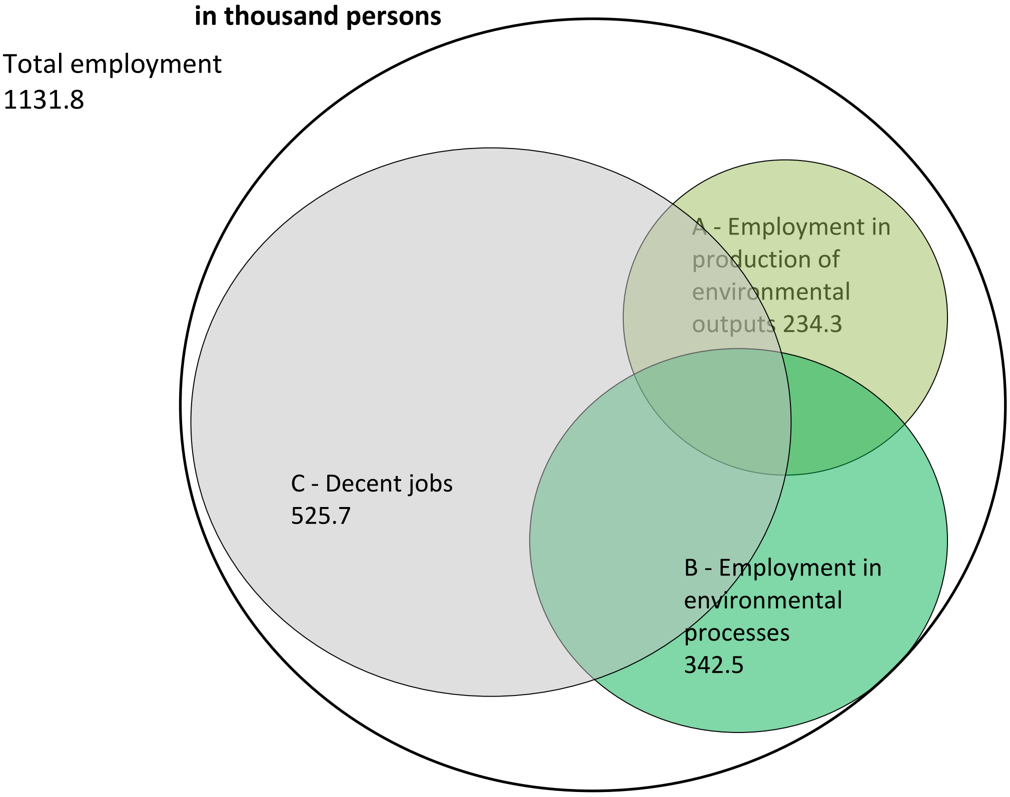
Figure 6.1 shows the distribution of employment in Mongolia according to the statistical definition of employment in the environmental sector and green jobs. Employment in the environmental sector is estimated at 378.5 thousand persons, out of which 234.3 thousand are employed in production of environmental outputs (denoted by A and light green) and 342.5 thousand persons are employed in environmental processes (denoted by B and green). Total number of decent jobs is estimated at 525.7 thousand persons (denoted by C and grey). The intersection of employment in the environmental sector and decent jobs ($(A \cup B) \cap C = 112.3$ thousand persons) represents green jobs.

Some 33.4 per cent (378.5 thousand) of all employed in Mongolia spend at least part of their working time on the production of environmental goods and/or services or using environmental processes and/or technologies. However, the percentage of those that spend more than half of their work time involved in production of environmental goods and services or using environmental processes is below 3 per cent.

Agriculture employs a large share of workers engaged in the environmental sector. Workers in the environmental sector are more likely than those in the overall economy to work as skilled agricultural workers and to be employed as animal husbandry holders – about 56.8 per cent of those employed in the environmental sector, compared with 27.0 per cent in the overall economy. About 68.0 per cent of skilled agricultural, forestry and fishery workers work in the environmental sector, compared with 28.1 per cent in total employment.

[1] The main results of the survey on employment in the environmental sector and green jobs were published in *Employment in the environmental sector and green jobs in Mongolia, Pilot Study,* in September 2017.

Figure 6.1 Employment in the environmental sector and green jobs, Mongolia, LFA 2016 Q2, in thousand persons



- Employment in the environmental sector: A∪B = 378.5 thousands (33.4%)
- Green jobs (employment in the environmental sector that is decent)[1]: (A∪B)∩C = 112.3 thousands (9.9%)

Jobs in the environmental sector are more likely than jobs outside the environmental sector to be filled by workers with less than a university degree. In Mongolia about three-quarters of all those employed in the environmental sector have less than a university degree, compared with about two-thirds in the total economy. In the environmental sector men are more likely than women to have less than a university degree (16.5 per cent of men compared with 29.2 per cent of women have university degrees).

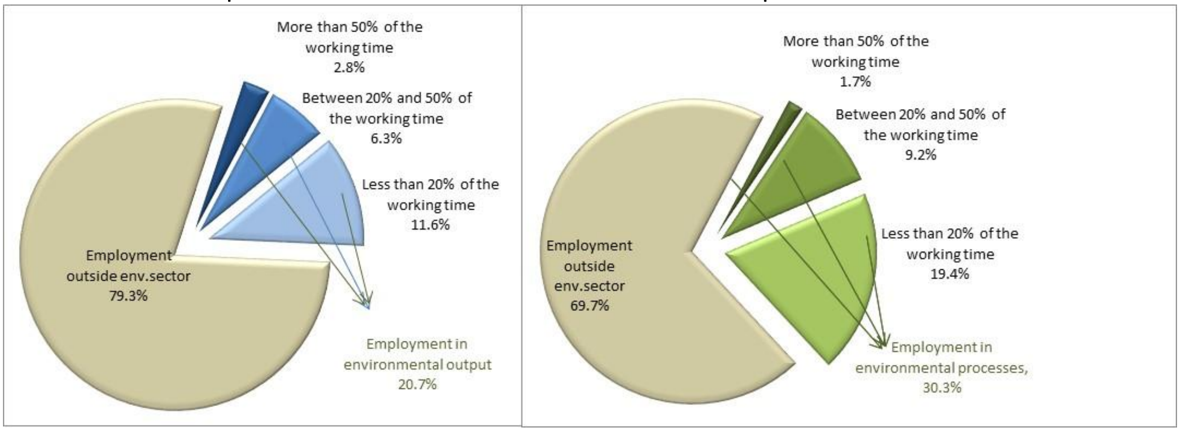
Women are somewhat underrepresented in the environmental sector compared with their share of the overall workforce. They hold four of every ten jobs in the environmental sector, whereas women's share of all jobs is almost 50 per cent.

Out of 374.1 thousand jobs in the environmental sector in the 2nd quarter of 2016, 196.8 thousand, which represents 17.4 per cent of total employment, are environmentally friendly (reduce or eliminate pressures on the environment or make more efficient use of natural resources) and pay decent wages (more than two-thirds of median earnings).

[1] Quality of the jobs was assessed on the basis of coverage by social security schemes.

Figure 6.2 Employment in production of environmental output and environmental process, by working time spent on production of environmental output, results from the Mongolia labour force survey, 2016 Q2

Employment in production of environmental output | Employment in environmental processes



As shown in Figure 6.2, left, and Table 6.1, 20.7 per cent of all employed are involved in the production of environmental outputs, but just 2.8 per cent spend more than half of their work time on actual production of environmental goods and services. By comparison, 17.9 per cent of all employed spend up to half of their time in the production of environmental goods and services.

Although 30.3 per cent of all employed in Mongolia are involved in environmental processes, only 1.7 per cent spend more than half of their work time on environmental processes (Figure 6.2., right), while 28.5 per cent of all employed spend less than half of their working time making production processes more environmentally friendly.

The transition to a low-carbon and resource-efficient economy will require a significant expansion of employment in a number of green economic activities that either replace polluting activities with cleaner alternatives (e.g., renewable energy displacing fossil fuels) or provide environmental services (e.g., waste management, reforestation).

The potential for employment growth in the environmental sector depends on national policies to support particular industries through, for example, tax breaks or subsidies, access to credit or government investment in new technologies. Alternatively, the number of jobs could be increased through pricing policies for competing products; for example, increasing oil prices may make alternative fuels relatively more affordable, driving up demand for products such as solar panels.

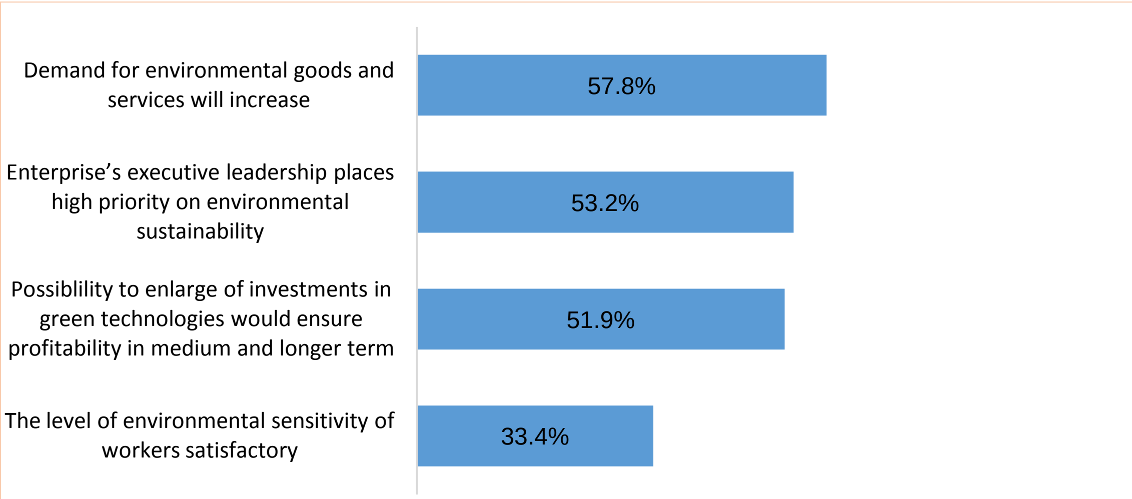
Table 6.1 Employment in environmental sector: summary of Mongolia LFS, 2016 Q2

	Per cent of total employment
Total employed	100.0
Employed person involved in the production of environmental output	20.6
• Employed person involved in the production of environmental output more than half of their working time	2.8
Employed person in environmental processes	30.2
• Employed person who spend more than half of their working time using environmental processes and technologies	1.7

The enterprise survey covered a number of optional questions regarding the environmental sensitivity of workers, constraints they face implementing "green" practices and expectations for increased demand for environmental goods and services. The results (Figure 6.3) are the following:

- Almost 60 percent of enterprises believe that the demand for environmental goods and services will increase.
- More than 50 percent consider environmental sustainability a high priority.
- More than 50 percent believe that enlargements of investments in green technologies would ensure profitability in the medium and longer term.

Figure 6.3 Establishments' perceptions and expectations, Mongolia 2014, (% of enterprises)



6.2 Green jobs in Albania, preliminary results, 2013[1]

6.2.1 Establishment survey

In Albania in 2013, 42 per cent of all employed persons worked in establishments that produced environmental output (Table 2.5). However, only 11.7 per cent of all those employed were involved in the production of environmental output. Many of these jobs are found in establishments that primarily produce goods and provide services that benefit the environment or conserve natural resources. Most of the jobs are in the manufacturing and construction industries.

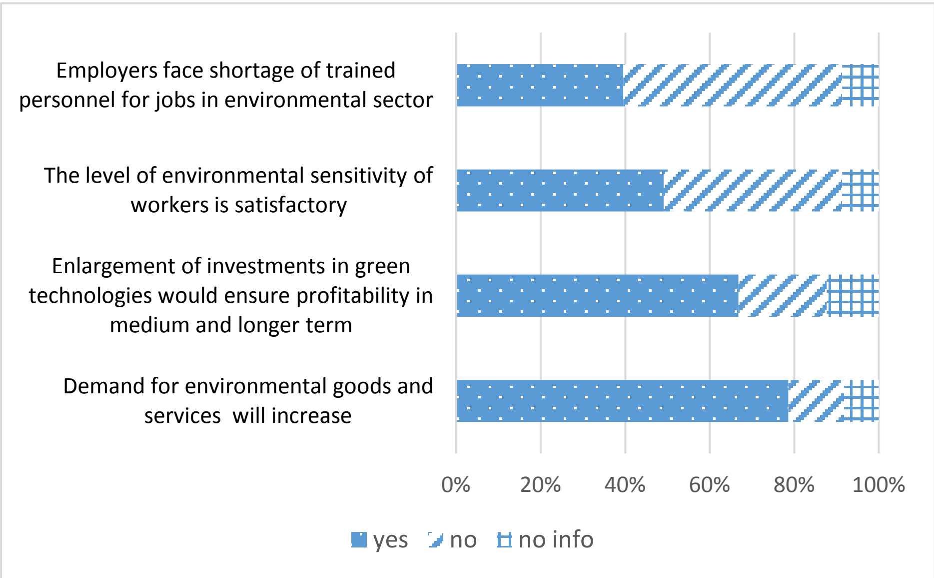
In 2013, 13.2 percent of all employed persons worked in establishments using environmental technologies (Table 2.5). However, only 4.4 per cent of all those employed spent more than half of their work time using these technologies. Close to 80 per cent of these jobs are occupied by persons in elementary occupations, craft and trade-related occupations or plant and machine operation.

[1] The full report, entitled *Report on the pilot project towards developing statistical tools for measuring employment in the environmental sector and generating statistics on green jobs* (ILO, 2014), is available at http://www.ilo.org/stat/Publications/lang--en/index.htm.

Table 2.5 Employment in the environmental sector, Albania establishment survey, 2013

	Per cent of total employment
Total employed in non-agriculture sectors	100.0
Employed in establishments that produce environmental output	42.0
• Out of which, employed in the production of environmental output	11.7
Employed in establishments that use environmental processes in production processes	13.2
• Out of which, employed spending more than half of work-time in environmental processes	4.4

Figure 2.4 Establishments' perceptions and expectations, Albania, 2013



6.2.2. Household survey

According to the Albania 2014 household survey (Table 2.6), 50.7 per cent of all employed persons were involved in the production of at least one category of environmental output. However, just 21.9 per cent of all those employed spent more than half of their work time on the production of environmental output. Many of these jobs involve the production of goods and provide services that conserve natural resources or benefit the environment (e.g., recycling).

In 2013, 64.8 percent of all employed persons in Albania spent some time using at least one environmental technology. However, only 18.8 per cent of all those employed spent more than half of their work time using environmentally friendly technologies.

Table 2.6 Employment in the environmental sector, Albania household survey, 2013

	Per cent of total employment
Total employed	100.0
Employed in the production of environmental output	50.7
• Out of which, employed in the production of environmental output more than half of their working time	21.9
Employed in environmental processes	64.8
• Out of which, employed in environmental processes – full-time equivalent	18.8

Annex 1: Green jobs module for establishment survey

Please report information for this establishment's activities in the period ending 31 December 20XX. Please respond even if you do not produce any environmental goods and services and do not use any green technologies or practices at your establishment.

1. Establishment name ____
   Address, city ________________________ ______________________
   Main economic activity code _______

2. What was the total employment at this establishment as of 31 December 2014? (Include paid employees, employers and contributing family works, both full- and part-time workers **as well as temporary and seasonal workers)**? _______

3. What are the main goods and services produced by your establishment? ___________________

Part 1: Employment in production of environmental outputs

4. During the last 12 months up to 31 December 20XX did your establishment produce, design, and manufacture any of the following categories of environmental goods and services intended for sale or transfer within your company. Do not consider internal green practices, such as recycling programs, use of renewable energy, use of green office products or cleaning materials, use of energy-efficient or pollution-reducing equipment or practices at the worksite, etc.)

Environmental goods and services are those goods and services whose main purpose is environmental protection and/or resource management. These goods and services include research and development, installation and maintenance services.

4.1. Energy from renewable sources

Product and services that:

- generate electricity, heat or fuel from non-fossil renewable sources and/or from waste (e.g., production of electric power from wind, solar, biomass, solid waste, hydroelectric or sources, etc.)
- manufacturing of wind turbine equipment, solar heating equipment, photovoltaic energy equipment, biomass-fired industrial boilers, etc.

Yes ☐
No ☐

4.2. Energy efficient goods and services

Goods and services that:

- reduce energy consumption (e.g. energy efficient manufacturing equipment, electrical appliances, buildings and vehicles; energy efficient lighting, including their maintenance and servicing)
- improve the energy efficiency of buildings and the efficiency of energy storage and distribution (such as Smart Grid technologies)

Yes ☐
No ☐

4.3. Recycling and reuse of waste

Product and services that are reducing the withdrawals of natural resources, such as:

- reuse, collect, sort, recycle, remanufacture waste material (metal, paper, glass, etc.)
- compost solid waste (waste management facilities);
- manufacturing of containers for collection of recycled materials, waste bags, and equipment for waste collection and waste treatment
- sale of second-hand clothing, appliances, vehicles.

Yes ☐
No ☐

4.4. Prevention, reduction and elimination of pollution and air emissions

Goods and services that:

- reduce or eliminate the creation of pollutants or toxic components,
- remove pollutants and hazardous waste from environment,
- reduce or eliminate the creation of waste materials (e.g., water and sewage treatment plants, equipment for treatment of industrial waste water and sewage, waste-to-energy facilities),
- are used to eliminate pollution (e.g., manufacture of waste gas absorbers, waste gas flare/incinerator, catalytic converters, pollutant recovery condensers, filters, absorbers, more-efficient wood-burning stoves, manufacturing of rechargeable batteries, etc.)

Yes ☐
No ☐

4.5. Environmental protection and natural resources conservation

Product and services that:

- protect air, soil, groundwater and surface water, aquatic resources, timber resources, water resources, mineral resources, biodiversity and wildlife (includes growing and planting trees for reforestation; ecotourism, etc.)
- remediation of soil, sediment and sludge (biological, physical and thermal treatment),
- land management,
- monitor and control the quality of air, water, soil,
- research and development on environmental protection.

Yes ☐
No ☐

4.6. Organic agriculture

Agricultural products (crops, vegetables, fruits, meat, dairy products, cotton, and wool) produced without or with very limited use of chemical fertilizers and pesticides, plant growth regulators such as hormones, antibiotic use in livestock, genetically modified organisms, artificial insemination, etc.

Yes ☐
No ☐

4.7. Environmental administration, compliance, training and teaching, and public awareness

Goods and services that:

- enforce environmental regulations and standards,
- provide education and training related to green technologies and practices,
- increase public awareness of environmental issues.

Yes ☐
No ☐

4.8 .Other environmental goods and services (that are beneficial for the environment or conserve natural resources) not mentioned previously

Yes ☐ Please describe: ____

No ☐

If "Yes" to at least one category of environmental goods and services in Q4, go to Q5. Otherwise, go to Part 2.

5. In the last 12 months, up to 31 Dec. 20XX, did your establishment have any revenues from the sale (including market value of goods and services rendered for transfer within your company) of environmental goods and services checked "Yes" in Q4?

Yes ☐ (Go to Q6)

No ☐ (Go to Q7)

6. (If "Yes" to Q5) What percentage of this establishment sales revenues during the last 12 months came from sales of environmental goods and services checked "yes" in Q4? ______% (estimation)

7. (If "No" to Q5) What percentage of employed in this establishment primarily works on production of environmental goods and services checked "yes" in Q4? _____% (estimation)

Part 2: Employment in environmental processes

8. In the last month (ending 31 Dec. 20XX), did your enterprise use any goods and services or technologies and practices aiming at **reducing or eliminating pressures of your establishment on the environment** or t**o make more efficient use of natural resources in the production process?**

Yes ☐

No ☐

If "Yes", please mark one or more of the following environmental technologies and practices used at your workplace and indicate the number of workers at your workplace that spent any of their time during the month of December involved in:

- researching, developing, maintaining, using or installing technologies and practices to reduce the environmental impact of their establishment, or
- training the establishment's workers or contractors in these technologies or practices.

8.1. Energy from renewable sources

Generate electricity, heat or fuel from renewable sources for use within your establishment (Electric power production from wind, solar, biomass, solid waste, hydroelectric sources, etc.)

Yes ☐ If yes, how many of the workers were involved: _____

No ☐

8.2. Energy efficiency

Use technologies and practices to increase energy efficiency within your establishment (e.g., use energy efficient appliances, energy efficient manufacturing equipment, energy efficient lighting, energy efficient buildings, use of alternative fuel vehicles (fuel cells/advanced batteries, hybrid vehicles, etc.)

Yes ☐ If yes, how many of the workers were involved: ______

No ☐

8.3. Recovery, reuse and recycling of resources and/or substitution of natural resources
Use technologies or practices to reduce the withdrawals of natural resources, or eliminate the creation of waste material as a result of your operations (e.g., collecting and reusing or recycling of glass, metals, paper, rubber, textiles) and waste water; composting solid waste, remanufacturing of waste material, etc.)

Yes ☐ If yes, how many of the workers were involved: ______
No ☐

8.4. Prevention, reduction and elimination of pollution and air emissions
Use technologies or practices

- to reduce or eliminate the creation or release of pollutants or toxic components as a result of your operations and/or
- to remove pollutants and hazardous waste from environment (e.g., carbon dioxide, methane, carbon monoxide, sulphur dioxide, nitrogen oxides, herbicides and pesticides, heavy metals, radioactive contamination, etc.).

Yes ☐ If yes, how many of the workers were involved: ______
No ☐

8.5. Environmental protection and natural resources conservation
Use technologies or practices in your operations to protect and conserve natural resources

- protection and remediation of soil, groundwater and surface water;
- reduction of water or other resource consumption (including by using storm water);
- protection of biodiversity and landscapes;
- protection and remediation of timber resources (includes sustainable forestry practices);
- protection and remediation of aquatic resources; etc.

Yes ☐ If yes, how many of the workers were involved: ______
No ☐

8.6. Sustainable agricultural practices, including organic agriculture
Use agricultural practices that do not cause long-term damage to soil (e.g., excessive tilling of the soil and irrigation without adequate drainage), cultivate crops, vegetables, fruits, animals without or with very limited use of chemical fertilizers and pesticides, plant growth regulators such as hormones, antibiotic use in livestock, genetically modified organisms, artificial insemination, etc.

Yes ☐ If yes, how many of the workers were involved: _____
No ☐

8.7. Research, planning, maintenance and control of technologies

- Research and development of processes to conserve energy or natural resources or to reduce pollution;
- planning, implementing, and monitoring of these processes;
- maintaining or installing equipment or infrastructure associated with the processes;
- measuring and controlling outputs of the process.

Yes ☐ If yes, how many of the workers were involved: ______
No ☐

8.8. Other environmentally friendly technologies and practices not mentioned previously
Please describe: ____

Yes ☐ If yes, how many of the workers were involved: _____
No ☐

9. Please indicate the total number of workers who spent **more than half of their working time** involved in environmental technologies and practices reported in Q8 in the month of Dec. 20XX (Note each worker should be counted only once, even if he/she involved in more than one technology and reported more than once in Q8. If no worker spent more than half his/her time, enter zero.) Number:______

10. Please indicate the occupations, number of employees in each occupation and average monthly wages of the workers reported in Q9 who spent more than half of their working time actively involved in environmental technologies and practices (example: Plumbers installing solar panels – Number: 6 – Average monthly wages: $1000).

Occupation	**Number**	**Average monthly wages**

Part 3: Opinions and expectations (optional)

11. Do you think that demand for environmental goods and services will increase?

Yes ☐
No ☐
Why? ____.

12. Do you think possible enlargement of investments in green technologies would ensure profitability in medium and longer term?

Yes ☐
No ☐
Why? ____

13. What obstacles do you face in the way of implementing “green” practices at your workplace? (Check all that apply)

- ☐ Shortage of workers with the knowledge or skills in environmental activities/practices
- ☐ Shortage of available training programs
- ☐ Costs of implementation
- ☐ Uncertain return on investment or too long payback period for green technologies
- ☐ Uncertain demand from the market
- ☐ Lack of information
- ☐ Government policies/regulations (not providing incentives to greening)
- ☐ Insufficient access to existing subsidies and fiscal incentives
- ☐ Other (describe) ____

14. What resources would help reduce or eliminate the creation or release of pollutants (e.g., CO_2 emissions) at your establishment? (Check all that apply)

- ☐ Information about specific actions to take to cost-effectively reduce emissions
- ☐ Success stories showing how similar businesses cost-effectively reduce their CO2 emissions
- ☐ Financing options to reduce emissions
- ☐ State-wide award programme to recognize businesses that successfully reduce emissions
- ☐ Protocol for reporting emissions
- ☐ Technical support (e.g., training and online questions and answers)
- ☐ None
- ☐ Other

15. Do you find the level of environmental sensitivity of workers satisfactory?

Yes ☐
No ☐
Why? ____

16. Does your establishment's executive leadership places high priority on environmental sustainability?

Yes ☐
No ☐
Why? ____

Thank you for completing this survey.

Annex 2: Green jobs module for labour force survey

Part 1. Employment in production of environmental outputs (to be completed for employed family members)

1. During the last month were you involved in production in any of the following categories of environmental goods and services intended *for consumption outside your work site*? These goods and services include research and development, installation, and maintenance services.								**2. During the last month what percentage of your working time did you spend on the production of the environmental goods and services reported in Q1?**
1.1. Energy from renewable sources	1.2. Energy efficient goods and services	1.3. Reduction and removal of pollution and greenhouse gas emission	1.4. Recycling and reuse of waste	1.5. Environmental protection and natural resources conservation	1.6. Environmental compliance, education and training, and public awareness	3.7. Other		
Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	If yes, describe	1-less than 20%; 2-between 20 and 50% 3-more than 50%
Product and services that - generate electricity, heat or fuel from non-fossil renewable sources and/or from waste (e.g., production of electric power from wind, solar, biomass, solid waste, hydroelectric or nuclear sources, etc.) - manufacturing of wind turbine equipment, solar heating equipment, photovoltaic energy equipment, biomass-fired industrial boilers, etc.	Goods and services that - reduce energy consumption (e.g., energy efficient manufacturing equipment, electrical appliances, buildings and vehicles; energy efficient lighting); - improve the energy efficiency of buildings and the efficiency of energy storage and distribution (such as Smart Grid technologies)	Goods and services that - reduce or eliminate the creation of pollutants or toxic components, - remove pollutants and hazardous waste from environment, - reduce or eliminate the creation of waste materials (e.g., water and sewage treatment plants, equipment for treatment of industrial waste water and sewage, waste-to-energy facilities), - manufacture of waste gas absorbers, waste gas flare/incinerators, catalytic converters, pollutant recovery condensers, filters, absorbers, more-efficient wood-burning stoves, manufacturing of rechargeable batteries, etc.	Product and services that - reuse, collect, sort, recycle, remanufacture waste material and/or - compost solid waste (including treatment and disposal of hazardous waste). - Includes manufacturing of containers for collection of recycled materials, waste bags and equipment for waste collection and waste treatment - sale of second-hand clothing, appliances, vehicles	Product and services that protect air, soil, groundwater and surface water, aquatic resources, timber resources, water resources, mineral resources, biodiversity and/or wildlife (e.g., organic agriculture, sustainable farming and forestry; trees for reforestation; planting trees; soil, water and wildlife conservation); land management, conservation of soil, water, biodiversity and wildlife); control, containment and monitoring services (air, water, soil)	Goods and services that - enforce environmental regulations and standards, - provide education and training related to green technologies and practices, - increase public awareness of environmental issues	Other environmental goods and services (that are beneficial for the environment or conserve natural resources) not mentioned previously		Only if "Yes" to at least one category of environmental goods and services in Q1.1 – Q1.7.

Part 2. Employment in environmental processes (to be completed by employed family members)

3. In the last months, did you use one or more of the following environmental technologies and practices at your worksite in order to reduce the environmental impact of your establishment, or to train the establishment's workers or contractors in these technologies or practices?								**4. During the last month what percentage of your time did you spent in researching, developing, maintaining, using or installing technologies and practices reported in Q3?**
3.1. Energy from renewable sources	3.2. Energy efficiency	3.3. Reduction and removal of pollution and greenhouse gas emission	3.4. Recovery, reuse and recycling of resources and/or substitution of natural resources	3.5. Environmental protection and natural resources conservation	3.6. Research, planning, maintenance and control of technologies	3.7. Other		
Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	If yes, describe	1-less than 20% 2-between 20 and 50% 3-more than 50%.
Generate electricity, heat or fuel from renewable sources for use within your establishment (e.g., electric power production from wind, solar, biomass, solid waste, hydroelectric or nuclear sources, etc.)	Use technologies and practices to increase energy efficiency within your establishment (e.g., use energy-efficient appliances, energy-efficient manufacturing equipment, energy-efficient lighting, energy-efficient buildings, use of alternative fuel vehicles (fuel cells/advanced batteries, hybrid vehicles, etc.)	Use technologies or practices - to reduce or eliminate the creation or release of pollutants or toxic components as a result of your operations and/or - to remove hazardous waste from the environment (e.g., carbon monoxide, sulphur dioxide, nitrogen oxides, herbicides and pesticides, heavy metals, radioactive contamination, etc.).	Use technologies or practices to reduce or eliminate the creation of waste material as a result of your operations (e.g., collecting and reusing or recycling of glass, metals, paper, rubber, textiles) and waste water; composting solid waste, remanufacturing of waste material, etc.)	Use technologies or practices in your operations to protect and conserve natural resources - Protection and remediation of soil (includes implementing organic farming); groundwater and surface water; - reduces water or other resource consumption (including by using storm water); - protection of biodiversity and landscapes; - protection and remediation of timber resources (includes sustainable forestry practices); - protection and remediation of aquatic resources; etc.	- Research and development of processes to conserve energy or natural resources or to reduce pollution; - planning, implementing, and monitoring of these processes; - maintaining or installing equipment or infrastructure associated with the processes; - measuring and controlling outputs of the process.	Other environmentally friendly technologies and practices not mentioned previously		Only if "Yes" to at least one category of environmental processes in Q3.1 – Q3.7.

Green Jobs Assessment Institutions Network (GAIN)

Training module 3:

Building Input–Output Based Employment Projection Models with Expanded Green Industries (Green EPMs)

Contents

1. Introduction

Key questions to answer

- What does an input–output table show?
- How is an input–output table structured?
- How can input–output analysis help to compare green and conventional industries?

Important observations

- Input–output tables can depict physical units, such as employment, as well as monetary flows.
- The main economic indicators of interest are employment, other value added and total final demand.
- Industries use their own products and the products of other industries as inputs to produce their products. Outputs from one industry become inputs to another.
- The IO framework is well suited to comparing the production structures of conventional and green industries making equivalent products.

This module provides guidance on how to expand conventional input–output (IO) tables, which do not feature most green activities, so that green industries can be distinguished. It offers a short introduction to building simple employment projection models (Green EPM). It is a step-by-step guide, using as a starting point conventional IO tables based on the International Standard Industrial Classification (ISIC). The module explains how to classify green industries according to the System of Environmental and Economic Accounts (SEEA) and how to split the ISIC-classified activities into green and conventional parts. A comparative static model is built, which forms the basis for a green employment projection model.

1.1 History of economic input–output accounting and modelling

The idea of modelling the economy in an input–output framework can be traced as far back as the 18th century, to François Quesnay's *Tableau Economique* (*Economic Table*), published in 1758 (Miller and Blair, 2009; Steenge and Van den Berg, 2008). This publication presented the first analytical description of the economy (O'Hara, 1999). In the 1870s Léon Walras developed the general equilibrium model, based on the idea that total inputs must equal total outputs (Silva, 2001). Inspired by these writings, Wassily Leontief developed the formal theoretical framework of IO analysis in the late 1930s (Bjerkholt and Kurz, 2006; Miller and Blair, 2009). Leontief further developed the input–output accounting framework in his 1941 and 1953 works on the structure of the economy of the United States of America. This led to the IO model that he first published in 1965, for which he received the Nobel Prize in Economic Science in 1973 (Miller and Blair, 2009). To this day key components of many types of macroeconomic analyses are based on Leontief's concepts. Probably, one of the most widely applied methods in economics is, indeed, IO analysis.

A basic IO table shows inter-industry transactions, with an equal number of industries in the columns and the rows. It also includes value added generated by industries and final demand for products in such a way that column entries record industries' expenditures, while the rows capture industries' revenues, and column and row totals are equal (the value of total inputs = the value of total outputs). There have been various modifications and extensions to the

A basic IO table shows inter-industry transactions, with an equal number of industries in the columns and the rows.

basic IO framework to incorporate additional detail on economic activity, such as employment and environmental issues (including, lately, green industries). IO models are then used to project economic activity, employment or environmental impacts by industry. They can be static, comparative or dynamic, depending on data availability and the scope of the analysis.

Intended users for this module

This module is meant for analysts who seek to build employment projection models using input–output tables and expand them to distinguish green industries and project green jobs. The reader will find familiarity with matrix algebra helpful.

Learning objectives of this module

- understand the logic of the input–output (IO) matrix;
- know the principles that govern construction of an IO table;
- understand how a conventional IO table can be expanded to distinguish green industries;
- understand how satellite accounts link physical data, such as number employed or CO2 emitted, to the financial information in an IO table;
- be able to build a static short-term IO model that projects output and employment from policy scenarios, which are modelled as changes in final demand or investment.

Structure of this module

Module 3 is organized into the following elements:

Chapter 1 presents the history of IO accounting and modelling and basics of the IO table as an accounting framework.

Chapter 2 discusses indicators for and definition of green sectors/industries/activities.

Chapter 3 explains how to perform an industry expansion to separate conventional from green sectors, industries and activities.

Chapter 4 addresses adjustment of production functions to reflect green technology and balancing the IO table.

Chapter 5 presents basic IO modelling examples with output and employment multipliers.

Chapter 6 explains how to calculate multipliers with a basic IO and with a green IO, making projections of the employment effects of alternative policy and investment scenarios.

1.2 Basics of the input–output accounting framework

An IO table features the following four major entry blocks:

- intermediate demand, industry-by-industry;
- gross value added;
- imports; and
- total final demand.

The entries in the IO table are typically in monetary values.[1] However, as will be shown later, the IO framework allows for combining monetary flows and physical units. Depending on the interest, these can include employment numbers in terms of jobs, energy use in kilowatt hours or pollution in terms of carbon emissions. To handle these non-monetary quantities in addition to the monetary values, so-called "satellite accounts" can be added to the IO framework.

The IO framework allows for combining monetary flows and physical units, including employment numbers.

Intermediate demand consists of all payments for goods and services between industries.

Value added consists of:

1. taxes minus subsidies;
2. compensation of labour; and
3. gross operating surplus, which includes distributed (to households) and non-distributed profits.

Total final demand is composed of:

1. exports;
2. government final consumption and investment;
3. household consumption; and
4. private investment.

It is important for the IO projection model to distinguish between consumption (notably, household demand) and investment. This is because final demand for consumption of non-durable goods has a composition different from that of final demand of investment for durable goods.

The main economic indicators of interest are employment, other value added and total final demand, which are used for the calculation of gross domestic product (GDP). For calculations of output and of value added and employment multipliers as well as of labour productivity, it is important to understand and calculate **gross value added (GVA)** and **gross output (GO)**. In short, GVA is composed of taxes (on products and production, not on incomes) minus subsidies, wages and operating surplus. GO is composed of GVA plus total domestic intermediate demand (industry-by-industry) and imports (Table 2.1). Typically, in public debates and economic reporting, intermediate demand is rarely mentioned. That is why we say that the main variables of interest are captured in GVA. However, as will become clear later in the module, intermediate demand is important to quantify the indirect effects, including on jobs, of economic growth.

1.2.1 Understanding the interconnections: basic input–output logic

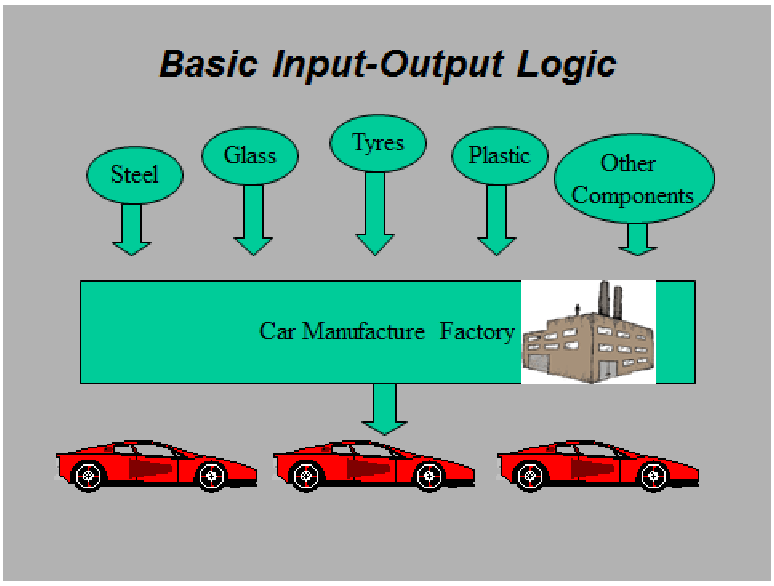
IO modelling centres on inter-industry transactions. Industries use their own products and the products of other industries as inputs to produce their products. Automobile producers are a good

IO modelling centres on inter-industry transactions.

[1] The IO table can be valued in basic or producer prices. The basic price is the price received by a producer of a good or service minus any taxes that the producer paid. The producer price is the basic price plus taxes paid on production (and does not include value added or other deducible taxes). Both types of price exclude any transport cost.

example of an industry using many intermediate inputs, such as steel, glass, rubber, electricity and glass, to produce cars (Figure 1.1). Thus, outputs from one industry become inputs to another. Therefore, when you buy a car, you affect demand for all those industries that supply the automotive industry with inputs, namely glass, plastic, steel, etc. An increase in demand for cars leads also to an increase in demand and therefore, production, of the inputs used to make the cars.

Figure 1.1 Inter-industry IO transactions: example of an automobile producer



Source: Perlich, no date

In an actual country the economy can conceptually be separated into purchasers and suppliers; with primary suppliers, intermediate suppliers, intermediate purchasers and final purchasers.

Primary suppliers sell primary inputs to other industries and receive primary inputs payments because these inputs will not be sold further. These primary supplies include labour, land and capital.

Intermediate suppliers buy the products of other industries to use in the production of their own outputs. In turn, they supply their outputs to other industries or sell to final purchasers such as households. To use the car maker example, cars can be used as inputs by such industries as trucking companies and taxi companies. Another example is the tyre producer, who buys rubber, steel and other products to produce tyres that will subsequently be sold either to a car factory for intermediate consumption or, as final demand, to households.

Intermediate purchasers buy inputs for processing into products for sale to other industries for use as intermediate inputs or for use by final purchasers. Thus, intermediate suppliers and intermediate purchasers are one and the same.

Lastly, **final purchasers** buy products for final use, sold to them in their final form by suppliers. An example is households buying tyres for final use. Unlike intermediate suppliers and purchasers, primary suppliers and final purchasers are not necessarily the same. However, if they happen to be the same – for example, households – their activities when they are primary suppliers are completely different from their activities when they are final purchasers.

Intermediate demand and **value added** are two distinct components of the production process. As pointed out above, intermediate demand is the demand for inputs/materials/services by each economic activity in order to produce outputs. In contrast, value added consists of compensation of employees, gross operating surplus (which includes profits) and net indirect taxes. These are called *factors of production*. They are the basis of the *circular flow of income* (Figure 1.2), which consists of flows of goods and services and factors of production between firms and households and shows connections between different sectors. The key components of the circular flow of income are:

- **Producers buy factors of production** – notably, labour and capital – on the factor market **and demand intermediate inputs** (domestically produced and imported) from the product market for use in the production process, to produce output that will be supplied on the product market.
- **Households supply primary factors of production** to producers – notably, labour and capital (which can be in the form of savings), and they **buy goods and services** from the product market for final consumption.
- **The Rest of the World sells imports** for use as intermediate inputs by producers and for final consumption by households, and it **buys exports** from the domestic market.

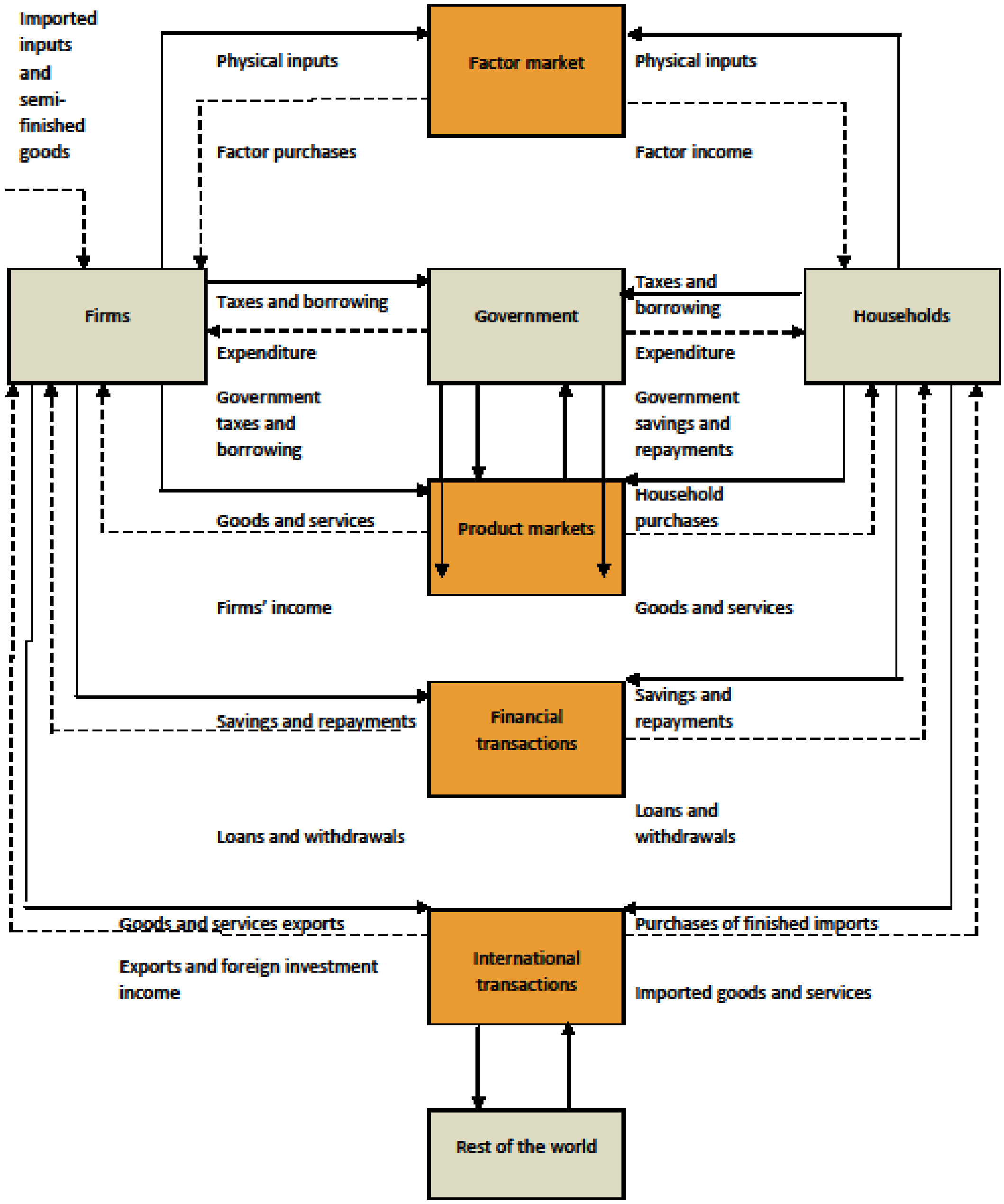
Applying the IO concept to the green economy, a car manufacturer shifting towards a greener economy and producing electric cars will have a different input structure from a maker of conventional cars. Instead of purchasing combustion engines, it will purchase electric motors and batteries as intermediate inputs. Similarly, taking the example of electricity generating enterprises, the IO framework shows that a coal-fired power plant will have a different input structure from that of a wind park. However, both enterprises will produce the same output, electricity. A thermal power plant requires coal as an input, whereas a wind park requires an initial number of wind turbines and probably more factor input, notably labour for operation and maintenance, than the coal-fired plant.

> A coal-fired power plant will have a different input structure from that of a wind park, but both will produce electricity.

Using the IO framework makes it possible to compare the production structure of a renewable energy producer with that of a thermal energy producer, or the structures of conventional and electric car manufacturers, for example. Thus, the approach is well suited to studying the effects on employment and income of structural change as green industries supplant conventional industries.

> The IO framework is well suited to comparing the production structures of conventional and green industries making equivalent products.

Figure 1.2 The circular flow of income



2. The IO table as an accounting framework

Key questions to answer

- Why can’t green enterprises be seen in standard IO tables?
- Why does every sector appear as both a column and a row in IO tables?

Important observations

- We calculate the technical coefficients by dividing the intermediate industry inputs and value added inputs by the total output.

Knowing the principles for constructing IO tables is important for understanding the different components of the resulting matrix. These principles are the following:

- The tables are constructed so that basic national account identities are respected. Thus, the figures are based on a fundamental identity – i.e., **supply equals demand**. This means that supply, or sectoral output X, must equal final demand Y + intermediate demand Z.
- All the data in the IO table are presented in **monetary terms** (satellite accounts with physical data, such as jobs, can be added).
- It is easiest, although not necessary, to assume that each sector (industry in statistical terminology) or activity produces only one product or output.

IO tables offer a snapshot of the structure of the economy, detailed for each industry (or sector).[1] Typically, national statistics offices, which compile the IO table for a country, follow the International Standard Industrial Classification (ISIC) of all economic activities. Thus, we can determine which of the classified industries are important for the other producing industries. We can also see the differences in industries in terms of their contribution to the production of inputs and final goods in the economy. We are able to learn and compare the differences in the primary factors (labour and capital) required by the different industries. We can tell which industries are export-oriented and which are not. We can tell the extent of relative dependence on imported inputs. As a result we can make informed guesses about, for example, what the likely impact of changes in the exchange rate would be on different industries. However, in conventional IO tables we cannot see green industries such as renewable energy or organic agriculture. This is because the ISIC does not classify them separately (see Module 2; only a very few, such as waste management, are ISIC-classified). The green industry’s activity is lumped together into broader sets of industries

> In conventional IO tables we cannot see the green industries because ISIC does not classify them separately.

[1] We will follow the UN Statistics Office Industrial Standard Classification of Industries (ISIC revision 4) and denote any economic activity accounted for in the IO as “industries”. These can be service industries, manufacturing industries or agricultural industries. We use the term “sectors” as a synonym for industries, although in a strict terminology the term “sector” refers to the three aggregated categories of primary, secondary and tertiary sectors. The System of National Accounts actually uses “sectors” to refer to the institutional sectors (households, corporations, government, etc.), rather than “aggregated industries”.

such as energy and agriculture. The next chapter explains how to expand the IO table to separate out the green industries.

2.1 Interpreting the numbers in the IO table

The rows in IO tables detail sales by industry, while the columns display the input purchases by industry. Table 2.1 is an example of an IO table.

Table 2.1 IO table in symbols

			Industry-by-industry Total domestic purchases of inputs			**Total final demand (D)**				
			Agriculture	**Manufacturing**	**Services**	**Household demand**	**Private investment**	**Government demand**	**Exports**	**Output (sales)**
	Industry by industry Total domestic production of outputs	Agriculture	O_{11}	O_{12}	O_{13}	C_1	I_1	G_1	EX_1	X_1
		Manufactur-ing	O_{21}	O_{22}	O_{23}	C_2	I_2	G_2	EX_2	X_2
		Services	O_{31}	O_{32}	O_{33}	C_3	I_3	G_3	EX_3	X_3
Gross value of output	IMPORT	Imports	M_1	M_2	M_3	M_C	M_I	M_G		M
	Gross value added	Taxes minus subsidy	T_1	T_2	T_3					T
		Wages and salaries	W_1	W_2	W_3					W
		Profit[1]	$Profit_1$	$Profit_2$	$Profit_3$					Profit
	Total input (payment)		X_1	X_2	X_3	C	I	G	EX	
Employment by industry			E_1	E_2	E_3					
CO2 emissions by industry			$CO2_1$	$CO2_2$	$CO2_3$					

[1] The term “profit” is used to simplify the national account concept of gross operating surplus, which includes depreciation and distributed and undistributed profits.

Source: Authors’ compilation

The contents of Table 2.1 can be formally presented as follows:

$X_1 = O_{11} + O_{12} + O_{13} + C_1 + I_1 + G_1 + EX_1$

$X_2 = O_{21} + O_{22} + O_{23} + C_2 + I_2 + G_2 + EX_2$

$X_3 = O_{31} + O_{32} + O_{33} + C_3 + I_3 + G_3 + EX_3$

where the Xs represent levels of production (total output); the intermediate inputs from industry i required to produce a unit of output of industry j is O_{ij}; and the final demand levels from the demand categories – namely, consumers, investment, government and exports – are, respectively, C, I, G and EX.

Table 2.1 depicts three production sectors: agriculture, manufacturing and services. These sectors are producing goods and services, and they are selling their products and services to other sectors (indicated as *intermediate demand*) and to *final demand* categories, namely, household consumption, investment, government expenditure and exports. Sectors also sell some of their products to other firms in the same sector. These deliveries are called *internal deliveries (sales)* and are visible in the diagonal of the IO table. All these aspects are shown in rows 1 through 3 in the table.

As seen in Table 2.1, each of the sectors appears twice in the table; as a column and as a row. *As a column*, a sector plays the role of purchasing goods and services (intermediate demand). This is referred to as the cost structure of the industry, because it shows the expenditures, industry-by-industry, necessary for producing goods or services. The sector then uses the goods and services as inputs in the production process. Hence, the columns contain input data. For example, reading downwards under the column for agriculture, the agricultural sector is found to purchase O_{11} units from itself, O_{21} from industry and O_{31} from services. It also uses M_1 of imports.

As a row, a sector plays the role of producing and selling the goods and services to itself and the other sectors in the economy. Therefore, the row contains sales or output data. By reading along the row, we are able to determine the sectoral contributions to output. Row 4 in the table indicates that some inputs are imported. These imports may include intermediate demand or final demand categories, such as consumption, investment or government expenditure. In row 5 gross value added is shown as the difference between total output (X_1) and the intermediate inputs of a sector.

Note that total input in agriculture (X_1) equals the total output in the same sector (X_1). Gross value added is subdivided into depreciation (to compensate for the wear and tear on capital), the remuneration of labour (wages) and the remuneration of capital (profits).

Now, we assume that Table 2.1 is our IO table, but with the values shown in Table 2.2 instead of symbols. Reading down the columns, we can calculate each input's share in total output – that is, the production share that each input (each cost item) represents relative to total output. These individual shares are called technical coefficients (typically abbreviated as "a") because they represent the technical structure of the industry's inputs. They are calculated by dividing each of the intermediate industry inputs and each of the value added inputs by the total output. In this case, $a_{11} = O_{11}/X_1$, with numbers, 12.5/500 = 0.025, which gives $O_{11}= a_{11}\ X_1$ and, with numbers, 12.5 = 0.025*500, etc. The matrix of technical coefficients is also known as the A matrix. Inserting the technical coefficients, we obtain the information below:

$X_1 \quad = 0.025\ X_1 + 0.03\ X_2 + 0.08\ X_3 + 0.1\ C + 0.005\ I + 0.21\ G + EX_1$

$X_2 \quad = 0.050\ X_1 + 0.06\ X_2 + 0.10\ X_3 + 0.3\ C + 0.66\ I + 0.04\ G + EX_2$

$X_3 \quad = 0.100\ X_1 + 0.06\ X_2 + 0.02\ X_3 + 0.2\ C + 0.005.I + 0.22\ G + EX_3$

$m \quad = 0.150\ X_1 + 0.12\ X_2 + 0.04\ X_3 + 0.4\ C + 0.33\ I + 0.53\ G$

$\text{taxes} = 0.025\ X_1 + 0.02\ X_2 + 0.02\ X_3$

$\text{wages} = 0.500\ X_1 + 0.60\ X_2 + 0.60.X_3$

$\text{profits} = 0.150\ X_1 + 0.11\ X_2 + 0.14\ X_3$

Table 2.2 **IO table in numbers, in units of a country's currency**

			Industry-by-industry Total domestic purchases of inputs			Total final demand (D)				
			Agriculture	**Manufacturing**	**Services**	**Household demand**	**Private investment**	**Government demand**	**Exports**	**Output (sales)**
	Industry by industry Total domestic production of outputs	Agriculture	12.5	27	60	40	4.5	82	274	500
		Manufacturing	25	54	120	120	594	16	16	900
		Services	50	54	80	80	4.5	85.3	461.2	750
Gross value of output	IMPORT	Imports	75	108	160	160	297	206.7		876.7
	Gross value added (GVA)	Taxes minus subsidy	12.5	18	15					45.5
		Wages and salaries	250	540	450					1 240
		Profit	75	99	105					279
	Total input (payment)		500	900	750	400	900	390	751.2	

Satellite accounts				
Employment by industry	125	96	89	310 (total employment)
CO_2 emissions by industry				
Other physical, social and environmental values, e.g., waste, water, skill level, youth, informal workers				

Source: Authors' compilation

3. Distinguishing green industries in IO analysis

Key questions to answer

- Why does it make sense, when analyzing employment, to distinguish between green and conventional industries?
- How does the approach “industry expansion through disaggregation” show green industries in an IO table?
- How can columns be expanded to show green industries if specific data on expenditures are not available?
- When can we assume that the sales structures of green and conventional industry are different and when are they similar?

Important observations

- Green industries typically do not have the same production structure as conventional industries (e.g. green versus conventional agriculture).
- The green industries are added both as columns and as rows so that the table remains square.
- Often, an IO table separating green and conventional industries can be built even if a representative sample survey of green industries is not possible.

3.1 Rationale for expanding the IO table

Expansion of the IO table is necessary because green industries typically are reported as part of broader categories of industries, lumped together under ISIC classifications. As discussed in Module 2, the ISIC guidelines aggregate activities according to the type of output of their main activity. For example, electricity is considered the main output – and, thus, the single classification – of all industries in electricity generation, whatever the source generating the electricity. As a result, coal-fired plants are aggregated with wind turbines. While the output of the main activity in both cases is “electricity”, the input structure, as well as the environmental externalities, is very different. The technology used makes a big difference in terms of impact on employment, income, value added and the environment.

Because of our focus on the green economy, we are interested not only in differences in input and production structures but also in differences in environmental externalities due to differences in the product and the processes used to produce it. From both environmental and economic development perspectives, then, it makes sense to distinguish green and conventional industries.

From both environmental and economic development perspectives, it makes sense to distinguish green and conventional industries.

To see green industries that are not ISIC-classified and, hence, do not feature in the conventional IO table, expansion of the IO table is required. The methodology presented here is called “industry expansion through disaggregation”. This methodology fully integrates the green industries into the IO table as standalone industries. The green establishment survey, described in Module 2, should provide data on intermediate demand, value added and imports. These data now can be inserted into the new IO table through expansion (see section 3.2). This requires turning the survey data into consistent values for the column and row entries of the green industries.

A second methodology, introduced in the Appendix, involves inserting the data on the green production structure as values in the final demand column. This is called the “synthetic industry” approach. This approach is much simpler; no modification of the production structure in the IO table is required. However, while the synthetic industry approach is a good method to compare outcomes of investment scenarios between industries, it has limitations for the development of direct and indirect employment and output multipliers and more advanced employment projection models. Also in the Appendix is a third methodology, which first disaggregates several industries at the same time and then aggregates them back into a single new industry. UN Statistics suggests this disaggregation–aggregation method to create industries of particular interest, such as international tourism, which is composed of several ISIC industry classifications.

The ultimate objective of this exercise, however, is to build a planning tool that compares alternative policies and their impacts on employment. So, here we present a methodology that disaggregates a single parent industry into a conventional and a green industry. In particular, organic agriculture is split from conventional agriculture, and renewable energy equipment manufacturing, from other manufacturing.

3.2 Expanding the IO table

Table 3.1 shows, in theoretical terms, how to expand the conventional IO table to distinguish green industries from non-green parts of the same broader industry. The green industries are added both column-wise and row-wise so that the table remains square. The examples used here are organic agriculture (e.g., the output is organic-labelled food) and manufacturing. (To make manufacturing more illustrative, we use renewable energy machinery manufacturing, e.g., wind turbines as the output produced.)

The green industries are added both column-wise and row-wise so that the table remains square.

Practically, however, the green industry expansion requires several steps, which can be subsumed into two main stages: First, green industries need to be defined and identified. Most importantly, data must be gathered on the particular production structures of green industries, including intermediate demand, value added and imports as well as employment. This is best done through a green establishment survey, either a subsample survey or attached to the standard establishment survey (see Module 2). Second, the data must be technically integrated into the IO table in such a way that the resulting matrix remains balanced while representing the particular structure of the green industries.

Table 3.1 IO table in symbols – green expansions

		Industry-by-industry Total domestic purchases of inputs					Total final demand (D)				
		Agriculture – conventional	Green agriculture	Manufacturing – conventional	Green manufacturing	Services	Household demand	Private investment	Government demand	Exports	Output (sales)
Industry by industry / Total domestic production of outputs	Agriculture – conventional	O_{11}	O_{12}	O_{13}	O_{14}	O_{15}	C_1	I_1	G_1	EX_1	X_1
	Green agriculture	O_{21}	O_{22}	O_{23}	O_{24}	O_{25}	C_2	I_2	G_2	EX_2	X_2
	Manufacturing – conventional	O_{31}	O_{32}	O_{33}	O_{34}	$O4_{35}$	C_3	I_3	G_3	EX_3	X_3
	Green manufacturing	O_{41}	O_{42}	O_{43}	O_{44}	O_{56}	C_4	I_4	G_4	EX_4	X_4
	Services	O_{51}	O_{52}	O_{53}	O_{54}	O_{33}	C_5	I_5	G_5	EX_5	X_5
Gross value of output / IMPORTS	Imports	M_1	M_2	M_3	O_4	M_5	M_C	M_I	M_{CG}		M
Gross value added	Taxes minus subsidies	T_1	T_2	T_3	T_4	T5					T
	Wages and salaries	W_1	W_2	W_3	W_4	W5					W
	Profit[1]	GOS_1	GOS_2	GOS_3	GOS_4	GOS_5					GOS
Total input (payment)		X_1	X_2	X_3	X_4	X_5	Consumption	Investment	Government	EXPORTS	
Employment by industry		E_1	E_2	E_3	E_4	E_5					
CO2 emissions by industry		$CO2_1$	$CO2_2$	$CO2_3$	$CO2_4$	$CO2_5$					

GOS = gross operating surplus

[1] The term "profit" is used to simplify the national account concept of gross operating surplus, which includes depreciation and distributed and undistributed profits.

Source: Authors' compilation

3.3 Expansion through “disaggregation of a single parent industry” into a conventional and a new green industry

From our green establishment survey, we have information on total green output or the share of green output in the total output of the parent industry. Also, we have information on purchases and sales related to inter-industry demand, value added, taxes minus subsidies, and imports and exports. This information is now used to disaggregate the parent industry into green and conventional industries.

> Information from the green establishment survey is used to disaggregate green and conventional industries.

If the production structures are very similar in the green and conventional components of the parent industry (or if there is no way to find information on the production structures), then only the total shares should be used for the disaggregation. In this case, technically, the entire column (also called a vector if it is a single line, as compared with a matrix) needs to be multiplied by the total shares (weights) calculated from the green establishment survey. For example, if agricultural production of organic produce is 2 per cent of total agricultural output, then the relative weights (w) are w1 = 0.02 for organic and w2 = 0.98 for conventional. We would use these weights to disaggregate the green from the conventional industry. First, the weights should be applied to the column. Second, the same action should be performed for the rows. Eventually, the resulting IO table would not differ from the initial one. As the production structures (cost structure/input shares) of the two new industries are the same, only the totals are different. The green accounts for 2 per cent and the conventional, for 98 per cent of total. This is because multiplying the full column vector with the total shares of 2 and 98 percent will simply replicate the same production structure for all inputs for both newly created industries, green and conventional.

However, as previously discussed, green agriculture does not have the same production structure as conventional agriculture. So, information on the difference in cost structure needs to be collected and inserted into the expansion. This is why the establishment survey is needed: to shed light on the individual green industries’ purchasing pattern and production/cost structure.

3.3.1 Column expansion

As noted, the columns in an IO table reflect industry purchases. Let us take the fictitious example of country B to show how columns can be expanded to distinguish the cost structure of a green industry from those of the conventional industry.

Following the guidance above, we define a simple and clear-cut indicator for green agriculture: the use of organic fertilizer and no use of chemical fertilizer. Let us assume also that there is a single Organic Farmers Association that groups all farmers who, in principle, apply certified organic practices and do not rely on chemical fertilizers. These farmers can be identified through a green label on their products. We undertake a representative sample survey of those farmers, using the questionnaire in Module 2, and then we extrapolate the results to estimate the totals of each of the expenditure category. This is done by multiplying the averages from the survey data by the number of organic farmers in the country. This yields the information in the box on the next page.

If we had data from a full establishment survey or a census from the same year as the IO table data, all we would need to do is to subtract the new green totals from the totals of the parent industry to create the green agriculture and remaining conventional agriculture industries. Adding back together the conventional and the green industries would result in the original parent agricultural industry. However, full establishment surveys, as discussed in Module 2, are very expensive and often not feasible. Representative surveys among industry association’s members are more realistic and provide data of sufficient quality.

Representative survey findings for organic/green agriculture

- **Agriculture:** Due to use of organic fertilizer, which is produced by the agricultural sector itself, organic agriculture spends 80 per cent more on intra-industry input than does conventional agriculture.
- **Manufacturing** input to organic agriculture is 20 per cent of conventional agriculture's spending because of an 80 per cent reduction of the purchasing of chemical fertilizers produced by the manufacturing sector.
- **Services** input to organic agriculture is 16 per cent more because of its higher knowledge component in how to plant, combat pests, prune and harvest in organic production systems.
- **Imports** input to organic agriculture is none, because imports constitute mainly chemical fertilizers, which are not used in organic production systems.
- **Taxes** are at the same rate; we assume that the two production systems are not treated differently.
- **Wage rates** are the same. Organic agriculture is 20 per cent more labour-intensive, i.e., 0.2 more is spent on wages, but wage per farmer/employee is the same.
- **Gross operating surpluses** are the same; we assume profit margins to be similar.

Source: Authors' compilation

If survey results cannot be reliably extrapolated or if only non-representative survey data or only interviews with experts and secondary literature review are available, we suggest using the best information available and proceeding with the same approach. It simply needs to be made clear in the assumptions what kind of data sources are used. To perform the technical expansion using the above data do the following:

Let P be the parent sector's intermediate expenditures on manufacturing (i.e., chemicals). This amount is to be split into conventional (P1) and green (P2) expenditures. We do not know how much the entire green agriculture industry spends on chemicals. However, from our representative survey or secondary sources we know that total organic produce is an estimated 2 per cent of all produce. That is, the share for the conventional industry (X1) is 0.98 and for the green industry (X2) is 0.02. From the sample survey we have data on expenditures for each of the intermediate demand and value added categories. Adding them gives us the total expenditures. From these we can calculate the shares (direct coefficients) that the industry spends on each category as a portion of its total expenditures. For example, let us assume that from our small survey we know that on average organic farmers spend one of every 100 outlays on chemicals. The IO table indicates that conventional farmers spend five of every 100. This means that green agriculture (X2) spends 1 per cent of its share on chemicals, while the conventional industry (X1) spends 5 per cent of its total. Dividing 0.01 by 0.05 gives us 0.2: The green industry spends only 20 per cent on chemicals of what the conventional industry uses. Now we need to find how much the entire conventional (P1) and entire organic industry (P2) spend on chemicals. Total expenditures on chemicals by the parent industry are P = P1 + P2 (Table 3.2).

Table 3.2 Example for calculating the production structure of the green industries

	Parent agriculture	Conventional agriculture	Organic agriculture
Agriculture	….	…	…
Chemical industry	P = P1 + P2	P1	P2
Totals	X = X1 + X2	X1	X2

Source: Authors' compilation

P = P1 + P2,

with P1 = p1*X1 and P2 = p2*X2

where p1 and p2 are the unknown shares.

Replacing P1 and P2 as well as knowing that X1 = 0.02X and X2 = 0.98X,

P = p1(0.02X) + p2(0.98X).

We know from the survey that P1 spends 20 per cent of what P2 spends, which is p1 = 0.2p2. Thus,

P = 0.2*p2(0.02X) + p2(0.98X)

P = p2*X(0.004 + 0.98)

P/(0.984*X) = p2.

Replacing p2,

P = P/(0.984*X) * 0.004*X + P/(0.984*X) * 0.98X.

Where the X cancels out,

P= P/0.984 * 0.004 + P/0.984 * 0.98.

Just for illustrative reasons let us assume that P = 100. Then,

100 = 0.41 + 99.59,

which results in

P1 = 0.41 and P2 = 99.59, and

p1 = 0.0041, or 0.41 per cent, and p2 = 0.9959, or 99.59 per cent

Now, in the case above, total spending of the parent industry on manufactured goods (chemicals) is 25; that is, P = 25.

This results in 25 = 0.1016 (green) + 24.8984 (conventional).

As shown from the result above, the weights for splitting the agriculture parent industry's spending on chemicals into green and conventional spending are 0.4 per cent for the green industry and 99.6 per cent for the conventional industry. The results are based on the assumption that the total share of agriculture that is organic is 2 per cent and that the organic industry spends 1 per cent of its total expenditures on chemicals, whereas the conventional industry constitutes 98 per cent of the industry and spends 5 per cent on its total expenditures on chemicals. This translates into 80 per cent less chemical inputs to organic agriculture.

The same calculations should be done for all expenditure/cost categories. Based on information from the sample survey and interviews with experts, Table 3.3 reports green expenditures. The last two columns report the calculated shares.

Table 3.3 Calculations for expenditure categories in agriculture

	Parent expenditures /costs	Comparative inputs to organic and conventional agriculture	Total green expenditure	Green share	Conven-tional shares
Agriculture	12.5.	Organic farmers spend 20 per cent as much as on inputs from manufacturing as conventional farmers but 80 per cent more on agriculture inputs, using organic fertilizer (compost, manure) from agriculture rather than chemical fertilizer from manufacturing.	0.442913386	0.035433	0.964567
Manufacturing	25		0.101626016	0.004065	0.995935
Services	50	Organic farmers spend 16 per cent more on services than conventional farmers, due to the greater need for extension services and expert advice.	1.156299841	0.023126	0.976874
Imports	75	Organic agriculture does not import chemical fertilizer, which is the bulk of all imports for conventional agriculture.	0	0	1
Taxes	12.5	The tax rate is the same for conventional and organic agriculture.	0.25	0.02	0.98
Wages and salaries	250	The wages are the same, but organic agriculture requires 20 per cent more labour due to higher labour requirements. Thus, labour expenses are 20 per cent higher.	5.976095618	0.023904	0.976096
Gross operating surplus	75	Profit margins are the same in conventional and organic agriculture.	1.5	0.02	0.98
Total output	500	Total organic output is estimated at 2 per cent of total agricultural output.	9.42693486	0.127149/7 =0.018[1]	

Source: Authors' compilation

[1] This share of 1.8% is calculated by dividing the sum (0.13) by the number of cost items (7). The 1.8 is the total share of the organic segment, which is different from the original 2% because it is based on individual information for each cost item.

If a representative green industry survey cannot be done, it is still possible to base the calculations, as done above, on a sample survey and expert interviews. Such a survey must collect data on intermediate, value added, import and total expenditures. In other words, the researcher needs to identify how much the sample green industry spends on individual cost items out of the sample total. Comparing green and conventional coefficients, in turn, makes it possible to calculate how much less or more the green industry spends on each of the cost items compared with the conventional industry. And, if even a sample survey is out of reach, expert interviews and secondary literature could provide estimates of how much less chemical and more organic fertilizer green agriculture purchases, for example, or how much more energy-efficient green industry is. The identified shares, in combination with the totals, can then be used to calculate individual expenditure coefficients and, subsequently, the new shares of the production function. Table 3.5 (page 118) applies the above shares, calculated from the sample survey results, in the column expansion.

Now, one more assumption is necessary to make the green industry expansion consistent with the SEEA guidelines: We assume that, if possible (that is, where an alternative exists), green industries purchase from each other. As a consequence, if possible, the green production share, which we have split from the conventional industry, should be allocated entirely to the green industries.

3.3.2 Row expansion

The rows in the IO table show where the sales of each sector are going. The row expansion, to distinguish green from conventional industries, should be carried out in such a way that the IO table remains square and balanced. Theoretically, the survey or expert interviews would also provide information on the sales structure of the green industry. This information could theoretically be used to calculate the shares for the row expansion. However, this would result in an unbalanced table. This is why it is suggested to use the sales data, composed of intermediate sales, final household demand, government demand and exports, only as a check.

To expand the row mindful of the assumption that green industries purchase only from green industries, the first task consists of simply expanding an empty row while moving the green production share to the green row (see green-shaded selection in Table 3.4).

Table 3.4 Row expansion for agriculture (empty row plus allocation of green share to green)

	Parent agriculture	Conventional	Green
Parent agriculture	12.50		
Conventional		12.06	0.00
Green		0.00	0.44

Source: Authors' compilation

Next, all other row cells, in this case green and conventional agriculture, need to be split. We assume that, overall and apart from green agriculture, there is no difference in the way industries sell products to other industries. This means that the sales structure of the green industries is identical to that of the conventional industries with the exception of intra-industry sales, which in this case is agriculture. We perform this split by multiplying the entire row by the average column share. The average column share is calculated dividing the total output of the newly created industry, minus the already fully allocated intra-industry sales, by the total output of the parent industry, but again minus the already allocated agricultural inputs. In the example above this is 9.43 − 0.44/500 − 12.5 = 0.0184. Multiplying the entire parent row by the same share results in a balanced matrix with rounding errors (Table 3.6, page 118).

This approach assumes that the sales structures of the green and conventional industry are identical. We assume this because we want, first and foremost, to analyse the green economy in terms of the difference in production structure rather than in sales structure. In electricity generation, for example, it does not matter where the electricity is sold and used; this makes no difference to environmental impact. (However, it makes a difference in sales if the price for green electricity is higher than for conventionally generated electricity. Here, though, we ignore prices for the moment.) Technically, the forward linkages will, thus, be the same in the green and conventional industry with the minor difference of intra-industry sales, which we assume to be only from green to green and from conventional to conventional.

Table 3.5 Column expansion for agriculture

	Parent agriculture	Conventional	Green	Manufacturing	Services	Household demand	Private investment	Government demand	Exports	Output (sales)
Agriculture	12.50	12.06	0.44	27.00	60.00	40.00	4.50	82.00	274.00	500.00
Manufacturing	25.00	24.90	0.10	54.00	75.00	120.00	594.00	16.00	16.00	900.00
Services	50.00	48.84	1.16	54.00	15.00	80.00	4.50	85.30	461.20	750.00
Imports	75.00	75.00	0.00	108.00	30.00	160.00	297.00	206.70		876.70
Taxes minus subsidies	12.50	12.25	0.25	18.00	15.00					45.50
Wages & salaries	250.00	244.02	5.98	540.00	450.00					1 240.00
Gross operating surplus	75.00	73.50	1.50	99.00	105.00					279.00
TOTAL	500.00	490.57	9.43	900.00	750.00	400.00	900.00	390.00	751.20	

Source: Authors' compilation

Table 3.6 Row expansion for agriculture

	Conventional agriculture	Green	Manufacturing	Service	Household demand	Private investment	Government demand	Exports	Output (sales)
Conventional agriculture	12.06	0.00	26.49	58.87	39.25	4.42	80.45	268.83	490.57
Green agriculture	0.00	0.44	0.50	1.11	0.74	0.08	1.51	5.05	9.43
Manufacturing	24.90	0.10	54.00	75.00	120.00	594.00	16.00	16.00	900.00
Service	48.84	1.16	54.00	15.00	80.00	4.50	85.30	461.20	750.00
Imports	75.00	0.00	108.00	30.00	160.00	297.00	206.70		876.70
Taxes minus subsidies	12.25	0.25	18.00	15.00					45.50
Wages & salaries	244.02	5.98	540.00	450.00					1 240.00
Gross operating surplus	73.50	1.50	99.00	105.00					279.00
TOTAL	490.57	9.43	900.00	750.00	400.00	900.00	390.00	751.20	

Source: Authors' compilation

Now, to complete the expansion exercise, the same split, but using different shares, is made with manufacturing (renewable energy equipment) as with agriculture. (From the survey findings we estimate that total production of renewable energy equipment is 5 per cent of the total. The box below shows the survey findings on the production structure of renewable energy equipment.

Survey results from the green manufacturing industry (renewable energy equipment)

- Intra-industry **conventional energy input** has the same share as the total output share of the renewable energy industry.
- Intra-industry **green energy input** has the same share as the total output share of the renewable energy industry.
- **Input from the manufacturing industry** is 20 per cent higher for renewable energy than for conventional energy because, for this particular case, the equipment is produced locally (say, an industrial policy led to the creation of a wind manufacturing industry, such as happened in China in the 2010s).
- **Services input** is 60 per cent higher in green energy because the equipment requires more maintenance.
- **There are no imports in renewable energy, as no fossil fuels are required and the technology is locally produced.**
- **Tax shares** are the same.
- **Wages** are the same, but renewable energy is 30 per cent more labour-intensive, and so the total wage bill is 30 per cent higher for renewable energy.
- **Shares going to gross operating surplus are the same.**
- **Green energy production** is 5 per cent of the total.

Source: Authors' compilation

Using the above shares and applying the same methodology used for agriculture, Table 3.7 (next page) shows the column and row expansion for manufacturing.

For the row expansion, the average expansion share, or expansion factor, is found by dividing the new total green output minus the green intra-industry input from agriculture as well as manufacturing by the total parent sector output minus the total intra-industry input: 42.36 − 3.21 − 0.1/900 – 54 = 0.046. Multiplying the entire manufacturing row by this share gives the green manufacturing sales pattern (row). Subtracting the green totals from the parent sector leaves the conventional industry as the remainder of the parent industry.

The result is an entire balanced IO table (Table 3.8, page 121) that features the particular production structure of the two green industries, in this case organic agriculture and renewable energy.

Table 3.7 Column and row expansion for manufacturing

	Conventional agriculture	Green	Parent manufacturing	Conventional	Green	Household demand	Services	Private investment	Government demand	Exports	Output (sales)
Conventional agriculture	12.06	0.00	26.50	26.42	0.07	39.26	58.89	4.42	80.49	268.95	490.58
Green	0.00	0.44	0.50	0.51	0.00	0.74	1.11	0.08	1.51	5.05	9.43
Conventional manufacturing	24.90	0.00	54.00	50.79	0.00	120.00	75.00	594.00	16.00	16.00	900.00
Green	0.00	0.10	0.00	0.00	3.21						
Services	48.84	1.16	54.00	49.81	4.19	80.00	15.00	4.50	85.30	461.20	750.00
Imports	75.00	0.00	108.00	108.00	0.00	160.00	30.00	297.00	206.70		876.70
Taxes minus subsidies	12.25	0.25	18.00	17.95	0.05		15.00				45.50
Wages & salaries	244.02	5.98	540.00	505.42	34.58		450.00				1 240.00
Gross operating surplus	73.50	1.50	99.00	98.74	0.26		105.00				279.00
TOTAL	490.58	9.43	900.00	857.64	42.36	400.00	750.00	900.00	390.00	751.20	

Source: Authors' compilation

Table 3.8 Full green IO expansion for green agriculture and green manufacturing

	Conventional agriculture	Green	Conventional manufacturing	Green	Household demand	Services	Private investment	Government demand	Exports	Output (sales)
Conventional agriculture	12.06	0.00	26.42	0.07	39.26	58.89	4.42	80.49	268.95	490.58
Green	0.00	0.44	0.51	0.00	0.74	1.11	0.08	1.51	5.05	9.43
Conventional manufacturing	23.75	0.00	50.79	0.00	114.46	71.54	566.58	15.26	15.26	857.64
Green	1.15	0.10	0.00	3.21	5.54	3.46	27.42	0.74	0.74	42.36
Services	48.84	1.16	49.81	4.19	80.00	15.00	4.50	85.30	461.20	750.00
Imports	75.00	0.00	108.00	0.00	160.00	30.00	297.00	206.70		876.70
Taxes minus subsidies	12.25	0.25	17.95	0.05		15.00				45.50
Wages & salaries	244.02	5.98	505.42	34.58		450.00				1 240.00
Gross operating surplus	73.50	1.50	98.74	0.26		105.00				279.00
TOTAL	490.58	9.43	857.64	42.36	400.00	750.00	900.00	390.00	751.20	

Source: Authors' compilation

4. Collecting data on employment in green industries

Key questions to answer

- What are satellite accounts?
- What is the difference between the IO table and the Leontief model?
- What kinds of questions can the Leontief model answer?

Important observations

- The difference in industry production structures determines the difference in social and environmental outcomes, including employment.
- The IO model is ideal for policy planning and making employment projections of differing growth scenarios.

So far we have focused on the production structure of the green industries. This is an important step in building the employment projection model because it is the difference in industry production structure that makes for differences in social and environmental outcomes. In technical terms, because of the direct link in the IO model between production structure and multipliers, this difference drives the results in terms of employment and gross domestic product (GDP) outcomes in the projection model.

Now, the second set of information necessary for the model is reliable estimates of the satellite accounts. These are mostly physical accounts that are added to the IO accounting framework such as employed workers, tons of CO_2 emissions or kilowatt hours (kwh) used. Importantly, this information is needed at the industry level; otherwise, at an aggregate level they are of little value. It follows that, regarding employment in the green industries, total numbers must be found. The survey instrument, as described in Module 2, includes a question on total employment. A census or even a representative sample survey would allow for the calculation of total employment in the industry. If it is impossible to find data on employment in the green sub-sector, the same share should be used as is used for the split of total output. In our example this is the same share as calculated for the row expansion. For green manufacturing we found that the green share of the total parent industry is 4.6 per cent. If no other data on employment were available, we would multiply total parent sector employment by 0.046, or 4.6 per cent, to estimate total green employment. In terms of economic reasoning, this approach assumes that labour intensity in the green and the conventional industry are the same. In other words, the direct employment coefficients – the number of workers needed to produce one unit of output – are the same.

However, in our example of organic agriculture and renewable energy, our fictional survey has found that these industries are 20 and 30 per cent more labour-intensive, respectively, than the corresponding conventional industries. It follows that the expansion factors for employment in green agriculture and green manufacturing are calculated the same way as for the values in the IO table (Table 4.1): First, employment coefficients are calculated the same way as the technical coefficients in the A matrix, dividing total employment by total output. The interpretation also is similar: Production of one unit of conventional agriculture requires 0.25 agricultural workers.

For example, Maia and colleagues (2011) make a detailed analysis of green activities in South Africa based on representative surveys and estimate the number of jobs created by the various activities. Table 4.2 outlines the main sectors unfolding from greening the South African economy and gives the estimates of direct jobs in each of the industries analysed. Sub-sector jobs, or indirect jobs, do not necessarily add up to the main sectors, as these are estimates.

Table 4.1 Employment levels – conventional and green

	Conventional agriculture	Green agriculture	Conventional manufacturing	Green manufacturing	Services
FTE employment	122	3	90	6	89
Total output	490.58	9.43	857.64	42.36	750
Employment coefficients	0.25	0.32	0.11	0.14	0.12

FTE = full-time equivalent

Source: Authors' assumptions

Table 4.2 Survey-based estimates of total direct jobs in green industries, South Africa

Parent industry	Conventional	Green	Green jobs
Energy	Fossil fuel energy	Green energy generation	13 500
		Wind energy	591
		Concentrated solar power	0
		Solar photovoltaic	3 816
		Landfill gas	70
		Biomass combustion	115
		Anaerobic digestion	131
		Pyrolysis/gasification	240
		Co-generation	2 348
		Large hydropower	218
		Small hydropower	338
		Marine power	0
		Biofuels	5 698
		Energy efficiency and resource efficiency	31 500
Construction	Conventional buildings	Insulation, lighting and windows	1 861
		Solar water heaters	1 508
Water	Overexploitation of water table sources	Rainwater harvesting	41
Transport	Individual car transport	Bus rapid transit systems	28 080
Manufacturing (electronics)	Conventionally designed electronics	Electric vehicle/lithium-ion industries	475
Manufacturing (energy equipment)	Fossil fuel combustion equipment	Clean stoves	132

Parent industry	Conventional	Green	Green jobs
Manufacturing (materials and electronics)	Steel, plastic, aluminium production from iron, raw oil, bauxite	Recycling	7 087
Waste	Dumping (unabated pollution)	Water treatment	74
		Emissions and pollution mitigation	8 400
Agriculture	Conventional agriculture	Natural resource management	44 600
		Soil and land management	27 322

Source: Maia et al., 2011

In the next chapter we will show how to move from a statistical data accounting framework, into which we incorporated green industries and employment, to a simple economic model. We combine the industry and employment data and integrate them into the model. This requires a short introduction to the general input–output model, also called the Leontief model (see box).

From IO accounting to the Leontief model

The Leontief model, or IO model, depicts the inter-industry relationships within an economy. It is based on the input–output table shown as Table 2.1. The IO table shows how output from one industrial sector is input to another industrial sector.

The difference between the IO table and the Leontief model is that the model shows how an increase or decrease in one industry has a multiplying effect on other industries.

> The Leontief model shows how an increase or decrease in one industry has a multiplying effect on other industries.

The output and employment multipliers are calculated by taking the inverse of the IO matrix, the Leontief inverse (providing a single solution for a set of simultaneous equations). The following chapters in this module describe, step-by-step, how to perform the Leontief inverse and multiplier calculation. We first discuss how to perform IO modelling using a conventional, non-green IO table. We show how to calculate output and employment multipliers. In addition to showing the inter-industry linkages, IO modelling takes into account the relationship between output and employment, on one hand, and final demand in the economy, on the other. Thus, the model answers the question: If the economy sees an increase in demand in the form of, for instance, an increase in investment demand or simply in consumer demand in a particular sector, how would the entire economy respond to meet such demand? Put differently, if growth in final demand or investment takes place, how will the economy change in terms of employment, output and value added?

We can calculate, for every one unit of additional demand in a sector, how much the entire economy expands and, particularly, how much the demand for employment increases or decreases. For example, growth in demand for the manufacturing sector implies that more manufactured commodities are produced. For these manufactured commodities to be produced, intermediates and value added to produce them also have to increase. Thus, in addition to the direct effect of increased intermediate demand and employment in manufacturing itself, there will be

> Because IO modelling shows how a change in one sector affects all other sectors, it is ideal for policy planning and employment projections.

“spillover”, or “multiplier” effects. Other, non-manufacturing sectors also will increase their production. The IO model enables us to measure these changes. Thus, it is ideal for policy planning and making employment projections of differing growth scenarios. The great value of IO models is the sectoral and structural detail that the industry-by-industry production structure offers as well as the possibility to link physical variables – such as employment and emissions – to the IO tables. The IO model also could be further developed into a linear programming model in which certain green economy constraints are defined and an optimization is performed. The simple version of the IO model, however, has the advantage of being very transparent and, therefore, easy to use for policy analysis and planning.

5. The IO accounting table used for a comparative static IO model

Key questions to answer

- What assumptions are made when using the IO table for a comparative static model?
- What is a comparative static model? What does an output and employment multiplier show?

Important observations

- The main assumption of an IO table is a production structure characterized by fixed input coefficients and constant returns to scale.
- The IO model determines the production levels of intermediate outputs required to satisfy a given final demand.
- An IO model can compare the economy-wide effects of growth scenarios and policy options in various sectors – including policies to shift production from conventional to green industries.

5.1 Assumptions

In simple terms, an economic model tries to describe the real economic world – in terms of structure and behaviour – by using empirical data to make projections into the future. In this Module 3, we have so far used and built empirical data from the System of National Accounts in the form of an IO table. The next step is to use the IO table for a simple economic static model. "Static" means simply that the structure of the economy is assumed to be fixed and not changing (as contrasted with a dynamic model, where changes are estimated). Thus, using the IO table for a comparative static model involves certain assumptions. Some of these assumptions often attract the criticism that they do not reflect the real economy. However, every model has to abstract from the real world and use assumptions. For the IO-based general Leontief model, these assumptions are the following:

The main feature of an IO table is a production structure characterized by **fixed input coefficients** and **constant returns to scale**. This assumption of a linear production function means that the proportions of inputs used in the production of an output do not change, irrespective of the level of production; a change in the output level of an industry implies a proportionate change in the inputs used. For example, if the production of one car entails intermediate input of 300 kg of steel and 100 working hours, the production of two cars would require 600 kg of steel and 200 working hours. Under this assumption input–output relationships are transformed into technical relationships that populate an input–output coefficient table, the A matrix – in which each column denotes a production technique.

Critics point out that this assumption of linearity (constant returns to scale) does not account for economies of scale. The linear assumption also implies that only the desired level of output to be produced determines the amount of inputs needed, with no consideration for other factors such as the availability of production factors, new technology and new markets. In terms of projections final demand is considered exogenous. A demand shock, assuming economic growth in the years to come, raises the demand for intermediate inputs linearly. Despite the criticisms, this assumption is justifiable, especially in the short term, since a production technique does not change significantly in the short run. (Even the 99^{th} and 100^{th} car will still require 300 kg of steel and, if made in the same factory, also 100 working hours of labour.)

A second assumption is that **prices are fixed** and do not respond to demand shocks. Thus, there is no mechanism for price adjustments, an assumption that is considered unrealistic since in reality demand shocks lead to price increases. However, as the technical coefficients imply linear relationships between intermediate demand and final output, an increase in the price of the intermediate product is assumed to increase the total price of the output. This assumption is a quite realistic. Still, the IO model does not allow for behaviour change − that is, substituting a product that has become cheaper for a product that has become relatively more expensive. In the 'price IO model', however, this assumption can be relaxed. (The model will not be presented here but can be found in Miller and Blair, 2009.)

A third assumption of basic IO modelling is that technical coefficients do not change over time − that is, there is **no technological change**. In the short run this assumption is not too restrictive, as technological change is felt in the long term. In any case, allowing for changes in the productivity of labour and capital in the projection model implicitly factors in technological change. Also, the modelling of green industries that have a different production structure can be said to describe technological change. However, in our case this is done prior to using the Leontief model and as such is not dynamic or reflected in the model as technological change.

Finally, IO modelling assumes **unlimited production capacity** with no supply constraints, implying that, if there is an increase in the final demand for a sector's output, it will be fully met by an increase in the output of this sector as well as that of other sectors. Intermediate consumption increases to meet the increase in output required to satisfy the increase in final demand. All sectors will be able to meet the additional direct and indirect requirements, without any capacity restrictions. This is not always realistic; in the real world supply is frequently constrained. This assumption can lead to overestimation of economy-wide impacts in IO analysis. This assumption, however, is relaxed in the projection model by introducing investments into capital to increase production capacity. For example, it means that in order to produce more electricity from renewable energy, capital investments will be made and modelled first. If the average time to install one megawatt of wind turbines is, say, one year and costs 1 million, then 1 million of investment is put into the model in year 1 before sequencing the final demand shock in the next period.

Assumptions for use of the IO table in comparative static analysis

1. fixed input coefficients and constant returns to scale
2. fixed prices
3. no technological change
4. unlimited production capacity

The next section will introduce the general Leontief-based IO model, which can be used for planning purposes, and, thus, assist policy-makers.

5.2 Input–output modelling example

An IO table can be the basis for the development of a simple IO model, given the following assumptions:

- A sector's intermediate inputs are a fixed share (a_{ij}, or technical coefficient) of its total output, $a_{11} = O_{11}/X_1$ and $a_{12} = O_{12}/X_2$, which gives the intermediate inputs $O_{11} = a_{11}.X_1$ and $O_{12} = a_{12}.X_2$.
- A sector's imports are a fixed share of its output, e.g., $M_1 = a_{41}.X_1$ or $M_2 = a_{42}.X_2$, which gives us $a_{41} = M_1/X_1$ or $a_{42} = M_2/X_2$.
- A sector's primary factors of production (such as labour and capital) are fixed shares of the total output it produces.

In a closed IO model, the sectoral final demand categories, except exports, are a fixed share of the total of each final demand category, as indicated in equation 4 below. For the closed IO model, only sectoral exports (E_1, E_2 and E_3) are exogenous. In contrast, in an open IO model, final consumption, government demand, capital investment and exports are exogenous, which means that they come from outside the model.

Given these assumptions, the input−output model can be formulated as follows repeating the first three equations from the accounting framework presented in Table 2.1, whose contents are formally written as:

$$X_1 = O_{11} + O_{12} + O_{13} + C_1 + I_1 + G_1 + EX_1 \quad (1)$$

$$X_2 = O_{21} + O_{22} + O_{23} + C_2 + I_2 + G_2 + EX_2 \quad (2)$$

$$X_3 = O_{31} + O_{32} + O_{33} + C_3 + I_3 + G_3 + EX_3 \quad (3)$$

The input–output model then becomes:

$$X_1 = a_{11} X_1 + a_{12} X_2 + a_{13} X_3 + a_{14} C + a_{15} I + a_{16} G + E_1 \quad (4)$$

Equation 4 shows how the production of sector 1 is distributed: It is used as intermediate inputs across sectors, for household consumption, for investment, for consumption by government and for exports.

X_2 $= a_{21} X_1 + a_{22} X_2 + a_{23} X_3 + a_{24} C + a_{25} I + a_{26} G + E_2$

X_3 $= a_{31} X_1 + a_{32} X_2 + a_{33} X_3 + a_{34} C + a_{35} I + a_{36} G + E_3$

Imports (M) $= a_{41} X_1 + a_{42} X_2 + a_{43} X_3$

Taxes $= a_{51} X_1 + a_{52} X_2 + a_{53} X_3$

Wages (W) $= a_{61} X_1 + a_{62} X_2 + a_{63} X_3$

Profits $= a_{71} X_1 + a_{72} X_2 + a_{73} X_3$

From the equations above we can obtain the coefficients a_{ij}, which are called the input–output, or technical, coefficients, as mentioned above.

In addition to the monetary accounts, the input−output table can include physical values such as employment, carbon emissions (in CO_2 equivalents, for example) or other social or environment-related information. These so-called satellite accounts also could include water consumption by industry, land use and deforestation, waste and pollution, for example. This depends on the interests and type of analysis that policy makers request.

IO models are commonly used for impact analysis and are, therefore, a suitable starting point to develop a model that projects social and environmental outcomes of various policy options. This type of analysis measures the change in output and employment resulting from projected growth in demand or investment changes. These demand changes could be derived from other GDP forecasting models or from industry outlooks, or they could be entirely simulated, based on assumptions about changes in economic or industrial policy.

> Impact analysis using an IO model measures the change in output and employment resulting from projected demand changes.

To build the IO model, recall the equations below, from the IO table with numerical examples (see Table 2.2):

X_1	$= 0.025\ X_1 + 0.03\ X_2 + 0.08\ X_3 + 0.1\ C + 0.005\ I + 0.21\ G + E_1$	(5)
X_2	$= 0.050\ X_1 + 0.06\ X_2 + 0.10\ X_3 + 0.3\ C + 0.66\ I + 0.04\ G + E_2$	
X_3	$= 0.100\ X_1 + 0.06\ X_2 + 0.02\ X_3 + 0.2\ C + 0.005.I + 0.22\ G + E_3$	
Imports (M)	$= 0.150\ X_1 + 0.12\ X_2 + 0.04\ X_3 + 0.4\ C + 0.33\ I + 0.53\ G$	
Taxes	$= 0.025\ X_1 + 0.02\ X_2 + 0.02\ X_3$	
Wages	$= 0.500\ X_1 + 0.60\ X_2 + 0.60\ X_3$	
Profits	$= 0.150\ X_1 + 0.11\ X_2 + 0.14\ X_3$	

We have seven equations and seven unknown variables in our simple model: X_1, X_2, X_3, Imports, Taxes, Wages and Profits. In this open IO model, we assume that C, I, G, E_1, E_2 and E_3 are given. Because the model allows us to solve for the unknown variables X_1, X_2, X_3, Imports, Taxes, Wages and Profits, it is possible for us to answer such questions as:

- What will be the level of total production of each industry (direct and indirect) required to satisfy that final demand?
- If there is an increase in exports, investment, consumer demand or government expenditures in any of the sectors, what will happen to value added and GDP, employment, CO_2 emissions or any other variable of interest that is attached through the satellite account?

Now, we can solve the system of equations and assess how much the levels of X_1, X_2, X_3, Imports, Wages, Taxes and Profits will change. Excel software can be used to solve the model. We can make our model even easier to solve by expressing it in matrix algebra, as described in the next section.

5.3 Input–output model expressed in vector notation

Here is how we can express the input–output model in vector notation, where X is a vector of sectoral outputs.

$$X = \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} \tag{6}$$

As shown below, *A* is a matrix of technical coefficients, or direct requirements coefficients, that shows the amount of inputs purchased directly by each and every industry to produce one unit of output. In other words, the A matrix represents the direct requirements of the inter-sectoral relationships; the rows of A give the amount of output from industry *i* required as intermediate inputs to produce one unit of output of industry *j*. As shown above, the sector's intermediate inputs are a fixed share (aij, or technical coefficient) of its total output, a11 = O11/X1, a12 = O12/X2, etc.

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \tag{7}$$

D is a vector of final demand per sector:

$$D = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \end{bmatrix} \tag{8}$$

with $D_1 = C_1 + I_1 + G_1 + E_1$, $D_2 = C_2 + I_2 + G_2 + E_2$ and $D_3 = C_3 + I_3 + G_3 + E_3$ inserted in equation (4), which can be written in matrix algebra as:

$$X = AX + D \tag{9}$$

$$\Rightarrow D = (I - A)X$$

where I is an identity matrix.

$$\Rightarrow X = (I - A)^{-1} D \tag{10}$$

$(I - A)^{-1}$ is called the Leontief inverse. Thus, for changes (defined as Δ):

$$\Delta X = (I - A)^{-1} \Delta D \tag{11}$$

The basic material balance equation of the IO model, equation 10 above, shows that total output of sector i (X_i) is distributed between intermediate consumption ($a_{ij}X_j$) and final demand (D). The direct and indirect output requirements per unit of final demand are given by (I − A).

The Leontief inverse is non-negative, which means that it is feasible to get a mathematical solution for any value of D. Even though this may not be economically feasible, we could use the estimate to check for consistency.

> The equation determines the production levels of intermediate outputs required to satisfy a given final demand.

Equation 11 is the solution of the static IO model. Given final demand, which is specified exogenously, the equation determines the resulting production levels of intermediate outputs required to satisfy the demand. Also, given exogenous final demand estimates, the Leontief inverse *$(I - A)^{-1}$* allows us to calculate the implied required sectoral production, which can then be evaluated for "reasonableness" by comparing it with current and projected sectoral capacities.

Such an approach already leads to a very simple dynamic model. In such a model the capacity necessary for the production of the expected final demand is estimated and translated into capacity/capital investments. The investments are then phased in over time. This simple dynamic model will be introduced in Module 4.

The inverse also can be used to calculate multipliers that reflect the impact of shifts in exogenous elements of final demand. Therefore, given estimates for D_1, D_2, D_3 demands, we can estimate individual industries' output (based on the a_{ij}'s). Also, if we consider a change in demand, we can now calculate how industry outputs and employment will change proportionately.

5.3.1 IO model validation – numerical example

By now we know that the impact of changes in final demand, ΔD_i, on industry output, X_i, can be determined. In the next section we will show how much gross output will need to change to meet a policy goal of increasing production for final consumption of industry goods by 25 units and of services by 30 units. Table 5.1 (next page) shows an example of a three-sector IO model using the same numbers from Table 2.2. You will recognize the upper left block as the intermediate demand, the upper right block as the final demand and the lower left block as value added.

Table 5.1 Example of a three-sector IO model

	Agricul-ture	Manufac-turing	Services	Household demand	Private investment	Government demand	Exports	Output (sales)
Agriculture	12.5	27	60	40	4.5	82	274	500
Manufacturing	25	54	75	120	594	16	16	900
Services	50	54	15	80	4.5	85.3	461.2	750
Imports	75	108	30	160	297	206.7		876.7
Taxes minus subsidies	12.5	18	15					45.5
Wages & salaries	250	540	450					1 240
Profits	75	99	105					279
	500	900	750	400	900	390	751.2	

Source: Authors' formulation

Table 5.2 Direct coefficients matrix of three-sector model example

	Agriculture	Manufacturing	Services	Household demand	Private investment	Government demand	Exports	Output (sales)
Agriculture	12.5	27	60	40	4.5	82	274	500
	12.5/500 = 0.025	27/900 = 0.03	60/750 = 0.08					
Manufacturing	25	54	75	120	594	16	16	900
	25/500 = 0.05	54/900 = 0.06	75/750 = 0.1					
Services	50	54	15	80	4.5	85.3	461.2	750
	50/500 = 0.1	54/900 = 0.06	15/750= 0.02					
Imports	75	108	30	160	297	206.7		876.7
	75/500 = 0.15	108/900 = 0,12	30/750 = 0.04					
Taxes minus subsidies	12.5	18	15					45.5
	12.5/500 = 0.025	18/900 = 0.02	15/750 = 0.02					
Wages & salaries	250	540	450					1 240
	250/500 = 0.5	540/900 = 0.6	450/750 = 0.6					
Profits	75	99	105					279
	75/500 = 0.15	99/900 = 0.11	60/750 = 0.14					
	500	900	750	400	900	390	751.2	

Source: Authors' calculations

Key policy questions can already be addressed by looking at the direct coefficients. These coefficients indicate the relative direct inputs required for each sector in any IO table to produce one unit of output. For example, how much input from services does the agriculture sector require to produce a unit of its output? This information, which measures the relative costs of producing agricultural output, is given by the technical coefficient matrix A. To calculate the coefficient matrix A (also called the direct input requirement matrix), we divide each cell by the column total, as shown in the second line of each row in Table 5.2.

The direct coefficients indicate the relative direct inputs required for each sector to produce one unit of output.

We start with an open IO model, which calculates the direct and indirect interrelationships between industries. In this case we use only the upper left block of intermediate demand, industry-by-industry. Thus, from Table 5.2 we can extract the matrix of inter-industry coefficients given below:

$$A = \begin{bmatrix} 0.025 & 0.03 & 0.08 \\ 0.05 & 0.06 & 0.1 \\ 0.1 & 0.06 & 0.02 \end{bmatrix}$$

Each coefficient can be interpreted as the proportion of sector *j*'s production input supplied by sector *i*. Thus, the value of a_{11} implies that the agriculture sector requires 0.025 units of agricultural inputs to produce one unit of its output. In terms of other intermediates, agriculture also uses 0.05 units from manufacturing and 0.1 units from services.

This analysis shows how an industry is linked to the rest of the economy. For example, if agriculture were to have zeros in its column of the A matrix, then no input would be used/consumed from the domestic economy. This can be interpreted as an industry that has little national economy-wide effects when growth is stimulated through policy, for example. If this sector has significant entry in imports, it means its intermediate goods are imported, with no effect on the national economy. However, this analysis does not allow estimates of change in total output and employment given a specified change in final demand. For this, the Leontief inverse must be calculated. We need to create a 3X3 identity matrix, which we use to calculate (I−A), which we then invert, following the formula above.

$$I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \text{ and } (I - A) = \begin{bmatrix} 0.975 & -0.03 & -0.08 \\ -0.05 & 0.94 & -0.1 \\ -0.1 & -0.06 & 0.98 \end{bmatrix}$$

For our example, the Leontief inverse is:

$$(I - A)^{-1} = \begin{bmatrix} 1.04 & 0.04 & 0.09 \\ 0.07 & 1.07 & 0.11 \\ 0.11 & 0.07 & 1.04 \end{bmatrix}$$

The Leontief inverse tells us that a one-unit increase in final demand in agriculture would increase intermediate agricultural input by another 0.04 units (which is called the direct multiplier, 1 + 0.04 = 1.04). In addition, a one-unit increase in agriculture would require 0.07 units of intermediate inputs from the manufacturing sector and 0.11 units from services (which are called indirect multipliers, 0.07 + 0.11 = 0.18). Total output would increase by the sum of the direct and the indirect multipliers, which is the total output multiplier = 1.22. Once we have the Leontief inverse, we are ready to carry out impact analysis.

5.4 Impact analysis

Input–output modelling can now be used to assess impacts of alternative growth scenarios and economic development policies. Of particular interest in our context are the social and employment-related impacts of environmental policies. Assessing such impacts requires, first, formulating the economic policy objectives – for example, what is the economy-wide employment impact of:

- an increase or shift in domestic demand for alternative consumer goods (organic rather than conventional agricultural produce)?
- an increase in public or private capital investments (such as rail or road infrastructure, renewable or fossil-fuel based electricity capacity or renovation and weatherproofing of buildings)?
- a strategy for diversification of the economy, growing infant industries in emerging manufacturing or services?
- an expansion in the capacity and output of various industries, such as in the green energy sector?
- a shrinking and down-scaling of particular (polluting) industries, such as mining?

By showing where a policy option might benefit the economy, IO modelling can identify the best option to attain desired goals.

A CO_2 reduction policy or a target to achieve a certain level of renewable energy in the energy mix could be the reason for the above-cited economic change. In IO modelling, because of its demand-driven construct, the economic growth scenario or policy objectives must be translated into final demand scenarios. For example, in a very simple model, a green tax reform (increase of tax on fossil fuels and tax decrease or subsidy of the same amount for renewables) may be modelled outside the Leontief model. Such a simple model could analyse the change in tax in terms of marginal propensity to consume. The propensity to consume can be taken from the IO model, where it is the consumption coefficient. So, the consumption coefficient could be interpreted as the tax multiplier and applied to the final demand. This would estimate how much demand would change following an increase or decrease in money available for consumption due to a change in taxes. By showing where a policy option might benefit the economy as well as where it is unlikely to produce substantial gains, input–output modelling can identify the best option to attain desired goals.

Input–output modelling helps to compare the impacts of different policies. Suppose a country wants to protect the environment by increasing or introducing green industries but at the same time wants to ensure that, net, no jobs are lost. Say the coal industry will be heavily taxed and will eventually cease to exist. The model will show how many direct and indirect jobs will be lost. At the same time, the substitution of alternative energy sources for coal energy will lead to the creation of indirect and direct jobs. The net effect can be calculated and optimized, minimizing losses and maximizing job creation. Alternative scenarios and technologies may be tested. This is an example of the policy issues that input–output modelling can address. Below we demonstrate calculating the impact of an increase in demand for selected sectors.

Suppose that the national development plan focuses on an industrialization and economic diversification strategy. The targets, or simply the projected final demand or GDP growth (from other sources and models), are a 25-unit increase of industrial goods (that is, a 2.7 percent growth of total output, 25/900) and a 30-unit increase of services (that is, a 4 percent growth of total output, 30/750) for the next year. These amounts are translated into the final demand vector D. Thus, the first question is how much gross output (X) will be needed to result in the production of these quantities of the targeted products and services. The answer is that:

$$\Delta X = (I - A)^{-1} \Delta D$$

that is,

$$\begin{bmatrix} 1.04 & 0.04 & 0.09 \\ 0.07 & 1.07 & 0.11 \\ 0.11 & 0.07 & 1.04 \end{bmatrix} \begin{bmatrix} 0 \\ 25 \\ 30 \end{bmatrix} = \begin{bmatrix} 4 \\ 30 \\ 33 \end{bmatrix}$$

We use projected growth from outside the model. To realize the industrialization plan, the economy will produce an additional four units of agriculture, 30 units of industrial goods (manufacturing) and 33 units of services. Note that there is an indirect impact on agriculture; its output also increases by four units even though it has no additional consumption requirement. This is because of the interlinkages in the economy, where sectors use inputs from other sectors for the production of their products. Note that these projected or planned changes in final demand could also be changes in projected or planned additional investment demand in the economy.

5.4.1 Sensitivity analysis

We can check how much our IO modelling results change with different values of final demand. This is referred to as sensitivity analysis. Sensitivity analysis provides a check of the robustness of the numerical results of the model.

If the additional consumption requirement for the economy is relatively lower than in the above scenario, we expect the increase in output to be relatively lower as well. Assuming that the additional consumption requirements are, instead, 20 and 18 for manufacturing and services, respectively, we assess how much additional output needs to be produced.

$$\begin{bmatrix} 1.04 & 0.04 & 0.09 \\ 0.07 & 1.07 & 0.11 \\ 0.11 & 0.07 & 1.04 \end{bmatrix} \begin{bmatrix} 0 \\ 20 \\ 18 \end{bmatrix} = \begin{bmatrix} 2 \\ 24 \\ 20 \end{bmatrix}$$

As expected, our example shows that production of lower additional output requires less additional consumption by all sectors.

5.5 Multiplier analysis

Even if we did not have quantified output targets, as in the example above, we could use the Leontief model to check which sector would yield the highest multiplier in the economy. This could be important information if, for instance, the government has limited resources to use to stimulate investment that would increase output throughout the economy. The basic question to be asked is, therefore, “What is the impact of a one-unit increase in final demand on each of the sectors?” We can derive the output multipliers directly from the Leontief inverse matrix. They are calculated by adding up each column of the inverse. The simple output multiplier is direct output + indirect output.

For example, in the matrix above, the services output multiplier is 0.09 + 0.11 + 1.04 = **1.24,** which is the sum of the third column of $(I-A)^{-1}$, thus demonstrating that the output multipliers can be read from the Leontief inverse. Similarly, the manufacturing output multiplier is 0.004 + 1.07= 0.07 = **1.18,** and the agriculture output multiplier is 1.04 + 0.07 + 0.11 = **1.22.**

This information alone is quite powerful for planning. If there is uncertainty about where to increase investment so as to maximize the spillover effects of such an investment, this method shows that the sector with the highest dividends for the economy, in

The sector with the highest output multiplier is not necessarily the sector with the highest employment multiplier.

terms of output, is the services sector, with an output multiplier of 1.24, compared with 2.28 for manufacturing and 1.22 for agriculture. Hence, the government could decide to stimulate the services sector by increasing investment demand and, thus, reap the maximum output dividends. However, the sector with the highest output multiplier is not necessarily the sector with the highest employment multiplier. In certain instances policy-makers might be concerned with employment creation more than increased output in the short run. Additionally, they may be concerned that certain investments may not be worthwhile if the number of jobs across the economy created is too few or fewer than would be created by investments in other sectors. (Typically, the sectors that have the lowest employment multipliers are those that rely heavily on imported inputs.) In addition, the labour and capital intensity of a sector affect employment multipliers. That is, a sector that relies mainly on machinery (large-scale mining), robots (modern car industry) or the computing power of computers and algorithms (information technology industry) has low labour intensity and high capital intensity. Total employment effects of an increase in output are expected to be low (see next section).

5.1.1. Employment multipliers

The employment multipliers show the total increases in employment throughout the economy and its distribution among the sectors resulting from an increase in final demand. In all sectors employment is measured in full-time equivalents (FTE).

As noted (section 5.1), the IO model assumes that levels of employment in an industry are directly related to output, such that an employment/output ratio can be defined that applies at all levels of output. (This is the same as for inter-industry demand.) This means that it is possible to estimate the relationship between the value of the output (in monetary terms) of a sector and employment in that sector (in physical terms).

Dividing each industry's total employment by total output results in the sector's employment coefficient *e* (which in matrix calculation we write in the diagonal, with zeros elsewhere):

$$e = E/X$$

where E is full-time employment and X is total output.

The direct and indirect change in employment due to a unit change in sectoral final demand is given by the Leontief inverse multiplied by the employment coefficient:

$$\Delta E = e[(I - A)^{-1}\Delta D]$$

Let us assume that the employment levels for a three-sector example are those shown in Table 5.3.

Table 5.3 FTE employment levels

	Agriculture	Manufacturing	Services
FTE employment	125	96	89
Source: Authors' assumptions			

With this information and the information on sectoral output given in Table 5.4, we can calculate the employment/output ratios by dividing the sectoral employment by the sectoral output. For example, for manufacturing the ratio is 96/900 = 0.11.

Table 5.4 Calculation of employment/output ratios

	Employment (E)	Output (X)	Employment coefficient (e = E/X)
Agriculture	125	500	0.25
Manufacturing	96	900	0.11
Services	89	750	0.12

Source: Authors' calculations

The employment multipliers are calculated by multiplying the input–output coefficients by the employment/output ratio.

$$\Delta E = e[(I - A)^{-1}\Delta D]$$

One would first need to create the diagonal of the employment coefficients. Then, multiplying the diagonal employment coefficient matrix with the Leontief inverse results in the employment multiplier matrix (Table 5.5):

$$\begin{bmatrix} 0.25 & 0 & 0 \\ 0 & 0.11 & 0 \\ 0 & 0 & 0.12 \end{bmatrix} * \begin{bmatrix} 1.04 & 0.04 & 0.09 \\ 0.07 & 1.07 & 0.11 \\ 0.11 & 0.07 & 1.04 \end{bmatrix} = \begin{bmatrix} 0.26 & 0.01 & 0.02 \\ 0.01 & 0.12 & 0.01 \\ 0.01 & 0.01 & 0.12 \end{bmatrix}$$

Table 5.5 Calculation of employment multipliers – total employment requirement matrix

	Agriculture	Manufacturing	Services
Agriculture	0.26	0.01	0.02
Manufacturing	0.01	0.12	0.01
Service	0.01	0.01	0.12
Total	0.28	0.14	0.16

Source: Authors' calculations

Thus, from our example, following a one unit increase in final demand for manufacturing, employment goes up by 0.01 units in agriculture, 0.12 units in manufacturing and 0.01 units in the services sector.

The total employment multiplier for the services sector is found by adding the direct and indirect employment multipliers (column totals). The total multipliers are 0.16 for services, 0.14 for manufacturing and 0.28 for agriculture.

Sensitivity analysis

As in the impact analysis section above (section 5.4), we can perform sensitivity analysis here. In this case we check how sensitive the IO modelling results are to various values of employment levels.

If we assume that manufacturing is more labour-intensive than in the previous scenario, we would expect an increase in the final demand from manufacturing to have higher employment multipliers. Below, we check how the employment multipliers are affected. Table 5.6 shows higher employment levels for manufacturing (275) than the initial example in Table 5.3.

Table 5.6 Higher FTE employment levels for manufacturing

	Agriculture	Manufacturing	Services
FTE employment	125	275	89

Source: Authors' assumptions

As in the previous example, for every unit of manufacturing output produced, 1.07 units of manufacturing input are required. Thus, the employment multiplier for manufacturing is obtained by multiplying 1.07 (direct requirement for manufacturing in its own production) by 0.31 (the manufacturing employment/output ratio), as Table 5.7 shows.

Manufacturing employment multiplier = 1.07*0.31 = 0.33.

Table 5.7 Calculation of employment multipliers for more labour-intensive Industry

	Leontief inverse	Employment/ output (X)	Employment multiplier
Agriculture	0.04	0.25	0.01
Manufacturing	1.07	0.31	0.33
Service	0.07	0.12	0.01

Source: Authors' calculations

As expected, a relatively more labour-intensive manufacturing industry results in higher employment multipliers for the manufacturing sector.

5.6 Impact analysis with green sectors

In this section we carry out the analysis as above, but we use the matrix in which the green sectors are distinguished from conventional sectors. We calculate both output and employment multipliers.

First, we start with the direct coefficients matrix. For ease of reference, the final green IO table is repeated on the next page as Table 5.8 (page 140).

Direct coefficients are calculated by dividing each cell by the column total.

The direct coefficients are calculated by dividing each cell by the column total. For example, the cell that represents intermediate demand for conventional agriculture is divided by its column total: 12.06 / 490.58 = 0.025. The direct input coefficient tells us that, out of total expenditures of conventional agriculture, about 2.5 per cent is spent on conventional agriculture goods for intermediate production. Comparing this with the green intermediate input consumption, we observe that the green agriculture sector requires 0.046 units from itself, or 4.6 per cent of total inputs to produce a unit of its output. The green agriculture production system relies more on its own inputs than does the conventional production system. Table 5.9 (page 141), which is the A matrix, shows the direct coefficients for all of the inter-industry relationships reported in Table 5.8.

The other coefficients are interpreted the same way. One can compare not only intermediate inputs but also value added components. For example, the coefficients tell us that green agriculture spends a higher share on wages than conventional agriculture, 63 per cent versus 50 per cent. This difference is due to the higher labour requirement of green agricultural practices. In contrast, conventional agriculture spends 15 per cent of its total for imports, while green agriculture makes no such expenditure.

Table 5.8 Impact analysis with green sectors

	Conventional agriculture	Green	Conventional manufacturing	Green	Household demand	Services	Private investment	Government demand	Exports	Output (sales)
Conventional agriculture	12.06	0.00	26.42	0.07	39.26	58.89	4.42	80.49	268.95	490.58
Green	0.00	0.44	0.51	0.00	0.74	1.11	0.08	1.51	5.05	9.43
Conventional manufacturing	23.75	0.00	50.79	0.00	114.46	71.54	566.58	15.26	15.26	857.64
Green	1.15	0.10	0.00	3.21	5.54	3.46	27.42	0.74	0.74	42.36
Services	48.84	1.16	49.81	4.19	80.00	15.00	4.50	85.30	461.20	750.00
Imports	75.00	0.00	108.00	0.00	160.00	30.00	297.00	206.70		876.70
Taxes minus subsidies	12.25	0.25	17.95	0.05		15.00				45.50
Wages & salaries	244.02	5.98	505.42	34.58		450.00				1 240.00
Gross operating surplus	73.50	1.50	98.74	0.26		105.00				279.00
TOTAL	490.58	9.43	857.64	42.36	400.00	750.00	900.00	390.00	751.20	

Source: Authors' calculations

Table 5.9 Direct coefficients matrix of green expanded economy (A matrix)

	Conventional agriculture	Green	Conventional manufacturing	Green	Services	Household demand	Private invest-ment	Government demand	Exports	Output (sales)
Conventional agriculture	0.02	0.00	0.03	0.00	0.08	0.10	0.00	0.21	0.36	0.80
Green	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06
Conventional manufacturin g	0.05	0.00	0.06	0.00	0.10	0.29	0.63	0.04	0.02	1.18
Green	0.00	0.01	0.00	0.08	0.00	0.01	0.03	0.00	0.00	0.14
Services	0.10	0.12	0.06	0.10	0.02	0.20	0.01	0.22	0.61	1.44
Imports	0.15	0.00	0.13	0.00	0.04	0.40	0.33	0.53	0.00	1.58
Taxes minus subsidies	0.02	0.03	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.09
Wages	0.50	0.63	0.59	0.82	0.60	0.00	0.00	0.00	0.00	3.14
Profit	0.15	0.16	0.12	0.01	0.14	0.00	0.00	0.00	0.00	0.57
TOTAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Source: Authors' calculations

However, the direct coefficients table does not tell us anything about the interlinkages of industries and the indirect effects of changes in final demand. For this, the Leontief model is required. Recall that, in an open Leontief model, final demand is exogenous. In this case imports and value added are not modelled and are considered as "leakages". Technically, the A matrix is, then, calculated only for inter-industry purchases and sales. In our case of the green expanded IO table, this is a 5x5 matrix (Table 5.10).

Table 5.10 Direct coefficients matrix of green-sector model (example from above)

$$A=\begin{bmatrix} 0.02 & 0.00 & 0.03 & 0.00 & 0.08 \\ 0.00 & 0.05 & 0.00 & 0.00 & 0.00 \\ 0.05 & 0.00 & 0.06 & 0.00 & 0.10 \\ 0.00 & 0.01 & 0.00 & 0.08 & 0.00 \\ 0.10 & 0.12 & 0.06 & 0.10 & 0.02 \end{bmatrix}$$

To know the total effect of an increase in demand (final consumption) on output, we use the Leontief model in equation 10.

$$(I-A)^{-1}\Delta D = \Delta X \tag{12}$$

$$(I-A)^{-1} = \begin{bmatrix} 1.04 & 0.01 & 0.04 & 0.01 & 0.09 \\ 0.00 & 1.05 & 0.00 & 0.00 & 0.00 \\ 0.06 & 0.01 & 1.07 & 0.01 & 0.11 \\ 0.00 & 0.01 & 0.00 & 1.08 & 0.01 \\ 0.11 & 0.13 & 0.07 & 0.11 & 1.04 \end{bmatrix}$$

Adding up the columns of the above Leontief inverse gives the output multipliers. For example, the multiplier indicates that when green agricultural demand increases by 1, with other demands remaining constant, total output increases by 1.22. By comparison, conventional agriculture increases total economic output by 1.21. The difference is due to differences in import structure.

Output multipliers are:

Conventional agriculture	Green agriculture	Conventional manufacturing	Green manufacturing	Services (no distinction between green and conventional)
1.21	1.22	1.18	1.22	1.24

The same calculation is done using equation 10 and multiplying the Leontief inverse by a final demand increase of 1 for green agriculture. Again, adding up the column of total output gives us the same total output multiplier as the one calculated above for green agriculture:

$$\begin{bmatrix} 1.04 & 0.01 & 0.04 & 0.01 & 0.09 \\ 0.00 & 1.05 & 0.00 & 0.00 & 0.00 \\ 0.06 & 0.01 & 1.07 & 0.01 & 0.11 \\ 0.00 & 0.01 & 0.00 & 1.08 & 0.01 \\ 0.11 & 0.13 & 0.07 & 0.11 & 1.04 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0.01 \\ 1.05 \\ 0.01 \\ 0.01 \\ 0.13 \end{bmatrix}$$

In this example comparing green and conventional agriculture, we see that investing in green agriculture would yield higher total economy-wide outputs due to its greater integration into the national economy.

5.6.1 *Comparative growth analysis*

We could now compare growth scenarios. Imagine that a Ministry of Finance and Planning is considering a policy to stimulate organic agriculture. This could be done through a reduction of subsidies for chemical fertilizer and tax rebates for organic fertilizer production and organic produce. The simple IO model presented here does not allow for price-based production changes, as prices are considered fixed in the short term. (This assumption will be relaxed in the price model presented later.) So, in the basic IO model, the price change needs to be translated into changes in final demand/investment. A simplifying way of doing this is to assume that the industry, as it grows, gradually shifts to organic agriculture – that is, keeping conventional output constant while increasing only organic output. Let us assume that total agricultural output currently is growing by 6 per cent annually, and this is also projected for the next year. In our example total final agricultural demand is 500 this year and is expected to increase by 0.06*500 = 30 to a total of 500 + 0.06*500 = 530 next year. If the green policy is enacted, we assume that the entire growth of 30 comes from green agriculture. If no policy is enacted, we assume that all growth comes from conventional agriculture. The policy planners want to evaluate the policy in terms of total economic activity. The model allows for short to medium term comparative projections, comparing an increase in final demand in conventional agriculture without the policy with an increase in green agriculture with the policy. Technically, we simply increase final demand in green agriculture and compare it with conventional agriculture, holding all else constant.

With the green policy, total output would increase to about 37, which is the sum of the total output column shown in the matrix below:

$$\begin{bmatrix} 1.04 & 0.01 & 0.04 & 0.01 & 0.09 \\ 0.00 & 1.05 & 0.00 & 0.00 & 0.00 \\ 0.06 & 0.01 & 1.07 & 0.01 & 0.11 \\ 0.00 & 0.01 & 0.00 & 1.08 & 0.01 \\ 0.11 & 0.13 & 0.07 & 0.11 & 1.04 \end{bmatrix} \begin{bmatrix} 0 \\ 30 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0.04 \\ 31.49 \\ 0.43 \\ 0.39 \\ 4.04 \end{bmatrix}$$

Increasing final demand in conventional agriculture results in a slightly lower total output of around 36, the sum of the total output column below:

$$\begin{bmatrix} 1.04 & 0.01 & 0.04 & 0.01 & 0.09 \\ 0.00 & 1.05 & 0.00 & 0.00 & 0.00 \\ 0.06 & 0.01 & 1.07 & 0.01 & 0.11 \\ 0.00 & 0.01 & 0.00 & 1.08 & 0.01 \\ 0.11 & 0.13 & 0.07 & 0.11 & 1.04 \end{bmatrix} \begin{bmatrix} 30 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 31.08 \\ 0.01 \\ 1.93 \\ 0.10 \\ 3.28 \end{bmatrix}$$

The policy planners, however, may not be so interested in total economic output, which is an abstract measure, but more interested in employment creation, income and GDP growth (which in our case is value added). The next sections calculate the employment and GDP multipliers.

5.6.2 *Employment model*

> The employment projection model makes possible employment comparisons between a conventional and a green growth scenario.

This section develops the basic Leontief model into an employment projection model. By using the green IO table as developed above, the employment projection model makes possible employment comparisons between a conventional and a green growth scenario. First, we show how employment multipliers can be calculated. From our survey we find total employment in the green and conventional industries. Recall that we increased wages to account for overall higher employment in green agriculture (by 20 per cent) and green manufacturing (by 30 per cent). First, we calculate employment coefficients, dividing total employment by total output (Table 5.11).

Table 5.11 FTE employment levels and employment coefficients – conventional versus green

	Conventional agriculture	Green agriculture	Conventional manufacturing	Green manufacturing	Services
FTE employment	122	3	90	6	89
Total output	490.58	9.43	857.64	42.36	750
Employment coefficients	0.25	0.32	0.11	0.14	0.12
Wages	244.02	5.98	505.42	34.58	450.00
Labor productivity: wage/employment	2	2	5.6	5.7	5.1

Source: Authors' calculations

An intuitive way to calculate total employment is to start by calculating direct employment requirements for every industry and then add up all resulting indirect jobs. Following the above example, and using the Leontief inverse, for every unit of conventional agriculture output produced, 1.04 units of agriculture output is required (that is, 1, to satisfy the increase in final demand, plus 0.04 as indirect intermediate demand). To obtain the employment multiplier for agriculture, we assume constant returns to scale, as above. We multiply the direct requirement table, or Leontief inverse, by the agriculture employment/output ratio: 1.04*0.25 = 0.26. So, if final demand for agriculture goes up by one unit, employment in agriculture goes up by 0.26 units. This is the direct effect.

Now, supplying industries also increase production and employ workers; we call this the indirect effect. We see from the Leontief inverse table that, when demand for conventional agriculture increases, there is no (i.e., zero) increase in green agriculture and green manufacturing production (this is because there is no interlinkage between those industries). Thus, there is no increase in employment, either. But intermediate demand from conventional manufacturing increases by 0.6 units and from service by 0.11 units. Multiplying the Leontief inverse by the employment output ratio translates into an increase of 0.01 units of employment in conventional manufacturing. Summing down the column gives the total employment multiplier, which for conventional agriculture is 0.28. In summary, if final demand in conventional agriculture increases by one, 0.28 more workers will be needed to satisfy this increase in final demand (Table 5.12 for conventional agriculture).

Table 5.12 Calculation of conventional agriculture employment multipliers

	Leontief inverse	Employment/ X	Employment multipliers
Conventional agriculture	1.04	0.25	0.26
Green agriculture	0.00	0.32	0.00
Conventional manufacturing	0.06	0.11	0.01
Green manufacturing-	0.00	0.14	0.00
Services	0.11	0.12	0.01
Total employment multiplier			0.28

Source: Authors' calculations

The same result is calculated using matrix algebra and the employment model formula $\Delta E = e[(I - A)^{-1}\Delta D]$. Please note that the employment coefficients need to be written in the diagonal with zeros elsewhere to create a full matrix of employment multipliers (Table 5.13). (In matrix algebra this is done to multiply a vector by a matrix.)

Table 5.13 Employment coefficients (e) in diagonal

0.25	0	0	0	0
0	0.32	0	0	0
0	0	0.11	0	0
0	0	0	0.14	0
0	0	0	0	0.12

Source: Authors' calculations

This results in the employment multiplier matrix, or total employment requirements matrix, shown in Table 5.14. Summing down the columns gives the total employment multipliers, which in the case of agriculture is the same as calculated above, 0.28.

Table 1.14 Employment multiplier matrix (e(I – A)’)

	0.26	0.00	0.01	0.00	0.02
	0.00	0.33	0.00	0.00	0.00
e(I-A)’ =	0.01	0.00	0.11	0.01	0.01
	0.00	0.00	0.00	0.14	0.00
	0.01	0.02	0.01	0.01	0.12
Total employment multiplier	0.28	0.36	0.13	0.17	0.16

Source: Authors’ calculations

The interpretation is the same as in the general Leontief model above. A 100-unit increase in total demand increases employment by 28 jobs in conventional agriculture, while it creates 36 jobs in green agriculture.

Now the two growth scenarios considered by the Ministry of Finance can be compared in terms of employment creation – a green agricultural growth scenario and a conventional agricultural growth scenario, both anticipating a 6 per cent (or 30-unit) increase in total agricultural production next year. Mathematically, following the formula, we multiply the total employment requirements matrix by a vector of final demand, increasing either conventional or green agricultural demand by 30 units.

As Table 5.15 shows, in a green growth scenario about 11 jobs would be created, while in a conventional scenario only about eight jobs would be created.

Table 5.15 Employment outcomes of alternative agricultural growth scenarios, total agriculture growing by 6 per cent per year in either green or conventional production

	Conventional agriculture	Green agriculture
	7.73	0.08
	0.00	10.02
	0.20	0.05
	0.01	0.05
	0.39	0.48
Total employment	8.34	10.68

Source: Authors’ calculations

Note that labour productivity is the same in conventional and green agriculture even though green agriculture is more labour-intensive. This is because wages are the same while the production system is different. Thus, more labour is required in the green system, while more capital goods and imports are required in the conventional system.

The policy-makers may now be interested in how green agriculture compares with conventional agriculture in terms of overall GDP growth. Here, total income, which should be equal to value added (VA), is used to calculate GDP. In the next section income/VA (GDP) multipliers are derived and growth scenarios are compared.

5.6.3 GDP/VA or income model

To compare GDP growth scenarios, we first calculate the GDP, or income, coefficients (Table 5.16). (Strictly speaking, we will refer to value added multipliers, as this is what they are.)

Table 5.16 Value added (GDP) coefficient

	Conventional agriculture	Green agriculture	Conventional manufacturing	Green manufacturing	Services
VA/total output	330	8	622	35	570
(GDP coefficient)	0.67	0.82	0.73	0.82	0.76

Source: Authors' calculations

We then use the same Leontief formula but pre-multiplied by the income/VA/GDP coefficient , $\Delta GDP = gdp[(I - A)^{-1}\Delta D]$ (Table 5.17). (As above, it needs to be written in diagonal to get the full income multiplier matrix.)

Table 5.17. Full value added (income/GDP) multiplier matrix

	Conventional agriculture	Green agriculture	Conventional manufacturing	Green manufacturing	Services
	0.70	0.01	0.03	0.01	0.06
	0.00	0.86	0.00	0.00	0.00
	0.05	0.01	0.78	0.01	0.08
	0.00	0.01	0.00	0.89	0.00
	0.08	0.10	0.05	0.08	0.79
Total VA/GDP multiplier	0.83	0.99	0.86	0.99	0.93

Source: Authors' calculations

We interpret the total GDP multipliers in the same way as the employment and output multipliers. If final demand grows by 100 in conventional agriculture, GDP will grow by 83, but if final demand grows by 100 in green agriculture, GDP will grow by 99. Again, in this stylized example, it is due to green agriculture's higher degree of interlinkages with the national economy.

When calculating GDP multipliers, it is important to understand that GDP, in national accounting, is calculated from different sources. It can be derived from total final demand. So, the question arises: Why calculate a GDP multiplier in the first place? If we increase GDP by one and then ask the model what would happen to GDP (calculated from the VA side), it makes little sense at first glance. However, it does make sense. This is because of so-called "leakages", which in our example is the spending on imports. Comparing the multipliers evaluates how much actual value added is generated within the national economy and how much is accruing outside. In our example leakages in the conventional industries are much higher due to their higher import shares.

The policy-maker may now use the same 6 per cent growth scenario to evaluate the effect of the green agricultural policy on GDP. Increasing total final demand by 30 in conventional agriculture increases GDP by about 25, while in the case of green agriculture it increases GDP by around 30 (Table 5.18).

Table 5.18 Comparing a 30-unit increase in final demand in conventional versus green agriculture

	Conventional GDP	Green GDP
	20.89	0.23
	0.01	25.80
	1.40	0.31
	0.08	0.32
	2.49	3.07
Total GDP	24.88	29.73

Source: Authors' calculations

5.7 Making employment projections for green and conventional growth scenarios

5.7.1 Define a business as usual growth scenario

To make employment projections, exogenous changes in final demand need to be estimated for each year in the assessment period, that is, $f_{t+1}, f_{t+2,}, f_{t+3,\ etc}$. This can be done as follows:

Define business as usual. As a first step the business-as-usual scenario should be defined. The simplest way is to project historic growth trends at the industry level into the near future, using GDP growth forecasts of recognized organizations such as the World Bank or International Monetary Fund. If sector growth rates are not available, a simplifying assumption could be made: taking the same growth rate for all industries. If historical data on sector growth trends and shifts between industries exist, these trends should be extrapolated. The final demand vector should be estimated year-by-year, industry-by-industry, comprising household demand, private investment, government demand and exports (HH, I, G, Ex).

Value added, income and employment can then be projected using the basic model $x_{t+1} = (I - A_1)^{-1} f_{t+1}$, which assumes that the technology matrix A remains constant while final demand is exogenously projected to year t + 1. Employment is calculated as follows:

$$Employment_{t+1} = ec_{t+1}\ (I - A_1)^{-1} f_{t+1}$$

where ec_{t+1} is the employment coefficient in year t + 1, $ec_{t+1} = {}^{jobs_1 * \Delta\ lp}/_{x_1}$,

with △*lp* being the exogenously projected change in labour productivity from year 1 to year t + 1. Using the equation above, suppose that, in year 1 some 100 workers produce an output of 10,000, but it is expected that in year t + 1 only 90 workers will be required to produce the same output. Thus, labour productivity is 100 in year 1 and 111.11 in year t + 1. The change in labour productivity is 100/111.11 = 0.90001, or roughly 90 per cent.

Income and value added are calculated the same way:

$$income\ or\ value\ added_{t+1} = vac\ (I - A_1)^{-1} f_{t+1},$$

where *vac* is the value added or income coefficient $vac = {}^{Value\ added}/_{x}$

Environmental indicators such as CO_2 emissions, energy use, deforestation or water pollution can be calculated the same way:

$$CO2_{t+1} = co2c\ (I - A_1)^{-1} f_{t+1},$$

where co2c is the CO_2 coefficient, $co2c = {}^{CO2 * \Delta\ efficiency}/_{x}$,

with $\Delta\ efficiency$ being the change in CO_2 intensity, to account for a possible reduction in CO_2 intensity per unit of output. As the equation shows, if CO_2 emissions per unit of output do not change between year 1 and year t + 1, the factor equals 1, resulting in no change. If, instead, CO_2 emissions in year t + 1 are only 90 per cent per unit of output of what they have been in year 1, then the factor is 0.9, a change in the CO_2 coefficient.

5.7.2 *Develop a green growth scenario*

In a **second step** a green growth scenario should be developed based on existing or potential policies and growth targets. Initially, the development of a scenario should start with a set of growth targets at the industry level, following the IO table's classification of activities. For example, the 10-year growth target for organic agricultural production could be set at 20 per cent of total agricultural production. In this case a green agricultural industry has to be created. For the economy as a whole, reductions in the supply of virgin metals, plastics, paper or glass could be similarly targeted. Commensurate with the reduction, an equal increase in supply from the recycling industry could be assumed. While there are many possible green growth scenarios, one should start with a simple one so as to understand the dynamics first.

> While there are many possible green growth scenarios, one should start with a simple one so as to understand the dynamics first.

5.7.3 *Implement the green growth scenario*

In a **third step**, importantly, the scenarios should be composed of (i) initial capital investment (assets) and (ii) subsequent final demand (consumption).

Capital investment. The scenario regarding capital investments should be based on physical capital requirements that are necessary to produce a given scale of final and intermediate demand as defined by the growth target. This means linking the consumption or final demand target to physical capital requirements. For example, in order to produce 100,000 cars a year, one car factory at a cost of 10 million may be required. To estimate the full set of capital requirements for such an investment, expansion capital coefficients are needed. They are defined as the capital requirements by sector j from sector i per unit increase of capacity in j. Estimating this coefficient requires compiling a table of the production of capital goods for direct and indirect use that balances capital sales and purchases. (The table is rectangular, as not all industries produce capital goods while most consume them.) Such a capital transaction table is the basis for a more dynamic model than the comparative static model addressed in this module. Here, only the direct aggregate capital purchases by sector j from each of the sectors i are estimated and assigned to the exogenous final demand.

Technically, such an aggregate capital requirement vector is the exogenous vector of gross capital formation, or simply (I) for investment, in the input–output table. For example, if the green growth scenario aims for a 100 per cent share of renewable energy supply 10 years from now, it should be estimated how many megawatts (MW) or gigawatts (GW) of installed capacity will be required in year 10. Ideally, the target is split into the types of renewable energy, for each of which total cost should be estimated. Price trends should be taken into consideration. Once total capital costs for the project are found, the capital requirements for each renewable energy technology should be estimated. Eventually, an investment vector should be estimated that splits the total investment into its industry shares. This requires studying existing investment projects to understand how much is spent on construction, how much on equipment, import, employment, etc. The investment vector should then be calculated for each of the 10 years and aligned with targeted capacity installations year by year. To simplify, an assumption could be made that the investments are equally spread over the 10 years. For example, if a total of 10,000 MW of renewable energy installation is the target in year 10 and will cost 10 million, the investment in each year is 1 million for 1,000 MW. Average inflation should be accounted for at, say, 3 per cent. If construction cost accounts for 40 per cent of total capital cost, electrical equipment for 30 per cent, imports for 25 per cent and taxes on production for 5 per cent, then the capital vector for each year is 400,000 for construction and 300,000 for equipment. In an open IO model, which captures only direct and indirect production effects, imports of 250,000 and indirect taxes of 50,000 are leakages that are not part of the final demand vector. However, their effects are captured when calculating the value added multiplier, hence the importance of adjusting value added in the expanded green IO table (see green industry expansion in section 5.3 of this chapter).

Total green investments should then be translated into an alternative conventional growth scenario commensurate with the size of the green investment so as to allow for a comparative impact analysis. In the example above conventional energy investment could be used for comparison.

Consumption. Next, the scenario for consumption should be calculated and aligned to the investment scenario. This should be done for both the green and the conventional scenarios. Technically, in the IO table this is final household consumption (HH final consumption) and government expenditures (G). In the above example, the time lag for the investment to become operational must be defined. If the renewable energy investment consists of incremental additions to the grid of micro equipment, such as PV panels and wind turbines, the assumption can be made that consumption starts in year 2, with the maturity of the investment at the end of year 1. It can be further assumed that each year 1,000 MW of additional renewable electricity is added to total consumption. The final consumption vector is then found by multiplying total renewable electricity consumption by the average expected price year-by-year. For the sake of the example, as most of the final demand goes directly as payment to the utilities producing the renewable energy, the final consumption vector could be composed of only this one entry covering 100 per cent of all expenses. As no fuels are to be imported, and operation and maintenance all happen locally, there are no imports. There is no entry for wages, as this is indirectly accounted for through the backward linkages of the energy industry, using production factors. Assuming a price of electricity of 10 cents per kilowatt hour (KWh), running at full capacity, the total cost for 1000 MWh (1 MW = 1000 KW) is 100,000. With a total economy-wide use of 10,000 MW, final consumption costs 1 million (In this example we abstract from load factors, that is when renewable technology does not produce electricity due to, for example, wind and sun variability. In a real world model, this should be accounted for.)

An additional assumption must be made regarding **inflation and price change**. For example, these can be assumed to be a combined 3 per cent per year. Final demand in year 1 is zero for renewables and 1 million for conventional. This is because only investments take place in renewable capacity, with no change in consumption. In year 2 consumption is 103,000 for the first 1,000 MW of installed capacity and in year 3, to pay for 2000 MWh, it is 206,000. Adding 3 per cent inflation and price increase, this becomes 212,180).

Importantly, in the green growth scenario, an assumption must be made regarding electricity consumption from conventional sources. It could be assumed that, while the share of renewable energy goes up, a commensurate reduction occurs in consumption of conventional electricity, at the average annual cost of 1,000 MW. So, the consumption vector should reflect the final demand shift from conventional to renewable energy spread over the 10 years).

In contrast to renewable energy, in many industries, such as in green buildings, capital accumulation will need more time to mature. Changes in consumption or final demand of the product or service, such as a shift in energy demand, operation and maintenance of the green building, will occur only thereafter. Therefore, it is important to define the **investment lags**, particularly for “lumpy” investments, which may take several years to become operational.

The remaining final demand vector for the green industries to be estimated is **exports** (Ex). If no reliable data on export forecasts for the green industries exist, the historic trend could be applied, or the export trend of the closest neighbour – often the parent industry – can be used.

Total investment, household demand, government demand and exports should then be added into a total final demand vector, industry-by-industry and year-by-year.

The green and conventional final demand vectors should then be applied to the model year-by-year up to the year of interest. Employment outcomes should be adjusted for trends in labour productivity year-by-year. Resulting total employment, income and value added can then be compared on a yearly basis between the green and the conventional scenarios.

6. Building a static comparative employment projection model step-by-step: summary

Key questions to answer

- What are the seven steps in building a static comparative employment projection model?
- How can exogenous changes in final demand be estimated?

Important observations

- An employment projection model is driven by scenarios and/or exogenous projections of final demand comprising investments and consumption.
- Data on employment in green establishments should be collected through sample surveys of green industries or expert interviews (see module 2).
- This model answers the question: If final demand in one sector increases by X, by how much will employment go up in the industry itself and in all other supplying industries?

This section provides a summary that links chapters 1 and 2 – introduction to input–output modelling – with chapters 3 and 4 – modelling green industries and analysing distributional impacts. Here we use the concepts presented in these chapters to build a static comparative employment projection model step-by-step. There are seven steps:

1. **Obtain a consistent IO/SAM for the latest available year** and designate this as year 0. Most likely, it is available from the central statistics office.

2. **Calculate the Leontief model for year 0**: $x_0 = (I - A_0)^{-1} f_0$, or simply $x_0 = L f_0$.

3. **Update the IO/SAM to the current year** – say, to year 1 – based on current data from the National Accounts. The A matrix – the technology-based production structure – remains the same as long as it is assumed that GDP, total output and final demand evolve in the same way. Applying annual growth rates of GDP for output and final demand will update the totals. This will change only totals and not the structure of the economy. (The A matrix remains the same.)

   In case the IO is outdated and sectoral change in production has evolved in a way significantly different from the evolution of final demand, the A matrix needs to be adjusted. In technical terms this means that intermediate demand (columns) evolved differently from intermediate consumption (rows) and total output. Statistical methods such as the RAS algorithm can be used to rescale and balance intermediate demand, consumption and output. If no industry- or sector-specific growth rates are available, there is no point in applying the RAS method, as the technology matrix will not change. So, only if data are available on sector and final demand growth and those differ, the following approach should be taken:

   a. Gather data on GDP growth at the industry or sector level, apply the linear trend rate to output growth, and estimate output for each industry for the current year 1. In Leontief model notation, this is $\boldsymbol{x_1}$ total output by the industry in year 1 (based on the assumption that GDP and output evolve in a linear way).

b. Estimate final demand $\boldsymbol{f_1}$ based on the latest data from the National Accounts or growth rates found in academic literature or from recognized international organizations or institutes such as World Bank or International Monetary Fund.

c. Estimate intermediate consumption (row vector) $\boldsymbol{ic_1} = \boldsymbol{x_1} - \boldsymbol{f_1}$.

d. Estimate intermediate demand (column vectors) $\boldsymbol{id_1} = \boldsymbol{x_1} - \boldsymbol{gdp_1}$.

e. Having found the three values $\boldsymbol{id_1 ic_1 x_1}$, now apply the RAS algorithm, which calculates the new technology matrix $\boldsymbol{A_1}$ by a sequential scaling of rows and columns until convergence

f. Calculate the Leontief model for the current year 1, $\mathbf{x_1} = (\mathbf{I} - \mathbf{A_1})^{-1}\mathbf{f_1}$, or simply $\mathbf{x_1} = \mathbf{Lf_1}$.

4. **Expand the IO of the current year 1 to feature green industries.**

   Green industries should be defined based on the System of Environmental and Economic Account indicators should be singled out based on those having an "environmental purpose". Broadly speaking, these are activities that produce outputs and apply processes that benefit the environment (see definitions of green industries and indicators above).

   Eventually, following the steps of green industry expansion above, a new industry-by-industry matrix with green industries, which have different production structures, will result.

   The green industry expansion should include and provide total employment numbers (that is, a row vector depicting total employment industry-by-industry). Green establishment employment should be separately accounted for, following the new green industry split. The job numbers are best collected in small sample surveys of green industries or, if that is not possible, through expert interviews. The employment numbers should then be attached as a satellite account vector to the IO table (see green input–output table above in section 3.10, with attached employment in Table 4.1).

   To study the effects of green structural change on GDP/value added and, as a proxy, workers' compensation, value added and wage vectors could be marked in the table. (There is no need to add information, as the IO table presented in section 3.10 includes information on VA and wages.)

   Similar to the employment satellite, which links physical units to values in the IO table, satellites to account for CO_2 emission by industry, energy use by industry, deforestation by industry or any other environmental data can be created. The effects of environmental policies on output, GDP and employment can then be studied.

5. Based on the green IO, **calculate the green Leontief model** for the current year 1, $\text{Green } \mathrm{x}_1 = (\mathrm{I} - \mathrm{A}_1)^{-1}\mathrm{f}_1$, or simply $\text{Green } \mathrm{x}_1 = \mathrm{Lf}_1$. The inverse is the basis of the output projection model. This model answers the question: If final demand in one sector increases by one, how much output will be produced industry-by-industry? The direct effect occurs in the industry where the final demand increases. The indirect effect occurs in supplying industries.

6. Next, **calculate the employment, income and value added multipliers** (and CO_2 or other).

First, compute the employment/output ratio. This is the number of jobs needed for the production of one unit of output; it is the employment coefficient by industry, $\boldsymbol{ec} = {}^{\boldsymbol{jobs}}/_{\boldsymbol{x}}$.

The same should be done for value added and income. This will result in value added and income coefficients.

Calculate the employment, income and value added multipliers using the Leontief model: $Green\ Employment_1 = ec\ (I - A_1)^{-1} f_1$. The employment multipliers are the foundation of the employment projection model, which makes possible short-term simulations. It can answer questions about different growth scenarios such as: How many direct and indirect jobs will be created or lost if total demand increases in the green industry while declining in the conventional industry? How much value added or income would be created?

To make possible short-term projections, labour productivity rates should be calculated for each industry. If no data are available at the industry level, estimates should be made at least for the primary, secondary and tertiary sectors. Labour productivity is defined as output produced per unit of labour, $lp = x/jobs$.

The annual change in labour productivity, $\vartriangle \mathrm{lp} = \ lp_0/lp_1$, should then be calculated for each industry. Averaging labour productivity over the period of available data will allow us to use a constant deflator for each year of the employment projection. Regarding the green industries, for which in most cases only one observation is available, the same productivity changes could be assumed as in the closest neighbour industry. That is, typically, the parent industry from which the green industry was expanded.

7. **Develop a business as usual and a green growth scenario for industries of interest.** Define a date in the future to which you want to project – for example, year 10. Define a final demand vector for the capital formation required for green products and services to grow year by year to achieve the target in year 10. Also, define a capital requirement vector for the wear and tear of conventional capital renewal.

   Add a vector of consumption (that is, final demand excluding investment, which you accounted for before) for the green and the conventional growth scenarios. Use total final consumption of the parent sector in year 10 as a starting point. First, apply it as a business-as-usual scenario in the conventional industries. Second, define your green target, and shift total final consumption year by year to reach total final green consumption as per the green target.

   Add total investment and total final consumption year per year and apply it to the model year by year. Employment, GDP, CO_2 and other indicators of interest can then be projected.

Green Jobs Assessment Institutions Network (GAIN)

Training module 4:

From IO and Supply-and-Use to Social Accounting Matrix Analysis

Contents

1. Introduction

Key questions to answer

- What is the relationship between social accounting matrices (SAMs), on one hand, and supply and use tables (SUTs) and IO tables (IOTs), on the other?
- What are the advantages of using SUTs or SAMs over IOTs?

Important observations

- SUTs are the preferred statistical source of both IOTs and SAMs.
- A green SUT can be obtained from source data and then transformed into a green IOT following standard SUT-to-IOT transformation methods.

The previous module introduced the input–output (IO) framework as an instrument for policy analysis, showing its versatility in capturing economy-wide effects of policies via the economic inter-linkages between productive sectors and sources of demand in an economy.

This module introduces some extensions and generalizations of the IO framework to provide a broader portfolio of instruments for analysis. Two additional statistical and analytical tools are available to the policy analyst and policy-maker:

- the supply and use framework and
- the social accounting matrices (SAMs).

Like input–output tables (IOTs), supply and use tables (SUTs) and SAMs can be used as statistical representations of an economy and can provide the basis for multiplier analysis and more complex simulation modelling.

> Supply and use tables (SUTs) and social accounting matrices (SAMs) can represent an economy statistically and provide the basis for multiplier analysis and more complex simulation modelling.

To understand these tools, we need to take a step back to look more closely at the construction of IOTs and the possible extension of the concept of IO multipliers. We will then take a few steps forward to understand how key national accounts and social statistics can be presented in a fully consistent framework that makes possible both the representation of economic, environmental and social relationships in an economy and a database for more complex modelling.

The **supply and use** framework summarizes the production and use of goods and services across the economy. It is nowadays considered a central part of a national account system and recommended as the instrument to balance supply and use of products and to generate more accurate estimates of the GDP. IOTs can be derived from SUTs by making assumptions about either the production technology or the sales structures of product and industries.

Social accounting matrices are expansions of supply and use or IOTs. SAMs typically include additional social statistics on labour and households, such as revenues and uses of incomes of disaggregated classes of labour and households.

IOTs, SUTs and SAMs are matrix representations of economic transactions between industries and institutional sectors.[1] These matrix systems can be expanded with satellite accounts, which are linked to the transactions without being fully integrated into the matrix accounting system. Satellite accounts typically measure the uses or the generation of physical quantities such as energy, emissions and employment. Monetary transactions involving green industries and products can be fully integrated into IOTs, SUTs and SAMs, while additional environmental data described in terms of physical units can be added in satellite accounts.

The supply and use framework has analytical value in itself: It is closer to the statistical sources and more general than IOTs, as it includes the possibility of secondary production of firms.[2] The supply and use framework can include "green industries" and "green goods and services" by breaking down standard industry and product classifications as indicated in module 3. If green activities and products can be identified in establishment and household surveys, a "green SUT" that distinguishes conventional and green industries and products can be derived before the IOT. The green SUT can then be transformed into a green IOT following standard transformation methods described in the following chapters.

> The supply and use framework can include "green industries" and "green goods and services". A "green SUT" can be transformed into a "green IOT" following standard SUT to IOT transformation methods.

Terminology and matrix notation

The System of National Account (SNA) is the internationally agreed standard set of recommendations on how to compile measures of economic activity. It describes a coherent, consistent and integrated set of macroeconomic accounts in the context of a set of internationally agreed concepts, definitions, classifications and accounting rules (United Nations, 2008). According to the SNA, productive activities are classified into "industries", while produced goods and services are called "products".

Input–output, supply and use and social accounting matrix theory and analysis have evolved over time, drawing from the contributions of both the economics and national account literature. Various terminology and structures of IOT, SUT and SAMs can be found in the literature and often serve specific analytical purposes. For instance, due to a long-standing tradition, the economic literature has favoured the term "commodity" to indicate produced goods and services.

Productive activities need to be grouped into mutually exclusive and collectively exhaustive groups that can represent the entire productive structure without double-counting. The conventional economic breakdown between "agriculture", "industry" and "services" (also called primary, secondary and tertiary sectors) has a great pedagogical advantage. In the SNA the term "industries" indicates groups of production activities, such as agriculture, manufacture, construction and services.

In this module we try to balance accuracy with simplicity, using the more precise statistical terms when necessary and some proxy terminology when simplification is necessary to support intuition. The terms

[1] Institutional sectors include households, financial and non-financial corporations, the general government, non-profit institutions serving households (NPISH) and the rest of the world. NPISH are often added to the household sector.

[2] Supply and use tables are obtained by classifying enterprises or establishments into industries according to their main product, called "primary" product. Enterprises and establishments may also produce goods and services that are not characteristic of the industry they belong to. The supply and use framework can include such "secondary" production and represent more closely the actual production processes and product flows between industries.

"commodity" and "activity", which are more commonly used in the economics literature on SAMs, will be used as synonyms of "product" and "industry" when necessary. The SNA use of the term "industries" will be used in conjunction with the word "industry" to mean a specific group of production activity, when the context allows.

In the SNA value added is composed of "compensation of employees", "mixed income", "operating surplus" and "other taxes on production". Economists, in contrast, prefer to simplify these classes of payments into "wages" and "profits" in order to have a direct connection to the primary inputs such as labour and capital. In the following chapters some simplified tables will use the terms "wages" and "profits" instead of "compensation of employees" and "operating surplus", taking into consideration that compensation of employees includes also social security contribution and that mixed income should be split between their wage and profit components.

The general term "sector" is conveniently used in IO analysis, when no distinction is made between *product*s and *industries*. As will be explained in the following chapters, SUTs are constructed using a product-by-industry classification, and IOTs are obtained either as product-by-product or industry-by-industry matrices. As IO analysis applies to both product-by-product and industry-by-industry matrices, we will take advantage of the ambiguity of the term "sector" to represent both.

Such productive sectors should be distinguished from the "institutional sectors" of national accounts, which include households, the general government, non-profit institutions serving households (NPISH) and the rest of the world.

Finally, since this module relies extensively on matrix algebra, we adopt the following matrix notation: (i) Bold letters are used to denote matrices and vectors, while their elements are indicated in non-bold letters with subscripts. For example, a_i indicates the i^{th} element in a vector, whereas $a_{i,j}$ indicates the i^{th} row and j^{th} column element of a matrix. (ii) A vector with the hat sign denotes a diagonal matrix whose diagonal elements are those of the original vector. Therefore, if $\boldsymbol{x}$ is a vector of dimension *n*, $\widehat{\boldsymbol{x}}$ is a diagonal matrix of dimensions *n* times *n*. (iii) The bold letter $\boldsymbol{i}$ denotes a vector of ones called the "summation" vector. The sum of the elements of any vector can be obtained by multiplying the vector by $\boldsymbol{i}$. When $\boldsymbol{i}$ is pre-multiplied to a matrix, it sums up the rows of the matrix. When it is post-multiplied to a matrix, it sums up its columns.

Intended audience for this module

This module is intended for analysts seeking to explore foundations and extensions of IO analysis through supply-and-use-tables (SUTs) and social accounting matrices (SAMs), which allow the study of income distribution, inequality and induced effects (the employment and output effects of household spending). The reader will find familiarity with matrix algebra helpful.

Learning objectives

- understand supply and use tables derived from National Accounts as foundations for IO accounting;
- understand the concept, structure and uses of SUTs and SAMs, which provide a full description of the circular flow of the economy;
- understand the difference between open and closed IO models;
- know how IO analysis can be expanded to SAM to assess distributional and inequality aspects of economic development and alternative development scenarios;
- further analyse the potential changes in quantitative and qualitative aspects of employment, such as gender, income distribution and the mix of occupations.

Structure of this module

This module is organized as follows:

Chapter 2 reviews the main notions of *open and closed IO models*; the distinction between the two is key to understanding how SAM multipliers work as expansions of SUT and IO multipliers.

Chapter 3 introduces the supply and use framework. SUTs are the actual statistical source of both IOTs and SAMs. They represent the production of goods and services by industries and the demand for products by industries and institutional sectors such as households, government and the rest of the world.

Chapter 4 discusses how SAMs are generated from IOTs or SUTs and introduces SAM multiplier analysis.

Chapter 5 suggests how these statistical representations of economic and social systems can be used as databases for more complex models.

2. Open and closed input–output analysis

Key questions to answer

- What are the possible structures of an IOT?
- What does the matrix of coefficients $\boldsymbol{A}$ represent under alternative IOT structures?
- What is the difference between an open IO model and a closed IO model?
- What is a satellite account and how can be used for IO analysis?

Important observations

- Open IO analysis uses only inter-sectoral flow accounts in production to determine changes of output ($\boldsymbol{x}$) from changes in final demand ($\boldsymbol{f}$).
- Under the typical assumptions of IO analysis, output can increase if it can generate more wage income, which can be spent as consumption demand. The closed IO analysis adds income and demand effects to output determination by including more linkages between accounts.
- The IO model (either open or closed) can be applied to study various aspects of the economy, such as the gender and occupational compositions of the workforce and greenhouse gas emissions.

This chapter expands module 3, on input–output analysis, by introducing the concept of open and closed input–output systems. The principle of closing with respect to some additional accounts is key to SUT and SAM multiplier analysis and will be explained in detail in the following sections.

2.1 Input–output tables

The IOT is a compact matrix representation of the economy's monetary transactions between productive sectors. It captures the sectoral composition of the GDP components such as household expenditure, government expenditure, investment (or "gross capital formation"), exports and imports as well as the sectoral composition of taxes and value added components such as wages (or "compensation to employees") and profits (or "operating surplus").

Tables 2.1a and 2.1b illustrate the basic structure of a typical three-sector IOT in symbols, with different treatment of imports. In general, a complete IOT consists of four components: a matrix of inter-industry flows, a matrix of final demand components, a matrix of value added and taxes on products and a vector of imports.

1. **The inter-industry flow matrix.** This is a square matrix in the upper left corner of the IO table, with each element labelled z_{ij}. This is called the inter-industry (or inter-sectoral) flow matrix because z_{ij} is the value of sector *i*'s output that is sold to sector *j* as sector *j*'s intermediate consumption in order to produce its total outputs.
2. The **final demand matrix**, to the right, contains sectoral data on household consumption expenditure, vector C; investment, I; government consumption expenditure, G; and exports (or net exports), E.
3. The **value added and taxes matrix** consists of a value added matrix, W, that includes wages and profits in the first and second rows, respectively, and of **taxes on products** vector, $\boldsymbol{t}$, which is net of **subsidies.**

Table 2.1a A three-sector IO table in symbols with domestic-imported product distinction

		Sector			Final demand (f)				
		Agriculture	**Industry**	**Services**	**Household consumption**	**Investment**	**Government consumption**	**Exports**	**Total output**
Sector	Agric.	z_{11}	z_{12}	z_{13}	C_1	I_1	G_1	E_1	x_1
	Industry	z_{21}	z_{22}	z_{23}	C_2	I_2	G_2	E_2	x_2
	Services	z_{31}	z_{32}	z_{33}	C_3	I_3	G_3	E_3	x_3
Imports		m_1	m_2	m_3	m_c	m_i	m_g	m_e	M
Value added	Wages	w_{11}	w_{12}	w_{13}					
	Profits	w_{21}	w_{22}	w_{23}					
Net taxes on prod.		t_1	t_2	t_3					
Total output		x_1	x_2	x_3					

Table 2.1b A three-sector IO table in symbols with total demand for products and net exports

		Sector			Final demand (f)				
		Agriculture	**Industry**	**Services**	**Household consumption**	**Investment**	**Government consumption**	**Net-exports**	**Total output**
Sector	Agric.	z_{11}	z_{12}	z_{13}	C_1	I_1	G_1	E_1	x_1
	Industry	z_{21}	z_{22}	z_{23}	C_2	I_2	G_2	E_2	x_2
	Services	z_{31}	z_{32}	z_{33}	C_3	I_3	G_3	E_3	x_3
Value added	Wages	w_{11}	w_{12}	w_{13}					
	Profits	w_{21}	w_{22}	w_{23}					
Net taxes on prod.		t_1	t_2	t_3					
Total output		x_1	x_2	x_3					

4 **The import vector:** The inter-sectoral transaction matrix and the final demand vectors can be netted out of imported products used for intermediate or final consumption. In that case $\boldsymbol{Z}$, $\boldsymbol{C}$, $\boldsymbol{I}$, $\boldsymbol{G}$ and $\boldsymbol{E}$ consist of domestically produced goods and services, and their sum (by sector) is the sectoral output $\boldsymbol{x}$. A row vector of imports $\boldsymbol{m}$ represents the values of intermediate consumption of products by sector of destination and the imported components of final expenditure by category. Its sum is total imports M **(**Table 2.1.a).

5 **Alternative treatment of imports**: The inter-sectoral transaction matrix and the final demand vectors can include both domestically produced and imported goods and services. In that case $\boldsymbol{Z}$, $\boldsymbol{C}$, $\boldsymbol{I}$, $\boldsymbol{G}$ and $\boldsymbol{E}$ consist of any used goods and services and represent total demand by sector and kind of use. However, the imported component of demand needs to be netted out from uses to obtain the total demand of domestic output that corresponds to supply of domestic output $\boldsymbol{x}$. A column of imports with negative signs can be added to the final demand block, or imports can be directly subtracted from exports to obtain *net exports* $\boldsymbol{E}$, which is a vector of exports less total imports

(used for intermediate consumption, final consumption, investment and export) by product (Table 2.1b).

The accounting relationships between IO components give a total measure of *uses* of domestic production:

$$\begin{aligned} z_{11} + z_{12} + z_{13} + f_1 &= x_1 \\ z_{21} + z_{22} + z_{23} + f_2 &= x_2 \\ z_{31} + z_{32} + z_{33} + f_3 &= x_3 \end{aligned} \qquad (1.a)$$

with:

$$\begin{aligned} f_1 &= C_1 + I_1 + G_1 + E_1 \\ f_2 &= C_2 + I_2 + G_2 + E_2 \\ f_3 &= C_3 + I_3 + G_3 + E_3 \end{aligned} \qquad (1.b)$$

System (1) states that the uses of each product equal total intermediate inputs plus final demand $\boldsymbol{f}$.

The value of the output *supplied* by domestic production units and imports is equal to:

$$\begin{aligned} x_1 &= z_{11} + z_{21} + z_{31} + w_{11} + w_{21} + t_1 + m_1 \\ x_2 &= z_{12} + z_{22} + z_{32} + w_{12} + w_{22} + t_2 + m_2 \\ x_3 &= z_{13} + z_{23} + z_{33} + w_{13} + w_{23} + t_3 + m_3 \end{aligned} \qquad (2)$$

where (2) follows the option of netting out imports from intermediate consumption $\boldsymbol{Z}$ and includes imported intermediates as a separate component.

The fundamental accounting identity between supply of output and uses of output in IOT implies that x_i in (1) are equal to those in (2) for each product.

Adding up the three-product sums in (1) and (2) yields another fundamental identity in national accounting, namely:

$$\sum_{i=1}^{3}(C_i + I_i + G_i + E_i - m_i) = GDP = \sum_{i=1}^{3}(w_{1i} + w_{2i} + t_i)$$

That is, the sum of final demands (net of total imports) is equal to the sum of incomes generated in production. The left-hand side is the *expenditure approach* and the right-hand side is the *income approach* to calculating the gross domestic product (GDP).

2.2 Input–output analysis: open system

The IOT shown in Table 2.1a can be represented in sub-matrices, as shown in Table 2.2: ***Z*** of inter-sectoral transactions, ***f*** of final demand, ***y*** of value added and ***x*** of total uses or supply. ***Z*** is a matrix of dimension (3 x 3), ***f*** and ***m*** are column vectors of dimension (3 x 1) (***m*** is a row vector), ***y*** is a matrix of dimension (2 x 3) (excluding taxes in this simplified case), and ***x*** is a row or column vector of dimension (1 x 3).

Table 2.2 IOT in matrix symbol notation

<table>
<tr><td></td><td>A</td><td>I</td><td>S</td><td>C</td><td>I</td><td>G</td><td>E</td><td>Use</td></tr>
<tr><td>A</td><td colspan="3" rowspan="3">$\boldsymbol{Z}$</td><td colspan="4" rowspan="3">$\boldsymbol{f}$</td><td rowspan="3">$\boldsymbol{x}$</td></tr>
<tr><td>I</td></tr>
<tr><td>S</td></tr>
<tr><td></td><td colspan="7">$\boldsymbol{m}$</td><td>M</td></tr>
<tr><td>Wage</td><td colspan="3" rowspan="2">$\boldsymbol{W}$</td><td colspan="5" rowspan="4"></td></tr>
<tr><td>Profit</td></tr>
<tr><td>Taxes</td><td colspan="3">$\boldsymbol{t}$</td></tr>
<tr><td>Supply</td><td colspan="3">$\boldsymbol{x}$</td></tr>
</table>

As discussed in the previous module, the first step toward an IO multiplier analysis is to determine the technical coefficient matrix $\boldsymbol{A}$. Let $a_{ij} = z_{ij}/ x_j$, which is the proportion of sector j's output value that goes to purchasing sector i's output as its intermediate input. Then, the technical matrix $\boldsymbol{A}$ for a three-sector IO is:

$$\boldsymbol{A} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} = \begin{pmatrix} \frac{z_{11}}{x_1} & \frac{z_{12}}{x_2} & \frac{z_{13}}{x_3} \\ \frac{z_{21}}{x_1} & \frac{z_{22}}{x_2} & \frac{z_{23}}{x_3} \\ \frac{z_{31}}{x_1} & \frac{z_{32}}{x_2} & \frac{z_{33}}{x_3} \end{pmatrix} \tag{3a}$$

or in matrix notation

$$\boldsymbol{A} = \boldsymbol{Z}\hat{\boldsymbol{x}}^{-1} \tag{3b}$$

That is, in matrix notation, $\boldsymbol{A}$ is obtained by post-multiplying the inter-industry transaction matrix $\boldsymbol{Z}$ by a diagonal matrix of inverses of the elements of $\boldsymbol{x}$. This is equivalent to dividing each column of $\boldsymbol{Z}$ by each element of $\boldsymbol{x}$.

The $\boldsymbol{A}$ matrix is called a *direct input requirement matrix* or *matrix of technical coefficients* because it specifies how much of each sector's outputs will be needed as inputs to produce a unit of each sector's output. It is called a technical matrix because it specifies the *technical requirement* of how much of each sector's outputs will be needed as inputs to produce each sector's output. Given definition (3), identity (1) can be expressed using the $\boldsymbol{A}$ matrix in matrix notation; that is:

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \cdot \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} + \begin{pmatrix} f_1 \\ f_2 \\ f_3 \end{pmatrix} \tag{4a}$$

or in matrix notation:

$$\boldsymbol{x} = \boldsymbol{A} \cdot \boldsymbol{x} + \boldsymbol{f} \tag{4b}$$

Assuming that the technical coefficient matrix $\boldsymbol{A}$ is given and does not change with the level of economic activity, it is possible to determine how much output has to be produced to support a given final demand. This is obtained by solving equation (5) for $\boldsymbol{x}$:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} \tag{5}$$

Equation (5) shows that pre-multiplying the "Leontief inverse" matrix $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ to the final demand vector $\boldsymbol{f}$ gives the vector of total output necessary to obtain the given final demand, once the intermediate consumption requirements are satisfied. An economic interpretation of this algebraic solution implies a causal relation between demand injections from $\boldsymbol{f}$ and gross output $\boldsymbol{x}$: The additional demand for final uses in $\boldsymbol{f}$ would stimulate the production of output through backward linkages. (The production of additional units of one product requires additional units of the same and other products as intermediate inputs, which ultimately requires additional production of all the products.) Such stimulus would increase total outputs to the point that final demand and inter-industry requirements are satisfied. In IO analysis $\boldsymbol{f}$ is treated as *exogenous*, as its value is given before solving the system. In contrast, $\boldsymbol{x}$ is treated as *endogenous*, as its value is determined by the system (i.e., it is part of the solution).

The two distinct treatments of imports presented in Table 2.1a and 2.1b have implications for the IO analysis, in particular for the size and interpretation of matrix $\boldsymbol{A}$ and the "Leontief inverse" matrix $(\boldsymbol{I} - \boldsymbol{A})^{-1}$, which represents the matrix of multipliers of final demand to total output.

This IO model uses only a limited number of accounts: namely, $\boldsymbol{Z}$, $\boldsymbol{f}$ and $\boldsymbol{x}$. The Leontief inverse is created by the production coefficients only ($\boldsymbol{A}$). Final uses (household consumption, government consumption, investment and exports) are aggregated into a vector of exogenous final demand, $\boldsymbol{f}$. Wages and profits $\boldsymbol{W}$ and imports $\boldsymbol{m}$ are not included in system (4).

> The main focus in **open IO analysis** is on the structure of the production system to determine the inter-sectoral requirements and impacts of a certain final demand.

This system is called **open IO analysis***,* as it includes the minimal number of accounts to obtain a solution for $\boldsymbol{x}$. It does not include any other accounts of the IOT. The multipliers obtained take into account only the inter-industry relationships of demand for intermediate inputs. The underlying assumption is that final consumption of households, government, investment (components of $\boldsymbol{f}$) and incomes (components of $\boldsymbol{W}$) are not affected by the working of the economic system. That is, increasing the demand for goods and services does not change any of the final demand components or the incomes of households via changes in the value added components ($\boldsymbol{f}$ is given, and $\boldsymbol{W}$ is excluded by the model). The main focus in open IO analysis is on the structure of the production system to determine the inter-sectoral requirements and impacts of a certain final demand.

Table 2.3 (next page) presents a numerical example that illustrates the method.

Table 2.3 A three-sector IO table, China, 2012

		Sectors			Final demand (*f*)				Total output
		Agriculture	**Industry**	**Services**	**Households consumption**	**Investment**	**Government consumption**	**Net exports**	
Sectors…………	Agriculture	123 205 603	472 227 907	57 064 125	205 860 844	73 149 506	6 076 074	7 816 221	**945 400 280**
	Industry	193 355 990	5 042 164 542	1 731 481 850	760 523 836	874 251 954		1 104 574 342	**9 706 352 515**
	Services	54 063 721	1 255 989 874	1 718 715 514	1 018 983 152	1 557 025 744	725 741 859	254 267 963	**6 584 787 826**
Value	Wages	529 963 186	751 413 303	1 359 964 724					
	Net profits		513 380 943	760 397 749					
	Depreciation	22 581 542	249 470 822	444 767 461					
Tax		(28 956 569)	383 157 476	381 861 346					
Imports		51 186 807	103 854 7922	130 535 058					
Total output		**945 400 280**	**9 706 352 515**	**6 584 787 826**					

Source : authors' calculation.

Table 2.3 is the numerical example of Table 2.2b. Notice that Table 2.3 also includes a row of depreciation, which was omitted in Tables 2.2a and 2.2b. Capital depreciation is netted out from profits to obtain net profits. It is then added as a separate row of the value added block to obtain gross value added.

The $\boldsymbol{A}$ matrix looks like this:

$$\boldsymbol{A} = \begin{pmatrix} 0.130 & 0.049 & 0.009 \\ 0.205 & 0.519 & 0.263 \\ 0.057 & 0.129 & 0.261 \end{pmatrix}$$

We already know that, with the given final demand vector $\boldsymbol{f}$, a vector of total outputs has to be produced to support it, as shown in equation (5).

Now, we might want to ask a different question: How would total outputs change in response to a change in final demand? For example, if China's industrial export demand were to increase by 10 per cent, how much more output will be produced? Let $\Delta\boldsymbol{f}$ be the net change in the final demand, which is 10 per cent of $\boldsymbol{E_2}$ in this case; the change in total output can be found by applying equation (5), that is:

$$\Delta\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\Delta\boldsymbol{f} \qquad (6)$$

Table 2.4 reports the results.

Table 2.4 Multiplier effects in an open IO model, China, 2012

	Agriculture (in million RMB)	**Industry (in million RMB)**	**Services (in million RMB)**
Output increase	2.061	31.582	6.407
Output increase in per cent	2.31%	3.64%	0.993%

It is clear from this result that, although there is a 10 per cent increase in export demand only in the industrial sector, the outputs of all sectors must increase to provide intermediate inputs for the manufacturing sector to meet the increase in its final demand. In other words, due to the inter-industrial linkages, one sector's increase in final demand will lead to output increases economy-wide, across all sectors.

Open IO analysis, focused solely on the effect of inter-industry demand for intermediate inputs, requires the minimum number of assumptions about other demand and supply components. (That is, the assumption of constant returns to scale and linearity of intermediate inputs demand are represented by constant inter-industry requirements expressed by the $\boldsymbol{A}$ matrix.) The multipliers obtained reflect both *direct* and *indirect effects* of final demand injections via successive rounds of demand for intermediate consumption.

In many cases, however, it is important to take into account *induced effects* of demand shocks via other demand or supply components that may affect the process of output and production expansion. This can be obtained by closing the system with respect to additional accounts.

2.3 Closed IO analysis and Type II multipliers

In the previous example total output increased because (1) there was higher final demand (exports), and (2) other sectors had to produce more outputs for use as intermediate inputs. This type of analysis is called **Type I multiplier analysis**. Under the typical assumptions of IO analysis (see Module 3), output can increase if it can generate more wage income, which can be spent as consumption demand. The way to incorporate this effect is to include "wages" and "household consumption" as an additional row and column in matrices $\boldsymbol{Z}$ and $\boldsymbol{A}$. This is *as if* "household consumption" were another productive sector of the economy like agriculture, industry and services. This new sector would generate the labour sold to each sector in exchange for wages, which are then spent on each sector for consumption. This extension of the IO system is a *closed IO* as it *includes* wages and household consumption. **Type II multipliers** can be obtained, which capture not only *direct* and *indirect,* but also *induced* effects of changes in final demand via changing wages and household consumption.

Table 2.5 Representation of an IO table in sub-matrix blocs, closed with respect to household consumption and wage income

<table>
<tr><th></th><th>A</th><th>I</th><th>S</th><th>C</th><th>I</th><th>G</th><th>E</th><th>Use</th></tr>
<tr><td>A</td><td colspan="4" rowspan="4">$\boldsymbol{Z}^*$</td><td colspan="3" rowspan="4">$\boldsymbol{f}^*$</td><td rowspan="4">$\boldsymbol{x}^*$</td></tr>
<tr><td>I</td></tr>
<tr><td>S</td></tr>
<tr><td>Wage</td></tr>
<tr><td>Profit</td><td colspan="4">$\boldsymbol{\pi}$</td><td colspan="3"></td><td></td></tr>
<tr><td></td><td colspan="8">$\boldsymbol{m}$</td></tr>
<tr><td>Taxes</td><td colspan="4">$\boldsymbol{t}$</td><td colspan="4" rowspan="2"></td></tr>
<tr><td>Supply</td><td colspan="4">$\boldsymbol{x}^*$</td></tr>
</table>

"Closing the model" with respect to households' consumption and incomes is the typical form of closed IO system. Table 2.5 shows this approach in matrix notation. Final consumption of households becomes an endogenous account in the sense that the *levels* of consumption are allowed to vary with output expansion. Similarly, some incomes received by households need to be endogenized, and they need to expand with the economy. (Note that in the IO model, the coefficients in $\boldsymbol{A}$ remain fixed, while intermediate consumption $\boldsymbol{Z}$ expands in proportion to gross output $\boldsymbol{x}$). In Table 2.5 we assume that only wage income changes with the level of production (i.e., through higher employment levels or more hours worked), while profits remain given (exogenous).

> In a closed IO model, final consumption of households becomes an endogenous account: Levels of consumption are allowed to vary with output expansion.

Household consumption and wages are appended to the matrix of inter-sectoral transactions $\boldsymbol{Z}$ as a new column and new row, respectively. The new matrix of transactions is called $\boldsymbol{Z}^*$, while the vector of exogenous final uses $\boldsymbol{f}^*$ includes the sum of the remaining expenditure groups (investment, government expenditure and exports) by product. The remaining components of value added, profits $\boldsymbol{\pi}$, are assumed exogenous and fixed. A matrix of coefficients $\boldsymbol{A}^*$ is obtained by dividing each element of the column of $\boldsymbol{Z}^*$ by the corresponding element in $\boldsymbol{x}^*$. Note that the elements of the household consumption vector are divided by total consumption, thus generating households' consumption shares by sector. Similarly, the elements in the wage component of $\boldsymbol{W}$ are divided by the corresponding output of the industry that generates them, representing the share of production costs (or supply) used for wages. Assuming a fixed proportion for $\boldsymbol{A}^*$ implies the assumption that consumption and wage shares are not changing with respect to the level and composition of economic activity (an additional assumption along with the assumption of a fixed technical coefficient of $\boldsymbol{A}$). Households are treated as a "sector" in the IO system that contributes to the multiplicative effect of exogenous shocks via fixed income and consumption patterns.

The analysis follows as in the case of the open IO system:

$$\boldsymbol{x}^* = \boldsymbol{Z}^* + \boldsymbol{f}^*$$
$$\boldsymbol{x}^* = \boldsymbol{A}^*\boldsymbol{x}^* + \boldsymbol{f}^*$$
$$\boldsymbol{x}^* = (\boldsymbol{I} - \boldsymbol{A}^*)^{-1}\boldsymbol{f}^* \qquad (7)$$

$$\Delta\boldsymbol{x}^* = (\boldsymbol{I} - \boldsymbol{A})^{-1}\Delta\boldsymbol{f}^* \qquad (8)$$

The elements of $(\boldsymbol{I} - \boldsymbol{A}^*)^{-1}$ represent multipliers that include the effect of rising incomes on consumption demand. Thus, the multiplier loop between intermediate consumption and production is extended by including income generation and expansion of final demand.

Table 2.6 illustrates the effects of a 10 per cent increase in export demand for industrial goods on total outputs based on Type II multipliers (along with Type I results). The Type II output increase is obtained by applying the new Leontief inverse $(\boldsymbol{I} - \boldsymbol{A}^*)^{-1}$ to the $\Delta\boldsymbol{f}^*$ change in final demands (8), while Type I multipliers are obtained as in the open IO model (6).

Table 2.6 Examples of Type I and Type II output effects, China, 2012

	Agriculture (in million RMB)	**Industry (in million RMB)**	**Services (in million RMB)**
Type I output increase	2.061	31.581	6.407
Type I output increase in per cent	2.30%	3.64%	0.993%
Type II output increase	4.681	50.364	17.977
Type II output increase in per cent	5.23%	5.81%	2.79%

As shown in Table 2.6, Type II multipliers result in much stronger output effects than Type I multipliers, due to the additional linkages generated by the inclusion of household consumption and their wages.

The concept of including additional components in the endogenous part of the system ("closing with respect to additional accounts") is the key mechanism of SAM multiplier analysis, which is discussed in chapter 5.

2.4 Applications of IO: employment, gender, occupation and emissions

Module 3 showed that introducing "environmental sectors" in the core structure of the IOT allows for studying the effects of policies and external shocks on those sectors, as well as the effects on the rest of the economy of policies targeting environmental sectors.

The IO model (either open or closed) can be easily applied to study various aspects of the economy, such as the gender and occupational compositions of employment and greenhouse gas emissions, by adding physical satellite accounts to the core IOT structure. The *satellite account* is not integrated into the transaction flows with the rest of the system, but rather it is merely linked to some IOT elements via some form of technical coefficient. These accounts normally express *physical* stocks or flows, such as emissions, capital and labour and its composition by characteristics of interest for the analysis.

The IO model first finds out the effects of change in final demand on sectoral output via Type I or II multipliers. Then, the final demand changes are linked to other satellite variables of interest.

Employment. The most common way of linking employment to the IO model is to obtain a diagonal matrix $\hat{\boldsymbol{e}}$, with $e_j = l_j / x_j$ being the labour output coefficient, and assuming that it is fixed over time. Thus, the change in total output can be translated into the change in employment by:

$$\Delta \boldsymbol{L} = \widehat{\boldsymbol{e}} \cdot \Delta \boldsymbol{x} \tag{9}$$

Let us go back to the example in which we estimated the effects of a 10 per cent increase in industrial exports on total outputs in China (Table 2.6). In the year 2012 employment in agriculture was 365,660,150; in industry, 294,559,566; and in services, 355,502,924. Hence, the employment coefficient matrix will be:

$$\hat{\boldsymbol{e}} = \begin{pmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{pmatrix} = \begin{pmatrix} \frac{l_1}{x_1} & 0 & 0 \\ 0 & \frac{l_2}{x_2} & 0 \\ 0 & 0 & \frac{l_3}{x_3} \end{pmatrix} = \begin{pmatrix} 0.409 & 0 & 0 \\ 0 & 0.0340 & 0 \\ 0 & 0 & 0.0551 \end{pmatrix}$$

To estimate the employment effect of a 10 per cent increase in manufacturing exports in China, we pre-multiply $\Delta \boldsymbol{x}$ by $\widehat{\boldsymbol{e}}$. Thus, we have:

$$\Delta \boldsymbol{L} = \begin{pmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{pmatrix} \cdot \begin{pmatrix} \Delta x_1 \\ \Delta x_2 \\ \Delta x_3 \end{pmatrix} = (8.43 \quad 10.73 \quad 3.53)$$

The multiplier analysis shows that a 10 per cent increase in export demand for manufacturing will result in employment increases of 8.43 million jobs in agriculture, 10.73 million jobs in manufacturing and 3.53 million jobs in services.

A less popular but more theoretically sound way of linking output change to employment is to rely on Okun's law $of\ l_i = \alpha_i + \beta_i\, x_i$, where α_i and β_i are Okun's intercept and coefficient, respectively, for sector *i*. In matrix form:

$$\Delta \boldsymbol{L} = \boldsymbol{\alpha} + \widehat{\boldsymbol{\beta}} \cdot \Delta \boldsymbol{x} \tag{10}$$

In equation (10) α is the vector of Okun's intercepts, and $\hat{\beta}$ is the diagonal matrix of Okun's slope coefficient. More often practitioners prefer to estimate employment effects using equation (9) for the sake of convenience, because it depends only on the availability of sectoral employment levels, whereas equation (10) requires econometric estimations of Okun's parameters at the sector level.

Gender. This framework can be extended to investigate the gender aspect of employment effects if sectoral gender composition is available. Let $\hat{\boldsymbol{G}}$ be a diagonal matrix of sectoral female (or male) to total employment ratios; $\Delta\boldsymbol{L}\cdot\hat{\boldsymbol{G}}$ would be the number of female (or male) workers affected by the employment change. Comparing the gender ratio of total employment change, that is, $(\boldsymbol{i}\ \cdot\Delta\boldsymbol{L}\cdot\hat{\boldsymbol{G}})$ / $(\boldsymbol{i}\ \cdot \Delta\boldsymbol{L}\cdot\ (\boldsymbol{I}-\hat{\boldsymbol{G}}))$, with the original total employment gender ratio, one will find whether the employment effects of final demand change are biased toward women or men. Again, the assumption behind this analysis is that gender compositions at the sector level are fixed over time.

Now, let us go back to the earlier example in which we estimated the employment effects of a 10 per cent increase in manufacturing exports on total outputs in China. Assume that the percentages of employment that are female are 45 per cent, 30 per cent and 60 per cent for the agriculture, manufacturing and services sectors, respectively. Matrix multiplication will then provide us with the numbers of jobs for females that will be generated in each sector:

$$\Delta\zeta=\begin{pmatrix}0.45 & 0 & 0\\ 0 & 0.30 & 0\\ 0 & 0 & 0.70\end{pmatrix}\cdot\begin{pmatrix}8.43\\ 10.73\\ 3.53\end{pmatrix}=(3.79\quad 3.22\quad 2.47)$$

Thus, the 10 per cent increase in manufacturing exports will generate 3.79, 3.22 and 2.47 million jobs for women in the agricultural, manufacturing and services sectors, respectively. Further, we can calculate the share of total employment generated that is female, that is, $\frac{3.79+3.22+2.47}{8.43+10.73+3.53}=0.418$, or 41.8 per cent. We can compare this value with the female share of total employment for the year 2007 in China, which was around 49.4 per cent. Thus, we can conclude that the employment effect of 10 per cent increase in manufacturing exports would favour men.

Occupations. Similarly, there can be an occupations-by-industry matrix $\boldsymbol{P}$ of dimensions $n\ \cdot\ k$, where *n* is the number of occupational categories and *k* is the number of sectors in the economy. Element p_{ij} is the proportion of sector i's employment that belongs to the jth occupation category. Hence, $\boldsymbol{P}$ is also called the *occupation composition coefficient matrix*. Assuming that this matrix does not change over time, $\boldsymbol{P}\ \cdot\ \Delta\hat{\boldsymbol{L}}$ (where $\Delta\hat{\boldsymbol{L}}$ is the diagonal matrix of calculated employment changes according to equation (9)) will result in a $n\cdot k$ matrix, each row indicating employment change across sectors and occupations.

Let us go back again to the example of a 10 per cent increase in industrial exports in China. Assume that we have occupational information about China's employment as described by matrix $\boldsymbol{P}$, below.

$$P=\begin{pmatrix}0.90 & 0.60 & 0.55\\ 0.05 & 0.10 & 0.35\\ 0.05 & 0.30 & 0.10\end{pmatrix}$$

Assume that for each sector there are three occupational categories, namely, workers, managers and accountants. The employment by sector (along columns) is split into occupation shares of each sector (along rows). For example, the first column indicates that for the agricultural sector in China, 90 per cent of those employed are workers, 5 per cent are managers, and 5 per cent are accountants. To assess the occupational effects of the 10 per cent increase in industrial exports, we post-multiply the $\boldsymbol{P}$ matrix by the diagonal matrix of the previously calculated employment changes, that is:

$$\boldsymbol{P} \cdot \Delta\hat{\boldsymbol{L}} = \begin{pmatrix} 0.90 & 0.60 & 0.55 \\ 0.05 & 0.10 & 0.35 \\ 0.05 & 0.30 & 0.10 \end{pmatrix} \cdot \begin{pmatrix} 8.43 & 0 & 0 \\ 0 & 10.73 & 0 \\ 0 & 0 & 3.53 \end{pmatrix} = \begin{pmatrix} 7.59 & 6.44 & 1.94 \\ 0.42 & 1.07 & 1.24 \\ 0.42 & 3.22 & 0.35 \end{pmatrix}$$

The resulting matrix, above, shows how employment generated by the 10 per cent increase in manufacturing exports will increase by sector (columns) and by occupation (rows). If we sum up the rows, we see that this increase in exports will create additional jobs for 15.97 million workers, 2.73 million managers and 3.99 million accountants.

Emissions. Finally, the IO framework can also be extended to estimate pollution impacts. Let $\boldsymbol{D^P}$ be a matrix of direct pollution impact coefficients in which each element d_{nk}^{P} is the amount of pollutant type n generated per dollar's worth of industry k's output. Then, $\boldsymbol{D^P}(\boldsymbol{I}-\boldsymbol{A})^{-1}\Delta\boldsymbol{f}$ is a matrix of pollution impacts generated by a change in final demand. For example, each industry produces two types of air pollutants – sulphur dioxide and hydrocarbons – and the $\boldsymbol{D^P}$ matrix looks like this:

$$\boldsymbol{D^P} = \begin{pmatrix} 0.5 & 0.7 & 0.2 \\ 0.3 & 1.5 & 0.8 \end{pmatrix}$$

The rows are the two pollution types, and the columns are the three sectors. Each element in this matrix indicates how much pollution (in 1,000s of kilos) will be produced for each million yuan's worth of output produced. To assess the pollution impact of a 10 per cent increase in manufacturing exports, we post-multiply $\boldsymbol{D^P}$ by a diagonal matrix of Δx_i (that is, $\boldsymbol{D^P}(\boldsymbol{I}-\boldsymbol{A})^{-1}\Delta\boldsymbol{f}$). Thus, we obtain:

$$\begin{pmatrix} 0.5 & 0.7 & 0.2 \\ 0.3 & 1.5 & 0.8 \end{pmatrix} \cdot \begin{pmatrix} 20.61 & 0 & 0 \\ 0 & 315.82 & 0 \\ 0 & 0 & 64.07 \end{pmatrix} = \begin{pmatrix} 10.31 & 221.07 & 12.81 \\ 6.18 & 473.73 & 51.26 \end{pmatrix}$$

The first row of the resulting matrix indicates how much additional sulphur dioxide will be generated in each sector due to the increase in export demand. Similarly, the second row is the resulting increase in hydrocarbons.

3. Supply and use tables

Key questions to answer

- What is the difference between a SUT and an IOT?
- What are the transformation methods to obtain an IOT from a SUT, and what are the underlying assumptions?
- What is the interpretation of the multiplier analysis when applied directly to the SUT?

Important observations

- SUTs can be used for multiplier analysis and as the basis of IOTs and social accounting matrices (SAMs).
- The SUT shows the fundamental identities of national accounting, namely, total supply of a product is equal to total use of that product, and the output of an industry is equal to its inputs. The SUT allows for secondary production of industries.
- Transformation methods from SUT to IOT have important implications for the interpretation of the multiplier analysis.

Supply and use tables (SUTs) represent the supply of goods and services by industries and the demand of products by industries and institutional sectors such as households, government and the rest of the world. A SUT can include secondary production by industry. It is, therefore, organized in a form of a supply table that shows the product composition of each industry's output and a use table that shows the product composition of each industry's inputs, as well as the use of the product for final consumption and exports.

An IOT represents both supply and uses in the same matrix. It is a transformation of a SUT that eliminates secondary production by making assumptions about the technology or sales structures of products or industries.

SUTs are compiled from the source data and are nowadays considered the best instrument for estimating national account aggregates. They represent accurately the flows of product demand and output by industry, and they allow for the fact that actual statistical units, such as enterprises or establishments, typically produce more than one product. For example, a unit that produces mostly agricultural products will be included in the agriculture sector, but it might also produce some manufactured products, such as processed food, or produce some construction works as well as provide restaurant and hotel services.

Supply and use tables are obtained by classifying enterprises or establishments into industries according to their *primary* product. Products not characteristic of that industry, which are produced by the same statistical unit, are considered *secondary* products. For example, if its primary product belongs to the agricultural sector, then the unit will be classified in agriculture. The size and number of secondary products will depend on the details of the product classification and the definition of the productive unit.

A more detailed product and industry classification and a breakdown of enterprises into establishments will in general reduce the incidence of secondary production. Nonetheless, secondary production cannot be fully eliminated through more fine-grained definitions of establishment and classifications of products and industries. Even if firms are broken down into production units that are as homogeneous as possible in terms of production, such as establishments or "kind of activity units" (KAUs), those units often are not able to identify how much of their intermediate consumption is required to produce their primary and their secondary products. Moreover, overhead costs at the establishment or KAU level may be due to the production of primary as well as secondary products, and imputation of costs can be impossible.

The SUTs explicitly account for the existence of secondary production and remain closer to the original data source by using a "product-by-industry" classification. In general, the product classification can be more detailed than the industry classification. In that case the supply and the intermediate consumption part of the use table are rectangular (more products than industries). SUTs are square when there is a one-to-one correspondence between product and industry classifications.

Each column of the use table represents the production requirements (the uses of inputs) of the entire industry (as the composition of the uses of inputs of its establishments or KAUs) even if those inputs are used for both primary and secondary production. Each column of the supply table represents the output of each industry broken down into different classes of products. In a square supply table, the diagonal elements represent the primary production of the corresponding industry, while off-diagonal elements indicate its secondary products.

SUTs are fundamental statistical and analytical tools. SUTs are the preferred statistical source of both IOTs and SAMs. They are transformed into IOTs by *assuming* a specific relationship between production and intermediate consumption. SUTs can be used directly for multiplier analysis, with the qualification discussed in this chapter. They also can be used directly as the basis of a SAM and, therefore, of SAM-based models, a topic discussed in Chapter 4.

3.1 The supply and use framework

Supply and use tables provide a detailed picture of the supply of goods and services by domestic production and imports and of the use of goods and services for intermediate consumption and final use (consumption, gross capital formation, exports). The use table also shows how industries generate the components of value added (compensation of employees, other net taxes on production, consumption of fixed capital, net operating surplus). Thus, supply and use tables give detailed information on production processes, inter-dependencies in production, use of goods and services and the generation of income by production. The balanced supply and use tables provide a coherent data structure, linking industries, products and institutional sectors. The following subsections introduce the basic structure of SUTs and their application for multiplier analysis similar to that of IO tables.

> Supply and use tables give detailed information on production processes, inter-dependencies in production, use of goods and services and the generation of income by production.

3.1.1 The supply table

A typical supply table has products on the rows and industries on the columns. Imports are added as an additional column, as they represent an additional source of goods and services (a sort of additional industry) (Table 3.1). [1]

[1] As indicated in the introduction "Industries" is the general SNA term to indicate groups of production activities. In this chapter and the following, we use a simplified classification of broad sectors of economic activity – "agriculture", "industry" and "services". "Industry" will include manufacturing, mining and construction activities.

Table 3.1 Supply table

Products \ Industries	Industries			Imports	Total
	Agriculture	Industry	Service activities		
Agricultural products Industrial products Services	Output by product and by industry			Imports by product	Total supply by product
Total	Total output by industry			Total imports	Total supply

Source: Eurostat, 2008.

Products are presented row-wise. Industrial products can be produced by any of a number of existing industries or else imported. The row sums give the total supply of each product, while the column sums give the total value of the output of each industry, that is, the sum of all products produced by each industry. For instance, in Table 3.2 the agricultural sector is producing agricultural products, industrial products and services with values of 270, 10 and 20, respectively, for a total output of 300. The total supply of agricultural products is given by the agricultural output of the domestic industries, 270, 30 and 50, and the agricultural imports, 20.

Table 3.2 Supply table: numerical example

Products \ Industries	Industries			Imports	Total
	Agricul-ture	Industry	Service activities		
Agricultural products	270	30	50	20	370
Industrial products	10	430	100	50	590
Services	20	40	550	30	640
Total	300	500	700	100	1 600

Source: Eurostat, 2008.

3.1.2 The use table

The structure of the use table is similar to that of an IOT. The fundamental difference is that the columns of the inter-industry transaction matrix represent the intermediate consumption of *industries*, such as agriculture, industry and services, whose units can produce more than one good or service using the inputs indicated along the rows (Table 3.3).

Table 3.3 Use table

Products \ Industries	Industries			Final uses			Total
	Agriculture	Industry	Service activities	Final consumption	Gross capital formation	Exports	
Agricultural products Industrial products Services	Intermediate consumption by product and by industry			Final uses by product and by category			Total use by product
Value added	Value added by component and by industry						Value added
Total	Total output by industry			Total final uses by category			

Source: Eurostat, 2008.

For instance, as the first column of Table 3.4 shows, the agricultural industry is using agricultural products, industrial products and services with values of 34, 106 and 70, respectively, to produce the agricultural, industrial and service products indicated in the supply table (Table 3.2, first column). Total demand of agricultural products is the sum of the demand of industries, 34, 59 and 143, as well as final uses, 81, 21 and 32.

Table 3.4 Use table: numerical example

Products \ Industries	Industries			Final uses			Total
	Agricul-ture	Industry	Service activities	Final consump-tion	Gross capital formation	Exports	
Agricultural products	34	59	143	81	21	32	370
Industrial products	106	119	77	123	103	62	590
Services	70	112	75	291	61	31	640
Value added	90	210	405				705
Total	300	500	700	495	185	125	

Source: Eurostat, 2008.

3.1.3 The SUT

The supply table and the use table are combined into a "supply and use framework" (Table 3.5), where products and industries are symmetrically ordered along columns and rows. The supply table, which has products as rows and industries and imports as columns, is transposed and constitutes the first block of the new table. The use table is added on the right and has a consistent order of product and industry groups. The supply and use framework is also called the supply and use table (SUT).

Table 3.5 The supply and use framework

		Products			Industries			Final uses			Total
		Agri-cultural products	Industrial products	Services	Agri-culture	Industry	Service activities	Final con-sumption	Gross capital formation	Exports	
Products	Agricultural products Industrial products Services				Intermediate consumption by product and by industry			Final uses by product and by category			Total use by product
Industries	Agriculture Industry Service activities	Output of industries by product									Total output by industry
Value added					Value added by component and by industry						Total value added
Imports		Total imports by product									Total imports
Total		Total supply by product			Total output by industry			Total final uses by category			

Source: Eurostat, 2008.

Table 3.6 The supply and use framework: numerical example

		Products			Industries			Final uses			Total
		Agri-cultural products	Industrial products	Services	Agricul-ture	Industry	Service activities	Final con-sumption	Gross capital formation	Exports	
Products	Agricultural products				34	59	143	81	21	32	370
	Industrial products				106	119	77	123	103	62	590
	Services				70	112	75	291	61	31	640
Industries	Agriculture	270	10	20							300
	Industry	30	430	40							500
	Service activities	50	100	550							700
Value added					90	210	405				705
Imports		20	50	30							100
Total		370	590	640	300	500	700	495	185	125	

Source: Eurostat, 2008.

The supply and use framework is generally formulated in terms of total supply and use of products (therefore, inclusive of imports) and total output and input by industry. The total value of imported goods by product is added to the total value of domestically produced goods and services (also by product) to obtain total supply. Similarly, uses by product include their imported component and sum up to total uses by products (irrespective of whether they are domestically produced or imported).

The SUT shows the fundamental identities of national accounting.

Therefore, the SUT also shows the fundamental identities of national accounting, namely, total supply of a product is equal to total use of that product (rows and columns 1–3), and the total output of an industry is equal to the value of total inputs plus the value added of the same industries (rows and columns 4–6), and can be used to estimate GDP (see Chapter 2).

3.2 Transformation of a SUT into an IOT: methods and interpretations

There are four basic transformation methods to convert a SUT into an IOT (see Eurostat, 2008 and United Nations, forthcoming). These methods are based on some key assumptions pertaining to either the technology used (for products or by industries) or sales structure (for products or by industries):

- **Product technology assumption** (Model A): Each product is produced in its own specific way, irrespective of the industry where it is produced.

  This generates a *product-by-product IOT*.
- **Industry technology assumption** (Model B): Each industry has its own specific way of production, irrespective of its product mix.

  This generates a *product-by-product IOT*.
- **Fixed industry sales structure assumption** (Model C): Each industry has its own specific sales structure, irrespective of its product mix.

  This generates an *industry-by-industry IOT*.
- **Fixed product sales structure assumption** (Model D): Each product has its own specific sales structure, irrespective of the industry where it is produced.

  This generates an *industry-by-industry IOT*.

While the intermediate consumption part of the use table and the supply table have a "product-by-industry" classification (by product on the rows and by industry on the columns), an IOT can be either product-by-product or industry-by-industry. The transformation from SUT to IOT requires an adjustment of the use table and a change in the composition of the columns (a reclassification of the industries) to obtain a product-by-product IOT or a change in the composition of its rows (a reclassification of the products) to obtain an industry-by-industry IOT.[1]

Note that, if there were no secondary production, the supply table would be diagonal, and there would be a one-to-one correspondence between industries and products. Moreover, the uses of products by industries would unequivocally represent the inputs into a production process (product-by-product) or the sales of one industry to another (industry-by-industry). There would not be any difference between a SUT and a product-by-product or an industry-by-industry IOT.

Assumptions on technology or sales structure are necessary to decompose the use table and reallocate the secondary products and their product requirements to primary production. This can be done either by rearranging the composition of the industries to obtain "product-adjusted industries" in the product-by-product IOT or by rearranging the composition of the products to obtain "industry-adjusted products" in the industry-by-industry IOT. All the information available in the use table and supply table is fully used, but it is not sufficient to identify the unknown parts of the IOT, and additional assumptions that correspond to the transformation methods are needed.

The "make matrix" is the transposed supply matrix and has industries on the rows and products (or "commodities") on the columns. Table 3.7 shows an example of a make matrix in symbols with two products and two industries. We define as "product output" *i* the value of the product *i* produced by all industries, and we define as "industry output" the value of all goods and services produced by industry *j*. For example, v_{12} is the value of product 2 made by industry 1. Therefore, the total output of product 1 is the sum of the production of that good or service by all industries, $v_{11} + v_{21} = q_1$, while the output of industry 1 is the sum of the output of that industry, $v_{11} + v_{12} = x_1$.

Table 3.7 The make matrix (transposed supply matrix) in symbols

	Product 1	**Product 2**	**Industry output**
Industry 1	v_{11}	v_{12}	x_1
Industry 2	v_{21}	v_{22}	x_2
Product output	q_1	q_2	

Dividing through each column of the make matrix $\boldsymbol{V}$ by product output $\boldsymbol{q}$, we obtain coefficient matrix $\boldsymbol{D}$, below:

$$\boldsymbol{D} = \begin{pmatrix} \frac{v_{11}}{q_1} & \frac{v_{12}}{q_2} \\ \frac{v_{21}}{q_1} & \frac{v_{22}}{q_2} \end{pmatrix} = \begin{pmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{pmatrix} \tag{11}$$

[1] The intermediate consumption part of an IOT is always square (same classification of product and industries), while the intermediate consumption part of a SUT can be rectangular (more products than industries). In the following we assume for simplicity that the SUT used to derive an IOT is square.

Matrix $\boldsymbol{D}$ is also called the "market share" matrix; it shows the contribution of each industry to the output of a product. The element d_{12}, for example, is the share of output value of product 2 that is produced by industry 1. The element d_{22} is the share of output value of product 2 that is produced by industry 2. They can be considered as weights indicating the relative contribution of each industry to the production of product 2; their sum is one.

Note that, in matrix notation $\boldsymbol{D}$ is obtained by post-multiplying the make matrix by a diagonal matrix of the inverse of the elements of $\boldsymbol{q}$, namely $\boldsymbol{D} = \boldsymbol{V}\widehat{\boldsymbol{q}}^{-1}$. This is equivalent to dividing each column of $\boldsymbol{V}$ by each element of $\boldsymbol{q}$.

The following accounting identity defines the relationship between $\boldsymbol{x}$ and $\boldsymbol{q}$:

$$\boldsymbol{Dq} = \boldsymbol{x} \qquad (12)$$

Equation (12) is simply restating that $v_{11} + v_{12} = x_1$ and $v_{21} + v_{22} = x_2$.

Dividing through each row of the supply matrix $\boldsymbol{V}$ by industry output $\boldsymbol{x}$, we obtain matrix $\boldsymbol{C}$, below

$$\boldsymbol{C} = \begin{pmatrix} \frac{v_{11}}{x_1} & \frac{v_{21}}{x_2} \\ \frac{v_{12}}{x_1} & \frac{v_{22}}{x_2} \end{pmatrix} = \begin{pmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{pmatrix} \qquad (13)$$

Matrix $\boldsymbol{C}$ is the "product mix" matrix. It shows the share of each product in the output of each industry. c_{12}, for example, is the share of industry 1's output value that consists of product 2. Thus, in matrix $\boldsymbol{C}$ the elements in each column give us the product composition of the output of each industry. They can be considered as weights of the relative importance of the two products in the production of the industry; their sum equals one.

In matrix notation $\boldsymbol{C}$ is obtained by post-multiplying the transposed make matrix by a diagonal matrix whose elements are the inverse of $\boldsymbol{x}$, namely $\boldsymbol{C} = \boldsymbol{V}'\widehat{\boldsymbol{x}}^{-1}$.

The following accounting identity must hold:

$$\mathbf{x}'\boldsymbol{C} = \boldsymbol{q} \qquad (14)$$

which restates that $v_{11} + v_{21} = q_1$ and $v_{12} + v_{22} = q_2$.

Table 3.8 shows a simplified use matrix in symbols.

Table 3.8 The use matrix in symbols

	Industry 1	**Industry 2**	**Final demand (*f*)**	**Commodity output**
Product 1	u_{11}	u_{12}	f_1	q_1
Product 2	u_{21}	u_{22}	f_2	q_2
Value added	w_1	w_2		
Industry output	x_1	x_2		

u_{12}, for example, is the value of product 1 that is used by industry 2. Dividing each column of the use matrix by total industry output $\boldsymbol{x}$, we obtain the coefficient matrix $\boldsymbol{B}$, as shown below:

$$\boldsymbol{B} = \begin{pmatrix} \frac{u_{11}}{x_1} & \frac{u_{12}}{x_2} \\ \frac{u_{21}}{x_1} & \frac{u_{22}}{x_2} \end{pmatrix} = \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \tag{15}$$

In matrix $\boldsymbol{B}$, b_{12} for example, is the value of product 1 used as input to industry 2 production, per unit of value of industry 2's output, x_2.

In matrix notation $\boldsymbol{B}$ is obtained by post-multiplying the intermediate consumption block of the use matrix $\boldsymbol{U}$ by a diagonal matrix with inverses of the elements of $\boldsymbol{x}$, namely $\boldsymbol{B} = \boldsymbol{U}\widehat{\boldsymbol{x}}^{-1}$, which is equivalent to multiplying each column of $\boldsymbol{U}$ by the inverse of each element of $\boldsymbol{x}$. The vector of product output $\boldsymbol{q}$ is identical to the sum of $\boldsymbol{Bx}$ (intermediate consumption by product) and $\boldsymbol{f}$ (final demand by product).

$$\boldsymbol{q} = \boldsymbol{Bx} + \boldsymbol{f} \tag{16}$$

Equation (16) is stating the well-known definition that total uses by product is equal to total production by product.

The $\boldsymbol{D}$ and $\boldsymbol{C}$ matrices are "transformation matrices" that can be combined with the use matrix to obtain the various components of the IOT. In the following we will show how the intermediate consumption block of the IOT can be obtained by combining the matrices $\boldsymbol{D}$, $\boldsymbol{C}$ and $\boldsymbol{B}$ and vectors $\boldsymbol{q}$ and $\boldsymbol{x}$. The value added and final consumption components of the IOT can be similarly derived for the product-by-product and industry-by-industry IOTs, respectively.[1]

Different algebraic combinations of these matrices correspond to different assumptions and methods for obtaining an IOT.

3.2.1 Product technology assumption

According to the *product technology assumption* (Model A): "Each product is produced in its own specific way, irrespective of the industry where it is produced." This method generates a product-by-product IOT whose columns represent specific production processes for each product.

The intermediate consumption block of the use table reports the uses of products by industries. Each industry can have more than a product output. A product-by-product IOT can be obtained by rearranging production processes (input composition) so that each process produces one and only one product. The *industry* classification needs to be *adjusted by product* to reflect the change in the composition of the input structure. This will affect the intermediate consumption, value added and indirect tax blocks of the IOT. In the following we will concentrate only on the intermediate consumption block of the SUT and IOT, as treatment of the other blocks is analogous.

Define $\boldsymbol{Z}_{PT}$ as the matrix of the intermediate consumption of the IOT to be derived under the assumption of product technology (subscript "PT"). This matrix has a product-by-product dimension and can be divided by the vector of product output $\boldsymbol{q}$.

The (unknown) matrix of intermediate consumption coefficients $\boldsymbol{A}_{PT}$ of the IOT is (by definition) equal to $\boldsymbol{Z}_{PT}$ post-multiplied by the diagonal matrix of the inverse of $\boldsymbol{q}$:

[1] We will limit this exposition to the derivation of the intermediate consumption part of the IOT and refer the reader to Eurostat (2008) or UN (forthcoming) for a description of the complete derivation of the IOT.

$$A_{PT} = Z_{PT}\hat{q}^{-1} \tag{17}$$

This matrix can be obtained by using the available "product mix" $\boldsymbol{C}$ and the matrix of intermediate consumption of the use matrix $\boldsymbol{B}$ according to the equation

$$\boldsymbol{B} = \boldsymbol{A}_{PT}\,\boldsymbol{C} \tag{18a}$$

Equation (18a) is stating that the matrix of intermediate consumption of the IOT under the assumption of product technology, $\boldsymbol{A}_{PT}$, should be *such that* its multiplication with the product mix matrix $\boldsymbol{C}$ results in the original intermediate consumption block of the use matrix $\boldsymbol{B}$.

Recalling an important interpretation of matrix multiplication, equation (18a) is stating that $\boldsymbol{B}$ is equal to a linear combination of each column *j* of $\boldsymbol{A}_{PT}$**,** using c_{ij} as weights. Denoting $\boldsymbol{a}_{PT}^{j}$ as the *j* column of matrix $\boldsymbol{A}_{PT}$ and considering two products only, (18a) can be rewritten as

$$\boldsymbol{B} = (\boldsymbol{a}_{PT}^{1}c_{11} + \boldsymbol{a}_{PT}^{2}c_{12}\,, \quad \boldsymbol{a}_{PT}^{1}c_{21} + \boldsymbol{a}_{PT}^{2}c_{22}\,) \tag{18b}$$

The vectors $\boldsymbol{a}_{PT}^{1}c_{i1} + \boldsymbol{a}_{PT}^{2}c_{i2}$ have "product dimension" and are as many as the number of industries.

For the two-product, two-industry case, we have

$$\boldsymbol{B} = \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} = \begin{pmatrix} a_{(PT)11}c_{11} + a_{(PT)12}c_{12} & a_{(PT)11}c_{21} + a_{(PT)12}c_{22} \\ a_{(PT)21}c_{11} + a_{(PT)22}c_{12} & a_{(PT)21}c_{21} + a_{(PT)22}c_{22} \end{pmatrix} \tag{18c}$$

The columns of $\boldsymbol{A}_{PT}$ represent the input structure *of each product* under the assumption that each product is produced in its own specific way irrespective of the industry of origin. As each industry may produce more than one product, the input structure *of the industry*, matrix $\boldsymbol{B}$, is a (linear) combination of the input structure *of each product* $\boldsymbol{a}_{PT}^{j}$ that represents the unique process to produce product *j*. The weights of this combination of processes are the shares of the products *i* in the output of industry *j*.

Industry 2, for instance, produces output 1 using the input structure $\boldsymbol{a}_{PT}^{1}$, and its production of 1 is a c_{21} share of its total production. The same industry uses the input structure $\boldsymbol{a}_{PT}^{2}$ for product 2, which is a c_{22} share of its total production. The sum of these components, $\boldsymbol{a}_{PT}^{1}c_{21} + \boldsymbol{a}_{PT}^{2}c_{22}$, is the vector of total product requirements of that industry and represents its uses of products for its intermediate consumption per unit of industry 2 output, x_2. This linear combination of production processes must be equal to the columns of matrix $\boldsymbol{B}$, which indicates the product inputs for each industry.

Working with matrices of coefficients allows for an easy interpretation of the transformation model. The matrix of the intermediate consumption of the IOT $\boldsymbol{Z}_{PT}$ can be directly derived from the available matrices $\boldsymbol{U}$ and $\boldsymbol{D}$ as

$$\boldsymbol{Z}_{PT} = \boldsymbol{U}\,\boldsymbol{D}'^{-1} \tag{19}$$

Post-multiplying (19) by $\hat{\boldsymbol{q}}^{-1}$ we can derive directly the IOT coefficient matrix $\boldsymbol{A}_{PT}$. Similarly, matrix $\boldsymbol{B}$ and the inverse of $\boldsymbol{C}$ can be directly used to obtain $\boldsymbol{A}_{PT}$**.**

$$\boldsymbol{A}_{PT} = \boldsymbol{U}\,\boldsymbol{D}'^{-1}\hat{\boldsymbol{q}}^{-1} = \boldsymbol{B}\,\boldsymbol{C}^{-1} \tag{20}$$

The inverses of $\boldsymbol{D}'$ and $\boldsymbol{C}$ can have negative elements and, therefore, $\boldsymbol{A}_{PT}$ can have negative inputs in the process of production of products. The "problem of negatives" in the transformation of a SUT into an IOT using the product technology assumption has been widely discussed in the literature and features importantly into the disadvantages of this method.

The product-by-product IOT based on the product technology assumption has, nonetheless, the important conceptual advantage of bringing the underlying productive structure of the IOT closer to traditional economic theory. This makes it one of the preferred IOTs for multiplier analysis and modelling.

3.2.2 Industry technology assumption

According to the *industry technology assumption* (Model B): "Each industry has its own specific way of production, irrespective of its product mix". This method generates a product-by-product IOT whose columns represent a combination of the production processes of each industry.

Define $\boldsymbol{Z}_{IT}$ as the matrix of the intermediate consumption of the IOT to be derived under the assumption of industry technology (subscript "IT"). This matrix has a product-by-product dimension and can be divided by the vector of product output $\boldsymbol{q}$.

Post-multiplying this matrix by the diagonal matrix of the inverse of $\boldsymbol{q}$**,** we obtain the matrix of intermediate consumption coefficients $\boldsymbol{A}_{PT}$ of the IOT.

$$\boldsymbol{A}_{IT} = \boldsymbol{Z}_{IT}\widehat{\boldsymbol{q}}^{-1} \qquad (21)$$

This matrix can be obtained using the available matrices of "market shares" $\boldsymbol{D}$ and the matrix of intermediate consumption of the use matrix $\boldsymbol{B}$ according to the equation

$$\boldsymbol{A}_{IT} = \boldsymbol{B}\ \boldsymbol{D} \qquad (22a)$$

Equation (22a) states that the matrix of intermediate consumption of the IOT under the assumption of industry technology $\boldsymbol{A}_{IT}$ is a linear combination of the intermediate consumption structure of industries (the columns in matrix $\boldsymbol{B}$), using the market shares of industries as weights. Denoting $\boldsymbol{b}^j$ as the *j* column of matrix $\boldsymbol{B}$ and considering two products only, (22a) can be rewritten as

$$\boldsymbol{A}_{IT} = (\boldsymbol{b}^1 d_{11} + \boldsymbol{b}^2 d_{12}\,,\quad \boldsymbol{b}^1 d_{21} + \boldsymbol{b}^2 d_{22}\,) \qquad (22b)$$

The vectors $\boldsymbol{b}^1 d_{j1} + \boldsymbol{b}^2 d_{j2}$ have "product dimension" and are as many as the number of industries.

For the two-product, two-industry case, we have

$$\boldsymbol{A}_{IT} = \begin{pmatrix} a_{(IT)11} & a_{(IT)12} \\ a_{(IT)21} & a_{(IT)22} \end{pmatrix} = \begin{pmatrix} b_{11}d_{11} + b_{12}d_{21} & b_{11}d_{12} + b_{12}d_{22} \\ b_{21}d_{11} + b_{22}d_{21} & b_{21}d_{12} + b_{22}d_{22} \end{pmatrix} \qquad (22c)$$

The columns of $\boldsymbol{A}_{IT}$ represent the input structure of each product under the assumption that each industry produces in its own specific way irrespective of the product output. As each product is made by more than one industry, the matrix $\boldsymbol{A}_{IT}$ is a (linear) combination of the input requirements of the industry requirement vectors $\boldsymbol{b}^j$**,** which represent the processes of each industry to produce their set of products. The weights of this combination are the shares of the industry output *j* in the output of product *i*, that is, the market share of industry *j* for product *i*.

Industry 2, for instance, produces both products 1 and 2 using the input structure $\boldsymbol{b}^2$. Its production is a d_{21} share of total product 1 output. Product 1 is also produced by industry 1, with the input structure

$\boldsymbol{b}^1$, and it is a d_{11} share of total product 1 output. The weighed sum of these components, $\boldsymbol{b}_{IT}^1 d_{11} + \boldsymbol{b}_{IT}^2 d_{21}$, is the vector of total product requirements for the production of product 1, in the whole economy, per unit of product 1 output, q_1.

The matrix of intermediate consumption of the IOT $\boldsymbol{Z}_{IT}$ can be directly derived from the available matrices $\boldsymbol{U}$ and $\boldsymbol{C}$ as

$$\boldsymbol{Z}_{IT} = \boldsymbol{U}\,\boldsymbol{C}' \qquad (23)$$

Post-multiplying (23) by $\widehat{\boldsymbol{q}}^{-1}$, we can derive directly the IOT coefficient matrix $\boldsymbol{A}_{PT}$ as follows:

$$\boldsymbol{A}_{IT} = \boldsymbol{U}\,\boldsymbol{C}'\widehat{\boldsymbol{q}}^{-1} = \boldsymbol{U}\widehat{\boldsymbol{x}}^{-1}\,\boldsymbol{V}\widehat{\boldsymbol{q}}^{-1} = \boldsymbol{B}\,\boldsymbol{D} \qquad (22d)$$

3.2.3 Fixed industry sales structure assumption

An industry-by-industry IOT requires a transformation of the rows of the SUT, which are classified by product. According to the fixed industry sales structure assumption (Model C): "Each industry has its own specific sales structure, irrespective of its product mix."

Define $\boldsymbol{Z}_{IS}$ as the matrix of the intermediate consumption of the IOT to be derived under the assumption of fixed industry sales structure (subscript "IS"). This matrix has an industry-by-industry dimension so that each row and column can be divided by the vector of industry output $\boldsymbol{x}$.

Post-multiplying this matrix by the diagonal matrix of the inverse of $\boldsymbol{x}$**,** we obtain the matrix of intermediate consumption coefficients $\boldsymbol{A}_{IS}$ of the IOT.

$$\boldsymbol{A}_{IS} = \boldsymbol{Z}_{IS}\widehat{\boldsymbol{x}}^{-1} \qquad (24)$$

$\boldsymbol{Z}_{IS}$ is obtained using the available product mix matrix $\boldsymbol{C}$ and the matrix of intermediate consumption of the use matrix $\boldsymbol{U}$:

$$\boldsymbol{U} = \boldsymbol{C}\,\boldsymbol{Z}_{IS} \qquad (25a)$$

The interpretation of (25) is made clearer by pre-multiplying both sides of (25) by $\widehat{\boldsymbol{q}}^{-1}$. Pre-multiplication of the diagonal matrix $\widehat{\boldsymbol{q}}^{-1}$ to a $\boldsymbol{U}$ is equivalent to dividing each row of $\boldsymbol{U}$ by each element of $\boldsymbol{q}$. The rows of the resulting matrix $(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U})$ indicate the fraction of product *i* that is sold to various industries.

Recalling that $\boldsymbol{C} = \boldsymbol{V}'\widehat{\boldsymbol{x}}^{-1}$ and rearranging:

$$(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U}) = (\widehat{\boldsymbol{q}}^{-1}\boldsymbol{V})\,(\widehat{\boldsymbol{x}}^{-1}\boldsymbol{Z}_{IS}) = \begin{pmatrix} \frac{v_{11}}{q_1} & \frac{v_{21}}{q_1} \\ \frac{v_{12}}{q_2} & \frac{v_{22}}{q_2} \end{pmatrix} \begin{pmatrix} \frac{z_{(IS)11}}{x_1} & \frac{z_{(IS)12}}{x_1} \\ \frac{z_{(IS)21}}{x_2} & \frac{z_{(IS)22}}{x_2} \end{pmatrix} \qquad (26a)$$

$(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U})$ is composed of two row vectors: $\boldsymbol{u}_{\boldsymbol{q1}}^{\boldsymbol{1}} = \left(\frac{u_{11}}{q_1}\ ,\frac{u_{12}}{q_1}\right)$ and $\boldsymbol{u}_{\boldsymbol{q2}}^{\boldsymbol{2}} = \left(\frac{u_{21}}{q_2}\ ,\frac{u_{22}}{q_2}\right)$**,** which are the vectors of products *i* delivered to industries *i* and *j* as a share of product *i* output.

$(\widehat{\boldsymbol{x}}^{-1}\boldsymbol{Z}_{IS})$ is composed of two row vectors: $\boldsymbol{z}_{(\boldsymbol{IS})\boldsymbol{x1}}^{\boldsymbol{1}} = \left(\frac{z_{(IS)11}}{x_1}\ ,\frac{z_{(IS)12}}{x_1}\right)$ and $\boldsymbol{z}_{(\boldsymbol{IS})\boldsymbol{x2}}^{\boldsymbol{2}} = \left(\frac{z_{(IS)21}}{x_2}\ ,\frac{z_{(IS)22}}{x_2}\right)$**,** which are the unknown vectors of industry output *i* delivered to industries *i* and *j* as a share of industry *i* output.

Equation (26a) is stating that each row of $(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U})$ is equal to a linear combination of each row *i* of $(\widehat{\boldsymbol{x}}^{-1}\boldsymbol{Z}_{IS})$, using $\frac{v_{ij}}{q_i}$ as weights.

$$(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U}) = \begin{pmatrix} \boldsymbol{z}^{\boldsymbol{1}}_{(\boldsymbol{IS})\boldsymbol{x1}}\frac{v_{11}}{q_1} + \boldsymbol{z}^{\boldsymbol{2}}_{(\boldsymbol{IS})\boldsymbol{x2}}\frac{v_{21}}{q_1} \\ \boldsymbol{z}^{\boldsymbol{1}}_{(\boldsymbol{IS})\boldsymbol{x1}}\frac{v_{12}}{q_2} + \boldsymbol{z}^{\boldsymbol{2}}_{(\boldsymbol{IS})\boldsymbol{x2}}\frac{v_{22}}{q_2} \end{pmatrix} \tag{26b}$$

In practice $\boldsymbol{Z}_{IS}$ can be obtained by rearranging (25a):

$$\boldsymbol{Z}_{IS} = \boldsymbol{C}^{-1}\boldsymbol{U} \tag{25b}$$

and it can include negative elements. This transformation is not recommended due to this possibility and the weak plausibility of the underlying assumptions.

3.2.4 Fixed product sales structure assumption

According to the fixed product sales structure assumption (Model D): “Each product has its own specific sales structure, irrespective of the industry where it is produced.” This generates an *industry-by-industry IOT* whose rows *i* are a linear combination of the fixed sales structure of the products used by industries *j*. The structure of the sales of products to the various industries is weighted by the contribution of each industry to the production of the goods and services used by the industries as inputs.

Define $\boldsymbol{Z}_{PS}$ as the matrix of the intermediate consumption of the IOT to be derived under the assumption of fixed product sales structure (subscript “PS”). This matrix has an industry-by-industry dimension, and both rows and columns can be divided by the vector of industry output $\boldsymbol{x}$.

Post-multiplying this matrix by the diagonal matrix of the inverse of $\boldsymbol{x}$**,** we obtain the matrix of intermediate consumption coefficients $\boldsymbol{A}_{PS}$ of the IOT.

$$\boldsymbol{A}_{PS} = \boldsymbol{Z}_{PS}\widehat{\boldsymbol{x}}^{-1} \tag{27}$$

$\boldsymbol{Z}_{PS}$ is obtained as the product of the market share matrix $\boldsymbol{D}$ and $\boldsymbol{U}$**:**

$$\boldsymbol{Z}_{PS} = \boldsymbol{D}\,\boldsymbol{U} \tag{28}$$

Pre-multiplying $\boldsymbol{Z}_{PS}$ by $\widehat{\boldsymbol{x}}^{-1}$ is equivalent to dividing each row of the matrix by the elements of $\boldsymbol{x}$ and, therefore, obtaining a matrix whose rows *i* are the sales of industry *i* to other industries per unit of industry *i* output. Recalling that $= \boldsymbol{V}\widehat{\boldsymbol{q}}^{-1}$, (28) can be rewritten as:

$$\widehat{\boldsymbol{x}}^{-1}\boldsymbol{Z}_{PS} = (\widehat{\boldsymbol{x}}^{-1}\boldsymbol{V})(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U}) = \begin{pmatrix} \frac{v_{11}}{x_1} & \frac{v_{12}}{x_1} \\ \frac{v_{21}}{x_2} & \frac{v_{22}}{x_2} \end{pmatrix} \begin{pmatrix} \frac{u_{11}}{q_1} & \frac{u_{12}}{q_1} \\ \frac{u_{21}}{q_2} & \frac{u_{22}}{q_2} \end{pmatrix} \tag{29a}$$

Each row of $(\widehat{\boldsymbol{x}}^{-1}\boldsymbol{V})$ represents the product composition of industry *i* output (product outputs per unit of industry *i* output). The factor $(\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U})$ is composed of two row vectors: $\boldsymbol{u}^{\boldsymbol{1}}_{\boldsymbol{q1}} = \left(\frac{u_{11}}{q_1}\ ,\frac{u_{12}}{q_1}\right)$ and $\boldsymbol{u}^{\boldsymbol{2}}_{\boldsymbol{q2}} = \left(\frac{u_{21}}{q_2}\ ,\frac{u_{22}}{q_2}\right)$**,** which are the vectors of products *i* delivered to industries *i* and *j* as share of product *i* output. Equation (ps2) can be interpreted as a linear combination of the rows of $\widehat{\boldsymbol{q}}^{-1}\boldsymbol{U}$, with weights corresponding to the rows of $\widehat{\boldsymbol{x}}^{-1}\boldsymbol{V}$:

$$\hat{\boldsymbol{x}}^{-1}\boldsymbol{Z}_{PS} = \begin{pmatrix} \boldsymbol{u}_{\boldsymbol{q1}}^{\boldsymbol{1}} \frac{v_{11}}{x_1} + \boldsymbol{u}_{\boldsymbol{q2}}^{\boldsymbol{2}} \frac{v_{12}}{x_1} \\ \boldsymbol{u}_{\boldsymbol{q1}}^{\boldsymbol{1}} \frac{v_{21}}{x_2} + \boldsymbol{u}_{\boldsymbol{q2}}^{\boldsymbol{2}} \frac{v_{22}}{x_2} \end{pmatrix} \tag{29b}$$

Each row of the resulting matrix is a linear combination of the sales structures $\boldsymbol{u}_{\boldsymbol{q1}}^{\boldsymbol{1}} = \left(\frac{u_{11}}{q_1}\ ,\frac{u_{12}}{q_1}\right)$ and $\boldsymbol{u}_{\boldsymbol{q2}}^{\boldsymbol{2}} = \left(\frac{u_{21}}{q_2}\ ,\frac{u_{22}}{q_2}\right)$ of products to be used as inputs by all industries, weighed by the share of each product in the total production of the industry corresponding to that row:

$$\left(\frac{z_{(PS)11}}{x_1}, \frac{z_{(PS)12}}{x_1}\right) = \boldsymbol{u}_{\boldsymbol{q1}}^{\boldsymbol{1}} \frac{v_{11}}{x_1} + \boldsymbol{u}_{\boldsymbol{q2}}^{\boldsymbol{2}} \frac{v_{12}}{x_1}$$
$$\left(\frac{z_{(PS)21}}{x_2}, \frac{z_{(PS)22}}{x_2}\right) = \boldsymbol{u}_{\boldsymbol{q1}}^{\boldsymbol{1}} \frac{v_{21}}{x_2} + \boldsymbol{u}_{\boldsymbol{q2}}^{\boldsymbol{2}} \frac{v_{22}}{x_2}$$

Combining (27) and (28), we obtain:

$$\boldsymbol{A}_{PS} = \boldsymbol{D}\, \boldsymbol{U}\, \hat{\boldsymbol{x}}^{-1} = \boldsymbol{D}\, \boldsymbol{B} \tag{30}$$

Negative elements, in the intermediate consumption part of the IOT, cannot emerge from such transformation. This advantage and the theoretical plausibility of having a fixed sales structure for *products* rather than industry (the pattern of sales depends on the nature of the product and not on who is producing it) makes this method one of the most appealing in general and the method preferred among the industry-by-industry IOTs.

3.3 SUT analysis

SUTs, like IOTs, can be used for multiplier analysis, but the interpretation of IOTs and SUT multipliers can be quite different.

3.3.1 Technical coefficient matrices using SUTs

The transformation methods discussed in the previous section generate IOTs with different technical coefficient matrices $\boldsymbol{A}_{PT}$, $\boldsymbol{A}_{IT}$, $\boldsymbol{A}_{IS}$ and $\boldsymbol{A}_{PS}$. These matrices are those actually used in the multiplier analysis presented in this module and in module 3, where a generic inter-sectoral coefficient matrix $\boldsymbol{A}$ was used to obtain sectoral gross output $\boldsymbol{x}$.

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{f} \tag{31}$$
$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f}$$

where $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the Leontief inverse matrix. Considering that in our current notation $\boldsymbol{x}$ indicates industry output and $\boldsymbol{q}$ is product output, we can obtain the gross product output as:

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A}_{PT})^{-1}\boldsymbol{f}$$

or

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A}_{IT})^{-1}\boldsymbol{f}$$

and the industry output as

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A}_{IS})^{-1}\boldsymbol{f}_{\boldsymbol{I}}$$

or

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A}_{PS})^{-1}\boldsymbol{f}_{\boldsymbol{I}}$$

depending on the kind of IOT used. Note that in the industry-by-industry case the vector of final expenditure, $\boldsymbol{f_I}$, needs to be adjusted to reflect the transformation of rows from products to industries.

3.3.2 Leontief inverse based on SUTs

If we try to apply IO analysis directly to the SUT, we have the problem that the use table has products on the row and industries in the columns. The SUT identity:

$$\boldsymbol{q} = \boldsymbol{Bx} + \boldsymbol{f} \tag{32}$$

cannot be used as the IOT to obtain

$$\boldsymbol{x} = \boldsymbol{Ax} + \boldsymbol{f}$$

and

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f}$$

However, if there were a transformation matrix, such as $\boldsymbol{T}$, that can transform x into q, or vice versa, then the IO model becomes applicable again. For example, if there exists a $\boldsymbol{T}$ such that $\boldsymbol{x} = \boldsymbol{Tq}$, then:

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{BT})^{-1}\boldsymbol{f} \tag{33}$$

It turns out that, if $\boldsymbol{T} = \boldsymbol{D}$, we have $\boldsymbol{x} = \boldsymbol{Dq}$, which corresponds to equation (12), and from (32) we obtain:

$$\boldsymbol{q} = (\boldsymbol{BD})\boldsymbol{q} + \boldsymbol{f}$$

and then

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{BD})^{-1}\boldsymbol{f} \tag{34}$$

which, recalling (22a), is equivalent to

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A}_{IT})^{-1}\boldsymbol{f}$$

This corresponds to the coefficient matrix of an IOT obtained with the *fixed industry technology* transformation method (Model B).

If we pre-multiply (31) by $\boldsymbol{D}$**,** we obtain an expression for the industry output $\boldsymbol{x}$

$$\boldsymbol{x} = (\boldsymbol{DB})\boldsymbol{x} + \boldsymbol{Df}$$

and then

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{DB})^{-1}\boldsymbol{Df} \tag{35}$$

which, recalling (30), is equivalent to:

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A}_{PS})^{-1}\boldsymbol{Df}$$

This corresponds to using the coefficient matrix from an IOT obtained with the *fixed product sales structure* transformation method (Model D).

These derivations are of particular interest if we intend to use the SUT as a direct source of multipliers for industry output $\boldsymbol{x}$ and product output $\boldsymbol{q}$.

As indicated in equations (16) and (12), the SUT identities can be written as:

$$\boldsymbol{B} \cdot \boldsymbol{x} + \boldsymbol{f} = \boldsymbol{q}$$
$$\boldsymbol{D} \cdot \boldsymbol{q} = \boldsymbol{x}$$

These can be written in matrix form as:

$$\begin{pmatrix} \boldsymbol{0} & \boldsymbol{B} \\ \boldsymbol{D} & \boldsymbol{0} \end{pmatrix} \cdot \begin{pmatrix} \boldsymbol{q} \\ \boldsymbol{x} \end{pmatrix} + \begin{pmatrix} \boldsymbol{f} \\ \boldsymbol{0} \end{pmatrix} = \begin{pmatrix} \boldsymbol{q} \\ \boldsymbol{x} \end{pmatrix} \tag{36}$$

and can be redefined as:

$$\boldsymbol{S} \cdot \bar{\boldsymbol{x}} + \bar{\boldsymbol{f}} = \bar{\boldsymbol{x}} \tag{37}$$

where:

$\boldsymbol{S} = \begin{pmatrix} \boldsymbol{0} & \boldsymbol{B} \\ \boldsymbol{D} & \boldsymbol{0} \end{pmatrix}$, $\bar{\boldsymbol{x}} = \begin{pmatrix} \boldsymbol{q} \\ \boldsymbol{x} \end{pmatrix}$ and $\bar{\boldsymbol{f}} = \begin{pmatrix} \boldsymbol{f} \\ \boldsymbol{0} \end{pmatrix}$.

Recalling the derivation of input–output multipliers from equations (5) and (6),

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{f}$$
$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f}$$

we can derive the SUT multipliers as follows:

$$\bar{\boldsymbol{x}} = (\boldsymbol{I} - \boldsymbol{S})^{-1}\bar{\boldsymbol{f}} \tag{38}$$

We note that the Leontief inverse $(\boldsymbol{I} - \boldsymbol{S})^{-1}$ must be a composition of matrix multiplication of $\boldsymbol{D}$ and $\boldsymbol{B}$. It can be shown that (38) results in a system with (34) and (35). That is, obtaining the multipliers from (38) is equivalent to obtaining the product output $\boldsymbol{q}$ through, and the IOT obtained with, the *fixed industry technology* transformation method (Model B) and the industry output $\boldsymbol{x}$ through, and the IOT obtained with, the *fixed product sales structure* transformation method (Model D).

This result is key to interpreting the multipliers of the SAM whenever a SAM is obtained directly from a SUT.

4. The social accounting matrix (SAM) and multiplier analysis

Key questions to answer

- What is the difference between a NAM and a SAM? What is their relation to the SUT and the IOT?
- In SAM analysis which accounts are considered endogenous (i.e., determined inside the model)?

Important observations

- SAM accounting emphasizes the generation, distribution and uses of income for institutional sectors.
- SAM multipliers help to assess the effect of changes in final demand on product output, industry outputs, factor incomes and household incomes.
- SAM-based multiplier analysis includes the effects not only of inter-industry linkages in production and demand but also of factor and household incomes and consumption patterns.

A social accounting matrix (SAM) links together the macro-statistics of national accounts with the micro-statistics of labour market, household income and consumption and other social statistics (see European Commission, 2008). The SAM is an *expansion* of the IOT or SUT. It is a compact matrix representation of the economy's main national accounts and extends them with information from social and labour statistics.

The national account system includes "goods and services" and "production" accounts that can be represented in SUT and IOT form by classifying economic activity by industries and products. It also includes the transaction flows between economic actors, called institutional sectors, such as households, corporations and the government. It provides a representation in matrix form of the interlinked "generation of income", "allocation of primary income", "secondary distribution of income" and "use of income" accounts as well as a set of "accumulation accounts" of each institutional sector. These are connected to the "goods and services" and "production" accounts to trace the flows of income from production to its use and the accumulation of assets. The "rest of the world" is included to obtain a perfectly closed and balanced system.

A full representation of these sets of national accounts in matrix form is also called the national account matrix (NAM). The NAM can be built using some aggregations of the accounts mentioned above, when this is required by data constraints or the specificity of the analysis. The SAM provides additional information by adding social and labour statistics to the national accounts.

4.1 Data structure

The social accounting matrix (SAM) is an extension of the SUT or of the IOT that includes transactions between extended institutional sectors (i.e., households broken down into socioeconomic classes or firms split by size) and flows between different factors of production (remuneration of various forms of labour and operating surplus) and extended institutional sectors. As in the cases of the SUT and the IOT, each row and corresponding column represent an account. Rows represent "incomings", or "incomes", while columns represent "outgoings", or "outlays". The sum of the entries on each row (incomes) should equal the sum of the entries on the corresponding column (outlays). The SAM is, therefore, naturally square, although other accounting conventions can be used for a section representing the "accumulation accounts" of the economy. The selection of the accounts depends on the purpose of the SAM and the policy question to be addressed.

> The NAM is a matrix form representation of the national accounts. The SAM provides additional information by adding social and labour statistics to the national accounts.

Table 4.1 (page 193) shows a complete NAM of a demonstrative economy. The accounts "1. Goods and services" and "2. Production" are the known *product* and *industry* accounts of the SUT. Block (1,2) is the sub-matrix at the intersection of the rows of the "1. Goods and services" account and the columns "2. Production" accounts. Such a sub-matrix represents the use matrix of the SUT. (2,1) is the make matrix. (1,6) is the final consumption expenditures of the three institutional sectors. (1,7) are inventories accumulations, while (1,8) is gross fixed capital formation. Summed together, they represent the gross capital formation or investment of the IOT and SUT. (1,10) is the demand for products by the rest of the world (exports), while (10,1) is the supply of products from the rest of the world (imports). (3,2) is the value added matrix, while (4,1) includes taxes on products. These matrices are the blocks of the SUT and (partly) of the IOT.

Table 4.1 shows how the NAM expands the SUT system to include "3. Generation of income", "4. Allocation of primary income", "5. Secondary distribution of income", "6. Use of income" and other accumulation accounts that show the flows of funds between sectors and their accumulation into capital goods and financial assets. This full system shows transactions between sectors at different stages of the income flow and provides a wealth of information for understanding and modelling the economy.

As the objective of this chapter is to introduce the basic concepts of the SAM and its use for multiplier analysis, we will limit the focus to accounts 1 through 3 and add to the SAM multipliers some aggregation of the other accounts to include consumption and distribution effects. We refer the reader to European Commission (2008) or United Nations (forthcoming) for a full presentation of the other accounts of the NAM and SAM.

Table 4.2 (page 194) shows a NAM where accounts 4 through 6 are aggregated by institutional sector, accounts 7 and 8 have no detailed breakdown, and value added is split into wages, profits and taxes on production.[1] It contains only information from national accounts that can be expanded by including social and labour market information to obtain a SAM.

Table 4.3 (page 195) shows an illustrative breakdown of wages into high- and low-skilled classes and of the household income and consumption by quintile. The disaggregation of labour remuneration into two kinds of labour groups expands the value added sub-matrix (3,2). This is the value added that is generated in production activities that is distributed to factors of production. Account 3 now has four classes of remuneration, which are mapped into the institutional sectors in sub-matrix (4,3). This shows how the different groups of households receive the payments for their labour. High- and low-skills wage incomes are allocated to households by income quintile, while profits are transferred to corporations and taxes to the government. The (1,4) block shows the consumption pattern of households by income class. Socioeconomic groups are expected to have differentiated consumption and saving behaviours, as

1 In this section we will use the national account breakdown of value added into "compensation of employees", "operating surplus", "mixed income" and "other taxes on production" for the full NAM. The simplified and aggregated NAM as well as the SAM regroup these classes into "wages" and "profits" by splitting "mixed income" of non-corporations into wage and profit components.

represented in (1,4) and (5,4), respectively. The (4,4) block shows transactions between different institutional sectors in the form of profit redistribution, social transfers and income taxes.

A SAM includes extended institutional sectors' transactions, showing flows of income for selected socioeconomic groups.

In general, the distinguishing feature of the SAM is the inclusion of extended institutional sectors' transactions to represent the flows of generation, distribution and use of income of selected socioeconomic groups. The value added components are typically grouped as payments to homogeneous classes of production factors such as "skilled labour" and "unskilled labour", "self-employed" and "wage workers" or to occupational groups. As in any partition, classes must be mutually exclusive and collectively exhaustive. Similarly, households need to be classified in groups that characterize the totality of this sector. In this example the SAM includes a disaggregation by income percentile. Other common classifications are between rural and urban households or by the main source of income of the head of household.

Table 4.1 A complete national account matrix

			1. Good and services			2. Production			3. Generation of income				4. Allocation of primary income			5. Secondary distribution of income			6. Use of disposable income			7. Capital			8. Gross fixed capital formation			9. Finance			10. Rest of the world current	11. Rest of the world capital	Total receipts
			Agriculture	Industry	Services	Agriculture	Industry	Services	Compensation of employees	Gross mixed income	Gross operating surplus	Other net taxes on production	Households	Corporations	Government	Households	Corporations	Government	Households	Corporations	Government	Households	Corporations	Government	Agriculture	Industry	Services	Currency and deposits	Loans	Other financial assets			
			1.a	1.b	1.c	2.a	2.b	2.c	3.a	3.b	3.c	3.d	4.a	4.b	4.c	5.a	5.b	5.c	6.a	6.b	6.c	7.a	7.b	7.c	8.a	8.b	8.c	9.a	9.b	9.c	10	11	12
1. Good and Services	Agriculture	1.a				17	78	4											10												57		166
	Industry	1.b				25	302	127											184				12		28	67	81				351		1,177
	Services	1.c				24	111	286											402		198				2	14	15				82		1,134
2. Production	Agriculture	2.a	134	10	1																												145
	Industry	2.b	3	728	25																												756
	Services	2.c	2	31	1,030																												1,063
3. Generation of income	Compensation of employees	3.a				17	139	389																									545
	Gross mixed income	3.b				3	6	57																									66
	Gross operating surplus	3.c				60	112	164																									336
	Other net taxes on production	3.d				-1	8	36																									43
4. Allocation of primary income	Households	4.a							545	66	54			106	5																4		780
	Corporations	4.b									262		38	51	52																25		428
	Government	4.c	1	60	24						20	43		38	5																		191
5. Secondary distribution of income	Households	5.a											742				2	110													2		856
	Corporations	5.b												191																			191
	Government	5.c													115	201	47														4		367
6. Use of disposable income	Households	6.a														653																	653
	Corporations	6.b															142																142
	Government	6.c																254															254
7. Capital	Households	7.a																	57										40	2		-3	96
	Corporations	7.b																		142								16	22	272		1	453
	Government	7.c																			56								-1				55
8. Gross fixed capital formation	Agriculture	8.a																				10	20										30
	Industry	8.b																					81										81
	Services	8.c																				47	25	24									96
9. Finance	Currency and deposits	9.a																				19	-3	-9								9	16
	Loans	9.b																				-1	58	8								-4	61
	Other financial assets	9.c																				21	260	32								-39	274
10. Rest of the world current		10	26	348	54									42	14	2		3															489
11. Rest of the world capital		11																													-36		-36
Total expenditure		12	166	1,177	1,134	145	756	1,063	545	66	336	43	780	428	191	856	191	367	653	142	254	96	453	55	30	81	96	16	61	274	489	-36	

Source: United Nations, forthcoming

Table 4.2 An aggregated national account matrix

			1. Good and services			2. Production			3. Generation of income			4. Institutions			5. Capital	6. Gross fixed capital formation	7. Finance			8. Rest of the world current	9. Rest of the world capital	Total receipts
			Agriculture	Industry	Services	Agriculture	Industry	Services	Wages	Profits	Other net taxes on production	Households	Corporations	Government			Currency and deposits	Loans	Other financial assets			
			1.a	1.b	1.c	2.a	2.b	2.c	3.a	3.c	3.d	4.a	4.b	4.c	5	6	7.a	7.b	7.c	8	9	10
1. Good and Services	Agriculture	1.a				17	78	4				10								57		166
	Industry	1.b				25	302	127				184			12	176				351		1,177
	Services	1.c				24	111	286				402		198		31				82		1,134
2. Production	Agriculture	2.a	134	10	1																	145
	Industry	2.b	3	728	25																	756
	Services	2.c	2	31	1,030																	1,063
3. Generation of income	Wages	3.a				19	143	423														585
	Profits	3.c				61	114	187														362
	Other net taxes on production	3.d				-1	8	36														43
4. Institutions	Households	4.a							585	80		1,395	108	115						6		2,289
	Corporations	4.b								262		38	384	52						25		761
	Government	4.c	1	60	24					20	43	201	85	374						4		812
5. Capital		5										57	142	56			16	61	274		-2	604
6. Gross fixed capital formation		6													207							207
7. Finance	Currency and deposits	7.a													7						9	16
	Loans	7.b													65						-4	61
	Other financial assets	7.c													313						-39	274
8. Rest of the world current		8	26	348	54							2	42	17								489
9. Rest of the world capital		9																		-36		-36
Total expenditure		10	166	1,177	1,134	145	756	1,063	585	362	43	2,289	761	812	604	207	16	61	274	489	-36	

Source: Authors' calculation based on United Nations, forthcoming

Table 4.3 A social accounting matrix with household and labour breakdown

			1. Good and services			2. Production			3. Generation of income				4. Institutions							5. Capital	6. Gross fixed capital formation	7. Finance			8. Rest of the world current	9. Rest of the world capital	Total receipts
			Agriculture	Industry	Services	Agriculture	Industry	Services	Wages high-skilled	Wages low-skilled	Profits	Other net taxes on	Households 1st quintile	Households 2nd quintile	Households 3rd quintile	Households 4th quintile	Households 5th quintile	Corporations	Government			Currency and deposits	Loans	Other financial			
			1.a	1.b	1.c	2.a	2.b	2.c	3.a	3.b	3.c	3.d	4.a	4.b	4.c	4.d	4.e	4.f	4.g	5	6	7.a	7.b	7.c	8	9	10
1. Good and Services	Agriculture	1.a				17	78	4					4	3	2	2	1								57		166
	Industry	1.b				25	302	127					64	46	37	28	9			12	176				351		1,177
	Services	1.c				24	111	286					141	101	80	60	20		198		31				82		1,134
2. Production	Agriculture	2.a	134	10	1																						145
	Industry	2.b	3	728	25																						756
	Services	2.c	2	31	1,030																						1,063
3. Generation of income	Wages high-skilled	3.a				9	71	212																			292
	Wages low-sklled	3.b				9	71	212																			292
	Profits	3.c				61	114	187																			362
	Other net taxes on production	3.d				-1	8	36																			43
4. Institutions	Households 1st quintile	4.a							102	102	28							38	40						2		313
	Households 2nd quintile	4.b							73	73	20							27	29						2		224
	Households 3rd quintile	4.c							58	58	16							22	23						1		179
	Households 4th quintile	4.d							44	44	12							16	17						1		134
	Households 5th quintile	4.e							15	15	4							5	6						0		45
	Corporations	4.f									262		13	10	8	6	2	384	52						25		761
	Government	4.g	1	60	24						20	43	70	50	40	30	10	85	374						4		812
5. Capital		5											20	14	11	9	3	142	56			16	61	274		-2	604
6. Gross fixed capital formation		6																		207							207
7. Finance	Currency and deposits	7.a																		7						9	16
	Loans	7.b																		65						-4	61
	Other financial assets	7.c																		313						-39	274
8. Rest of the world current		8	26	348	54								1	1	0	0	0	42	17								489
9. Rest of the world capital		9																							-36		-36
Total expenditure		10	166	1,177	1,134	145	756	1,063	292	292	362	43	313	224	179	134	45	761	812	604	207	16	61	274	489	-36	

Source: Authors' calculation based on United Nations, forthcoming

4.2 SAM multipliers

A typical SAM structure can be illustrated in symbols as shown in Table 4.4.

Table 4.4 Social accounting matrix structure in symbols

	1. Good and services	2. Production	3. Generation of income	4.a House holds	4.b Other institutions	5. Capital	6. Gross fixed capital formation	7. Finance	8. RoW current	9. RoW capital	Total receipts
1. Good and Services		$\boldsymbol{B\hat{x}}$		$\boldsymbol{C\hat{y}}$			$\boldsymbol{f}$				$\boldsymbol{q}$
2. Production	$\boldsymbol{D\hat{q}}$										$\boldsymbol{x}$
3. Generation of income		$\boldsymbol{W\hat{x}}$									$\boldsymbol{v}$
4.a Households			$\boldsymbol{Y\hat{v}}$				$\boldsymbol{h}$				$\boldsymbol{y}$
4.b Other institutions	**Net taxes on products**		**Other income**	**Transfers**	**Transfers**				**Transfers**		
5. Capital				**Savings**	**Savings**			**Borrowing**		**Capital Transfers**	
6. Gross fixed capital formation						**Gross fixed capital formation**					
7. Finance						**Lending**				**Net lending to RoW**	
8. RoW current	**Imports of products**			**Transfers**	**Transfers**						
9. RoW Capital									**Current external balance**		
Total expenditure	$\boldsymbol{q'}$	$\boldsymbol{x'}$	$\boldsymbol{v'}$	$\boldsymbol{y'}$							

Let us start with the thick-boxed sub-matrix in the upper-left corner. The first three rows and two columns correspond to the SUT, with $\boldsymbol{q}$ being the product output (a vector of total output of a given product), $\boldsymbol{x}$ being the industry output (a vector of total output of a given industry), $\boldsymbol{v}$ being the total income generated by production, and $\boldsymbol{y}$ being the total income received by groups of household. As in the case of the IOT and the SUT, dividing the elements by their column sums generates coefficient matrices (see equations (3) in section 2.2). Therefore, $\boldsymbol{B\hat{x}}$ is the use matrix of intermediate consumption and $\boldsymbol{D\hat{q}}$ is the make matrix. $\boldsymbol{B}$ and $\boldsymbol{D}$ are the coefficient matrices defined in section 3.2. $\boldsymbol{C}$ is a vector or matrix of households' consumption propensities out of income, and $\boldsymbol{y}$ is a vector of household incomes. $\boldsymbol{W}$ is a matrix of value added coefficients (the remuneration to factors of production per unit of output). Therefore, $\boldsymbol{Y}$ is a matrix of distribution coefficients that maps factor incomes to households as household incomes, and $\boldsymbol{\hat{v}}$ is a diagonal matrix of value added (factor incomes). The symbols outside of the thick-boxed sub-matrix are the vector of final consumption expenditure $\boldsymbol{f}$ (which sums up household and government consumption, investment and exports) and the vector of transfers to households, $\boldsymbol{h}$ (which includes transfers for other domestic institutional sectors and those from the rest of the world).

SAM multiplier analysis is a natural extension of IOT and SUT analysis. The goods and service account, the production account, the generation accounts and the household account will be considered endogenous, meaning that their value will be determined by the solution of the system. Within those accounts the coefficient matrices $\boldsymbol{D}$, $\boldsymbol{B}$, $\boldsymbol{C}$, $\boldsymbol{W}$ and $\boldsymbol{Y}$ are assumed to be fixed, which implies that production coefficients as well as income share and consumption shares of income are assumed to be fixed. In contrast, the vectors, $\boldsymbol{x}$, $\boldsymbol{v}$, and $\boldsymbol{y}$ (and their diagonal matrices, with hat signs) need to adjust to accommodate the change in the exogenous accounts $\boldsymbol{f}$ and $\boldsymbol{h}$.

The following equations are obtained from the accounting identities:

$$\begin{aligned} &\boldsymbol{B} \cdot \boldsymbol{x} + \boldsymbol{C} \cdot \boldsymbol{y} + \boldsymbol{f} = \boldsymbol{q} \\ &\boldsymbol{D} \cdot \boldsymbol{q} = \boldsymbol{x} \\ &\boldsymbol{W} \cdot \boldsymbol{x} = \boldsymbol{v} \\ &\boldsymbol{Y} \cdot \boldsymbol{v} + \boldsymbol{h} = \boldsymbol{y} \end{aligned} \tag{39a}$$

or by showing the sub-matrices blocks:

$$\begin{pmatrix} \mathbf{0} & \boldsymbol{B} & \mathbf{0} & \boldsymbol{C} \\ \boldsymbol{D} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{W} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \boldsymbol{Y} & \mathbf{0} \end{pmatrix} \cdot \begin{pmatrix} \boldsymbol{q} \\ \boldsymbol{x} \\ \boldsymbol{v} \\ \boldsymbol{y} \end{pmatrix} + \begin{pmatrix} \boldsymbol{f} \\ \mathbf{0} \\ \mathbf{0} \\ \boldsymbol{h} \end{pmatrix} = \begin{pmatrix} \boldsymbol{q} \\ \boldsymbol{x} \\ \boldsymbol{v} \\ \boldsymbol{y} \end{pmatrix} \tag{39b}$$

We can further express (39) simply as:

$$\boldsymbol{S} \cdot \bar{\boldsymbol{x}} + \bar{\boldsymbol{f}} = \bar{\boldsymbol{x}} \tag{40}$$

where:

$$\boldsymbol{S} = \begin{pmatrix} \mathbf{0} & \boldsymbol{B} & \mathbf{0} & \boldsymbol{C} \\ \boldsymbol{D} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \boldsymbol{W} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \boldsymbol{Y} & \mathbf{0} \end{pmatrix}, \bar{\boldsymbol{x}} = \begin{pmatrix} \boldsymbol{q} \\ \boldsymbol{x} \\ \boldsymbol{v} \\ \boldsymbol{y} \end{pmatrix} \text{ and } \bar{\boldsymbol{f}} = \begin{pmatrix} \boldsymbol{f} \\ \mathbf{0} \\ \mathbf{0} \\ \boldsymbol{h} \end{pmatrix}.$$

Recall the derivation of input–output multipliers from equations (4) and (5):

$$\begin{aligned} &\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \boldsymbol{f} \\ &\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} \end{aligned}$$

Similarly, from equation (40), we can derive the SAM multipliers as:

$$\bar{\boldsymbol{x}} = (\boldsymbol{I} - \boldsymbol{S})^{-1}\bar{\boldsymbol{f}} \tag{41}$$

With such SAM multipliers, we are able to assess the effect of changes in final demand on commodity outputs, industry outputs, factor incomes and household incomes (the four endogenous accounts). That is:

$$\boldsymbol{\Delta}\bar{\boldsymbol{x}} = (\boldsymbol{I} - \boldsymbol{S})^{-1}\boldsymbol{\Delta}\bar{\boldsymbol{f}} \tag{42}$$

Equations (41) and (42) are analogous to equations (4) and (5) in the IO model and to equations (37) and (38) in the SUT model. The SAM analysis includes more endogenous accounts than the IOT and the SUT. Therefore, the Leontief inverse $(\boldsymbol{I} - \boldsymbol{S})^{-1}$ generates larger multipliers. The principle of "closing with respect to" a larger set of accounts expands the multiplicative effects of a change in the exogenous accounts (say, government expenditure, investment or exports).

4.3 An example of SAM multipliers analysis

In this section we present a simple example of SAM multiplier analysis. Here we want to address the question: What would happen if export demand for the economy's agricultural sector were to increase by 10 per cent? We want to find both absolute effects and relative effects. The first step is to generate the absolute "shock" of final demand; the 10 per cent raise in export demand affects one of the elements in the $\bar{f}$ vector. Next, we apply equation (42) to calculate the economy-wide effect of the increase in demand for agricultural exports for this economy. Table 4.5 shows the effects on the endogenous accounts.

Table 4.5 Effects of a 10 per cent increase in agricultural exports demand on the endogenous accounts

	Net effect	Effect in %
Agricultural product output	6.61	3.98
Industrial product output	3.06	0.26
Service product output	4.06	0.35
Output in agriculture	5.36	3.70
Output in industry	2.10	0.28
Output in services	3.85	0.36
High-skilled wages	1.31	0.45
Low-skilled wages	1.31	0.45
Profits	3.25	0.90
Households 1st quintile	0.12	0.46
Households 2nd quintile	1.02	0.46
Households 3rd quintile	0.81	0.46
Households 4th quintile	0.61	0.46
Households 5th quintile	0.20	0.46

Table 4.5 shows that SAM-based multiplier analysis can calculate the effects of a shock not only on outputs but also on factor and household incomes. With a 10 per cent increase in demand for agricultural export, we observe expansions across products, industries, factors and households. It is not surprising to see that the effects are greatest on agricultural outputs because the shock comes from the agricultural sector directly. Other sectors, factors and households experience weaker induced effects via the fixed coefficients.

Furthermore, with relevant information on employment coefficients and emission coefficients, we can calculate the employment and emission effects of the 10 per cent agricultural exports expansion, following the method presented in section 2.4.

5. Summary, conclusions and perspectives

Key questions to answer

- What is accomplished by closing the system with respect to certain accounts?
- What are the pros and cons of multiplier analysis versus more complex models?

Important observations

- Multiplier analysis based on IOTs tables is easier to carry out, while SUTs and SAMs multipliers have broader scope but require more careful interpretation.
- The strengths and limitations of multiplier analysis flow from its simplicity and "strong" but straight-forward assumptions.

Social accounting matrices (SAMs) represent the economic and social structure of an economy. They bring together national accounts ("goods and services", "production", "generation of income", "allocation of primary income", "secondary distribution of income", etc.) in a matrix format and allow the breakdown of these accounts to represent groups of socio-economic actors (or "institutional sectors" in national accounts terminology), such as different classes of primary factors, households, firms and the rest of the world. The breakdown of production, consumption and investment classes, as well as the grouping of actors, is determined by analytical purposes. It is constrained by the availability of data. SAM compilation relies heavily on national account systems, labour account systems and data at the individual and household levels.

SAMs are naturally built on the supply and use tables; the SUT framework brings together "goods and services", "production" and "generation of income" in a matrix format as it identifies the sources of supply of and demand for products and the generation of value added in an economy. SAMs are expanded from SUTs by adding data from other national accounts and complementing them with the findings of household and labour force surveys to take into consideration important social aspects of the economy.

IOTs and SUTs focus on production relationships, taking into account the composition of final demand and the generation of value added. The extensive portfolio of analytical tools developed for IOTs has been extended and adapted to SUT- and SAM-based analysis. IO analysis takes the form of "multiplier analysis", which identifies how much new output is necessary to obtain an additional unit of final demand, or how much labour or emissions or uses of physical resources are associated with production of such output.

The principle of "closing" the system with respect to some additional accounts makes it possible to expand the scope of multiplier analysis as the total effects of an injection of final uses are amplified by the relationships among the new coefficients, the uses of product, and incomes generated in inter-industry transactions. Endogenizing (or "closing with respect to") household consumption and wage income (as a component of value added) is a typical example. SAM-based multiplier analysis relies on the extension of the multiplier principle to other accounts in the SAM, such as the generation of income by different kind of labour, the distribution of income to different classes of households and the various uses of different goods and services. The principles of closing and of adding satellite accounts extend nicely to SAM analysis, provided that the resulting multipliers are correctly understood.

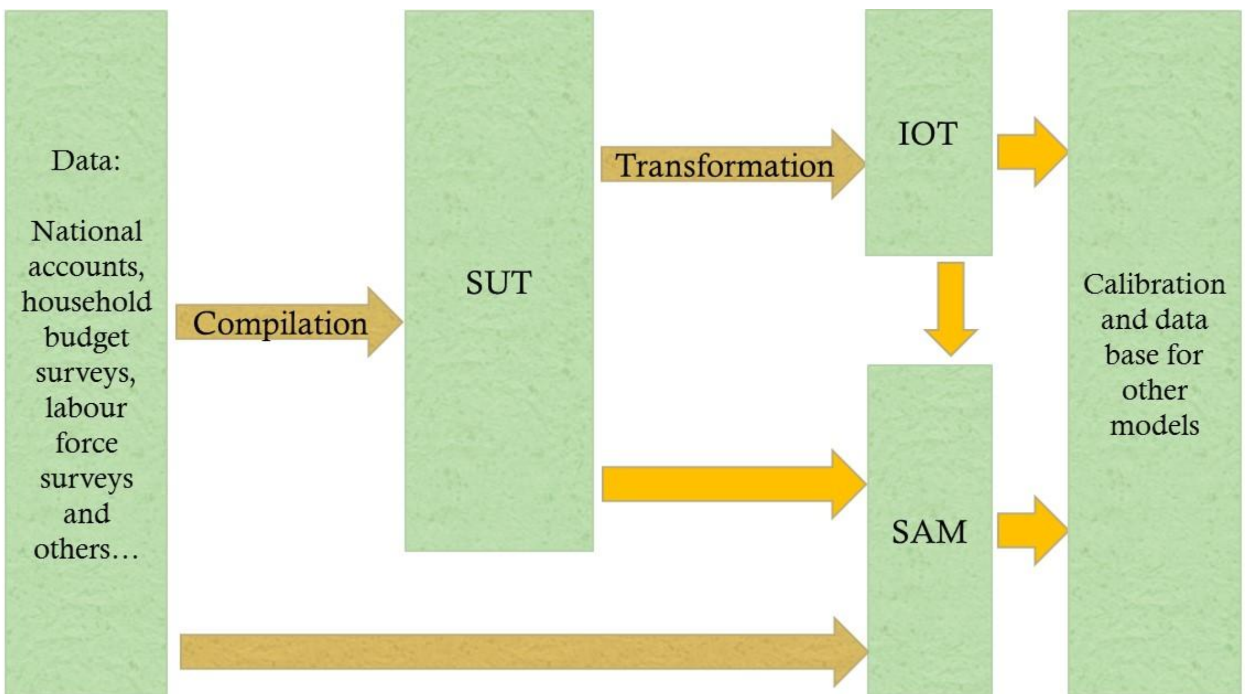
In modern national account systems, IOTs are derived from SUTs through a transformation that makes it possible to represent the economy as if each industry produced one and only one product.[1] Such transformation relies on some analytical assumptions about technology and sales of the product and about the industry. While multiplier analysis based on IOTs is easier to carry out, SUTs and SAMs multipliers have broader scope but require more careful interpretation.

As we have seen, obtaining multipliers from SUTs also implies assumptions about technology and sales of the products. The analysts need to choose carefully the source of their multiplier analysis on the basis of the assumptions that are most plausible in the specific case.

> Analysts need to choose carefully the source of their multiplier analysis on the basis of the assumptions that are most plausible in the specific case.

Finally, IOTs, SUTs and SAMs all can provide the basis of data and accounting relationships for more complex modelling approaches. Figure 5.1 shows the flow of use of data from the compilation of a SUT to the transformation into an IOT. Together with the addition of social and labour market statistics, both can be used to build a SAM. Both the IOT and SAM can be used to calibrate simulation models.

Figure 5.1 From data to matrix representation and analysis



The strengths and limitations of multiplier analysis are its simplicity and “strong” but straight-forward assumptions. More complex models can incorporate the effects of more complex behaviour (e.g., price effects, more complex consumption and investment decision-making behaviour, labour market wage and employment interactions). However, they do so at the cost of relying on assumptions that can be considered “strong” (meaning lacking general applicability) and “unrealistic”. The problem of economic modelling is that an assumption can be strong both when it postulates a simple behaviour (e.g.,

[1] SUTs can be transformed into industry-by-industry or product-by-product IOTs relying on different assumptions about sales structure or technology. See section 3.2.

consuming a constant fraction of income) or non-behaviour (e.g., prices do not change) and when it requires behaviours whose complexity and/or specificity may limit their applicability.

The power of a more complex model is to address more complex questions, using a broader palette of policy instruments. This requires more endogenous variables (i.e., outcomes generated by the model), including policy goals, and more exogenous instruments (i.e., given outside the model) including policy tools.

The strength of IOT-, SUT- and SAM-based models is the reliability and consistency of the accounting data structure of the databases. The matrix form of IO tables, SUTs and SAMs provides the main accounting relationships as *supply = uses* and *cost of input = value of output* and *income = expenditure + savings* at the product, firm and household levels. Economic models then turn these identities into equilibrium conditions and postulate adjustment mechanisms that satisfy them. Deciding on behaviour, endogenous versus exogenous variables, and any additional relationships that determine such an equilibrium (i.e., specifying an “adjustment mechanism”) is the mixed blessing of the modeller.

The strength of IOT-, SUT- and SAM-based models is the reliability and consistency of the accounting data structure of the databases.

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