Australian Government
Productivity Commission

Vulnerable Supply Chains

Productivity Commission Interim Report

March 2021

This interim report focuses on how disruptions to supply chains might affect Australians' access to essential goods and services. To contribute to this study, please send a submission or brief comment before 30 April 2021.

An appropriate reference for this publication is:

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The Productivity Commission

The Productivity Commission is the Australian Government's independent research and advisory body on a range of economic, social and environmental issues affecting the welfare of Australians. Its role, expressed most simply, is to help governments make better policies, in the long term interest of the Australian community.

The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by concern for the wellbeing of the community as a whole.

Further information on the Productivity Commission can be obtained from the Commission's website (www.pc.gov.au).

Terms of reference

I, the Hon Josh Frydenberg MP, pursuant to Parts 2 and 4 of the *Productivity Commission Act 1998*, hereby request that the Productivity Commission undertake a study into Australia's resilience to global supply chain disruptions.

Background

Australia's experience with the COVID-19 pandemic has highlighted Australia's potential vulnerability to global supply chain disruptions. While Australia's supply chains have held up relatively well during the COVID-19 pandemic, future shocks to supply chains will likely be different in nature.

Scope

The purpose of the study is to examine the nature and source of risks to the effective functioning of the Australian economy and Australians' wellbeing associated with disruptions to global supply chains, identifying any significant vulnerabilities and possible approaches to managing them.

In undertaking the study, the Commission should consider Australia's part in global supply chains as an importer and exporter, and:

- consider the factors that make supply chains vulnerable
- develop a framework for identifying supply chains that are vulnerable to the risk of disruption and also critical to the effective functioning of the economy, national security and Australians' wellbeing
- use trade and other relevant data to identify supply chain vulnerabilities
- explore risk management strategies, including the roles of, and options for, government and businesses to manage supply chain risks.

Process

The Productivity Commission should undertake appropriate consultation, and provide an interim report focusing on Australia's role as an importer in March 2021; and a final report including Australia's role as an exporter in late May 2021.

The Hon Josh Frydenberg MP
Treasurer

[Received 19 February 2021]

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Preface

This interim report focuses on imports

In response to the terms of reference, the Commission has prepared an interim report that focuses on how disruptions to imports might affect Australians' access to essential goods and services. The interim report develops a framework to identify risks that might affect supply chains, and ultimately Australians' wellbeing.

The final report will add material relating to exports

The final report will analyse disruptions to supply chains that can affect exports. These are risks to the economy. There are two main sources of disruptions to exports: disruption to upstream supply chains and disruption to downstream supply chains, including to market access. The report will review risk management strategies to deal with these types of disruptions.

Consultations

The Commission received final terms of reference on 19 February. As a result, consultation for this interim report has been limited to workshops and bilateral meetings with relevant Australian Government agencies.

To contribute to this study, please send a submission or brief comment before 30 April 2021.

Find out how to reach us at: www.pc.gov.au/inquiries/current/supply-chains

Abbreviations

ABS	Australian Bureau of Statistics
ACBPS	Australian Customs and Border Protection Service
ACCC	Australian Competition and Consumer Commission
AMGC	Advanced Manufacturing Growth Centre
ANAO	Australian National Audit Office
ANZSIC	Australian New Zealand Standard Industrial Classification
BEC	Broad Economic Classification
CIF	Commercial invoice value, insurance costs, and freight
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DFAT	Department of Foreign Affairs and Trade
DISER	Department of Industry, Science, Energy and Resources
EU	European Union
FOB	Free on board
HHI	Herfindahl Hirschman Index
HS	Harmonized System
HTISC	Harmonized Tariff Item Statistical Code
IFAM	International Freight Assistance Mechanism
IOIG	Input-Output Industry Groups
IOPC	Input-Output Product Classification
IOPG	Input-Output Product Group
JIT	just-in-time
NMS	National Medical Stockpile
NSW	New South Wales
OPEC	Organization of the Petroleum Exporting Countries
PPE	Personal Protective Equipment
SA	South Australia
SITC	Standard International Trade Classification

SNA	System of National Accounts
TGA	Therapeutic Goods Administration
US	United States
WCO	World Customs Organization
WTO	World Trade Organisation

Executive summary

Australia's supply chains proved generally resilient in response to the COVID-19 pandemic, but the experience with COVID-19, following the devastating 2019-20 bushfires has highlighted Australia's potential vulnerability to supply chain disruptions. Panic buying of some goods, notably personal protective equipment, and the imposition of export restrictions on these products by some countries added a degree of urgency to the unfolding situation.

In this febrile environment, understanding the nature of possible disruptions received relatively little attention, but it did prompt a host of views on Australia's degree of self-sufficiency and strident opinions on how best to manage the risks involved. The Economist Intelligence Unit, a research advisory service, projected global value chains may become shorter, less fragmented and more regional. Others were less equivocal. For example, Andrew Liveris, then special adviser to the National COVID-19 Commission, said that: 'Australia drank the free-trade juice and decided that off-shoring was OK. Well, that era is gone … We've got to now realise we've got to really look at onshoring key capabilities.'

Regardless of the response, managing the risks of supply chain disruptions — whatever their origin — inescapably entails costs on businesses, consumers and governments. These costs vary substantially and depend on the choice of mitigation strategy — stockpiling, supplier diversification, contingent contracting, developing domestic capability, among others. They also depend on the state of preparedness of firms and governments to assume responsibility, and to make effective decisions, on the level and manner of risk management to take.

The purpose of this study is to help further Australia's preparedness to deal with possible global supply chain disruptions. The report considers the factors that make supply chains vulnerable, with a focus on the international linkages and dependencies from trade. Importantly, we have developed and piloted a framework for identifying those supply chains and products that are vulnerable to disruption and critical to the effective functioning of the economy, using imports and production data. We then explore effective risk management strategies for governments and businesses and provide policy guidance on the roles for governments.

Supply chains and risks

Supply chains are networks of firms participating in the process of transforming inputs into final products that are delivered to consumers. Improvements in technology and trade liberalisation have made it easier and cheaper to source many goods and services from overseas. This has brought benefits from specialisation and economies of scale. It has also lifted the complexity of supply chains — modern supply chains often rely on inputs from

across the globe and can consist of thousands of firms. The Toyota supply chain, for example, is estimated to consist of over 2100 suppliers.

This intricate web of economic interdependencies means that a supply chain is potentially exposed to the many types of shocks that can affect every business, both in Australia and overseas: geopolitical (for example, a trade war), environmental (a natural disaster), economic (a financial crisis), societal (a pandemic) and infrastructure-related (cyber-attacks). Firm-level exposure to these risks depends on the characteristics of supply chains. A lack of flexibility, such as a dependency on one firm for a critical input, geographic clustering when all firms in an industry are in one location, and lengthy supply chains increase firm-level risk. To manage their exposure and appetite for these risks, those businesses that are most vulnerable use sophisticated tools and strategies.

From a policy perspective, however, it is not whether one firm in the market might experience disruption, but rather the exposure to 'market-level' risk that matters. In other words, what matters is whether the whole market for a product could be at risk of disruption. This is the set of supply chains that supply end-product firms that sell competing goods in a market. For example, there is a market-level supply chain for automobiles, which includes the global supply chains that produce all automobiles for sale in Australia — Toyota's firm-specific supply chain is one part of the market-level automobile supply chain. Lack of flexibility and geographic clustering also shape market-level risk.

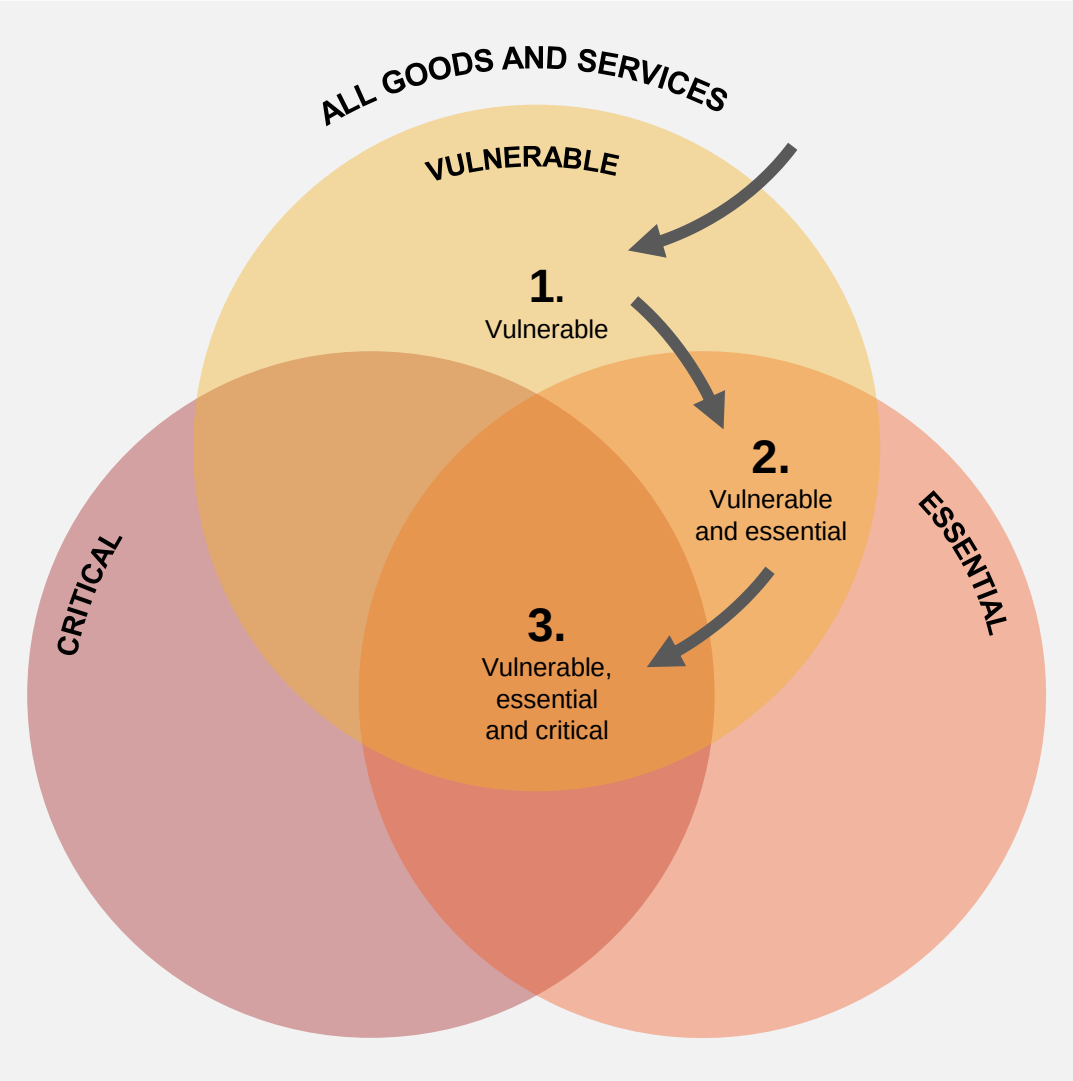
At an economy-wide level, it does not matter which downstream firm supplies a particular good or service. If the supply chain for one of many downstream firms producing the same product is disrupted, that business may bear a substantial cost, but the societal cost may be small if alternatives are available. Rather, it can be costly to society if the entire system that supplies downstream firms is disrupted. For example, one brand of amoxicillin (a widely used antibiotic) disappearing from pharmacy shelves would not be a problem; but the disappearance of all amoxicillin could be a serious problem.

A 'data-with-experts' framework to identify vulnerable supply chains

The Commission has developed a framework to distinguish supply chains that are critical to the functioning of the economy, national security and Australians' wellbeing.

A novel feature of the framework is the development of a 'data-with-experts' approach (figure 1). It casts a wide net by first identifying those products that are vulnerable to supply chain disruptions using a data scan. Then it identifies which of these vulnerable products are used in essential industries. The final step relies on expert assessment and other methods to stress test the data-driven analysis and to determine, from among the vulnerable products used in essential industries, those which are critical (goods and services that cannot be substituted easily, or the production process cannot be adjusted in the short term to avoid their use).

Figure 1 **Analytical framework**



The Commission's method differs from the approach of relying on expert consultations to identify essential sectors and the key inputs that may be at risk. One of the strengths of first applying a data scan is that it is largely agnostic (a priori at least) on those products likely to be identified as vulnerable to disruption. This reduces the probability of missing a good or service that *is* vulnerable, therefore reducing the likelihood of a 'false negative'. Equally, it may raise the likelihood of identifying a good or service as vulnerable when it is not, akin to producing a 'false positive'.

The framework still relies on some judgement, notably in specifying the goods and services that are considered essential. This can be decided by the analyst, but for this study, the Commission defined essential goods and services as those that meet the basic needs of Australians. Basic needs are part of the output of numerous industries, including water,

health, communications, energy, logistics, finance, and government. Food, while essential, is excluded from the analysis because Australia is a major and diversified producer of food. While food products may have vulnerable supply chains, food as a category is much less so.

Another area of judgment is the time frame of analysis for assessing the economic impacts of disruption. We have focused on severe short-term (six-month) supply chain disruptions, because in the long run there is greater capacity to adjust and adapt to shocks.

Testing the framework with imports data

The framework developed by the Commission was piloted with Australian imports and global trade data to assess import vulnerability.

High-level trade statistics illustrate imports as a key source of supply chain vulnerability. Australia imported 5950 different product aggregates in 2016-17 with a combined value of A$272 billion, equivalent to around 16 per cent of gross national income. These imports came from 223 countries, although, the majority by value were from the five largest suppliers — China, the United States, Japan, Thailand and Germany. The main imports by value were motor vehicles and parts; electrical, optical and other specialised equipment; fuel; pharmaceuticals; and chemicals.

As a first step to operationalise the framework and identify which imported products are vulnerable, filters are applied to the trade data. The first filter ascertains whether the market for each product that Australia imports is highly concentrated (when the main supplying country accounts for over 80 per cent of imports of a product). The second filter determines whether there are limited alternative suppliers that Australia could access in the event of a disruption (considered to be when the main supplying country globally accounts for over 50 per cent of global exports). The third filter determines whether Australia sourced its concentrated imports from the main global supplier in a concentrated market.

The results of these filters suggest that one-in-five products (1327 products worth A$30 billion) imported by Australia is highly concentrated. However, the global trade data (filter 2) indicate that for many of these products alternative sources of supply exist and could be utilised should the need arise. Once all three filters are applied, the result is that one-in-twenty Australian imports (292 products worth about A$20 billion) are identified as originating from concentrated sources of global supply and, by this combination of criteria, might be vulnerable. Two-in-three of these vulnerable imports came from China.

The list of vulnerable imports arising from the broad-based data scan reveal many products that, while having high import concentrations, are unlikely to be essential — either directly or as an input into the production of essential goods and services — for the material wellbeing of Australians. Examples of such products include festive decorations, Champagne, clothing items, and toys.

The second step in operationalising the framework involves identifying whether any vulnerable imports were used to produce essential goods and services. This involves linking trade and production data that relate to a group of essential industries. The essential industries are mainly service producing industries that primarily use locally sourced services in their production; vulnerable imports constitute a small fraction of all the inputs into essential goods and services. Further, fewer than half of all vulnerable imports are used in essential industries.

Taken together, the analysis offers suggestive — but not conclusive — evidence that many essential goods and services do not depend critically on vulnerable imported inputs. The main supply chain disruption risks that could be problematic arise from the reliance on concentrated imports of some basic chemicals, or some personal protective equipment.

These results have limitations, mainly stemming from a lack of product detail and difficulties in linking trade and production data. This is where specialised expertise is vital in stress testing the data-led approach. In addition, expert knowledge is required to identify whether an import is technically critical in the sense that its absence would interrupt the supply of an essential good or service. While not a substitute for expert knowledge, the Commission tested whether estimating demand elasticities for a selection of chemicals could corroborate the findings gleaned from the 'data-with-experts' approach. This can be informative, but data limitations make it difficult to apply the estimation approach systematically.

How is risk managed and is there a role for government?

Efficient supply chain risk management balances the trade-off between the costs of a disruption — a large increase in the cost of purchasing goods and services upstream — with the opportunity cost of investing in risk management. To make effective decisions on the level of action to take, firms need to understand the nature of the potential disruption (likelihood, size etc.), and its potential impact to their supply chains. The analytical framework developed for this study is a tool that can be used for that purpose.

However, it is not straightforward to assimilate the information. Supply chains can be long, complex, and opaque, and data on a firm's supply chain can be difficult to obtain. Biases can also affect the decisions of firms to invest in risk management. For example, because of their recent experience with the COVID-19 pandemic, firms may overinvest in strategies that seek to mitigate this risk, when other risks may be more probable and imminent.

Notwithstanding these challenges, risks are best managed by those who have direct incentives to mitigate against them, and typically this means firms. Similarly, government has a responsibility to manage risks in supply chains for which they purchase and deliver goods and services directly. Key mitigation strategies used to prepare for supply chain risks include: no action, stockpiling, supplier diversification, contingent contracting, and developing domestic capability. Several strategies are likely to be required to mitigate the risks that firms face.

There can also be circumstances where there is a rationale for government to intervene in market risk management. For example, intervention may be justified where risk management by a firm is hampered by regulation, or there is a divergence in risk appetite between firms and the community. A divergence could come about if, for instance, disruptions have 'contagion' effects, or might affect national security. In these cases, government could consider options ranging from providing information about risks that they are best informed about, to taking more direct ownership of risk management (such as maintaining government stockpiles, mandating or subsidising private stockpiles, or maintaining domestic production capacity).

That said, government intervention may crowd out private investment in risk management, imposing higher costs on the community. For example, the costs of maintaining a local capability could outweigh many times the cost of other strategies. Further, onshoring could still rely on a critical input (such as crude oil), or Australia might lack the expertise to produce locally and be competitive. Even when firms consider onshoring, they often maintain several locations globally to diversify risks — and control costs. Hence, even where an in-principle case for government intervention exists, any case for intervention needs to demonstrate that the benefits of intervention outweigh its costs.

One area where governments could focus their efforts is on ensuring firms do not face unnecessary constraints on how they plan and respond to disruptions. A stable and rules-based trading environment, for example, facilitates firms' ability to diversify their suppliers in preparation for, and their ability to find alternative suppliers in response to, a supply chain disruption. A responsive regulatory environment is another example.

Lastly, it is important that government periodically reviews and updates the list of goods and services that are vulnerable to supply disruptions and essential for the wellbeing of Australians, as it is likely to change over time. The frameworks developed in this study provide a means to repeat such reviews, and ideally reviews would begin with industry consultation. While time consuming, this approach is recommended to better understand where vulnerabilities will be visible in data, and thereby inform the use or gathering of data best suited to identifying vulnerable, essential, and critical goods.

Findings

Applying the framework

FINDING 4.1

One-in-five products imported by Australia is considered highly concentrated; however, the global trade data suggest that for many of these products alternative sources of supply exist and could be utilised should the need arise. The result is that one-in-twenty Australian imports might be vulnerable to concentrated sources of global supply.

FINDING 4.2

Most vulnerable imports are classified as either consumption or intermediate goods, with fewer capital goods. But by value, capital goods typically form the highest share of vulnerable imports. Though important in the long run, disruptions to the supply of capital goods that might appear vulnerable are unlikely to affect wellbeing in the short run.

FINDING 4.3

For many products, the main supplier of vulnerable imports is China, accounting for roughly two-thirds of those products. Notwithstanding this, the main source of supply varies by product.

FINDING 4.4

The list of vulnerable imports consists of a variety of products that are used in production or consumption, but many of them are not essential to the wellbeing of Australians.

FINDING 4.5

Vulnerable imports are a small share of the goods used in essential industries, by value. This is suggestive, but not conclusive, evidence that vulnerable imports may not be critical to the production of essential goods and services.

FINDING 4.6

Since the narrow definition of essential industries used in this study comprises mainly service producing industries, locally-sourced services are primarily used in their production, rather than locally-sourced or imported goods. Consequently, vulnerable imports are a small share in their production costs. Furthermore, many of the vulnerable products identified, such as textile products, are unlikely to be *critical* to the production of these services.

Vulnerable imports that are inputs into the goods-producing industries of petrol refining and medicine manufacturing are more likely to be critical.

FINDING 4.7

Combining imports and production data suggests that the supply of essential goods and services in Australia is not highly susceptible to a short-term disruption to the supply of imported goods. Vulnerable imports represent a small fraction of the value of essential goods and services consumed by Australians — whether that consumption be direct (final goods, A$20 million out of total consumption of essential goods and services of A$593 billion) or indirect (as inputs into Australian production, A$2.7 billion). But this evidence is not conclusive and industry experts are required to determine criticality.

Risk management and the role of government

FINDING 5.1

Effective risk management requires a good understanding of a firm's risks to ensure that the net benefits of any investment to mitigate the costs of disruptions is matched by their potential effects and costs.

Supply chain risk management is similar to buying insurance for any other types of risk. In effect, a firm pays an insurance premium upfront to invest in a range of strategies such as, stockpiling, supplier diversification, contingent contracting, and domestic capability, to insure itself against potentially large cost increases if a disruption occurs. The focus of these risk management strategies is on the physical restoration of supply chains, rather than taking out insurance for a pure financial compensation in the event of a disruption.

FINDING 5.2

Risks are best managed by those who have direct incentives to mitigate against them. Firms are primarily responsible for managing risks in their supply chain.

Governments have responsibility, like any firm, to manage risks in supply chains for which they purchase and/or deliver goods and services directly, particularly when these are essential goods and services.

Each strategy has costs and some will perform better under different types of disruptions and contexts. Firms will employ a range of strategies to effectively manage risk.

FINDING 5.3

There are conditions where government intervention in private sector risk management may be justified — specifically, if society's tolerance for a residual risk is lower than the residual risk that results from the market. Another situation is where government or other impediments prevent firms from effectively managing their risks.

That said government intervention could crowd out private investment in risk management. The net benefit of any intervention would have to outweigh the possible costs.

The Australian Government also has responsibility for maintaining and promoting a respected and rules-based international trading system which promotes low-cost trading and firms' ability to insure themselves and respond to disruption. And all levels of government have responsibility for ensuring regulations are fit for purpose, including making temporary changes that let firms adjust to temporary disruptions.

1 About this study

1.1 Background to the study

The COVID-19 pandemic raised concerns about Australia's ability to supply goods and services to meet Australians' needs. Fear of shortages led to panic buying across the nation. Australia was not unique in this respect, with most countries manifesting concerns about how their reliance on imports would jeopardise their ability to meet their population's needs during the COVID-19 pandemic.

The COVID-19 pandemic also highlighted how many countries rely on China for many goods and services. The lockdown in Wuhan led to shortages for some goods. One of the biggest shortages was in face masks (box 1.1).

Box 1.1 Face masks and the COVID-19 pandemic

The COVID-19 pandemic led to a surge in the global demand for face masks. This increase in demand and limitations on expanding supply, due to interruptions in production in Wuhan and limited exports out of China, led to a global shortage of face masks. That said, it was not face masks that were in shortage, but an input into their manufacturing — non-woven polypropylene, or 'meltblown'. Only a few firms produce meltblown due to the high initial investment required. This high initial investment meant that firms could not easily or quickly start producing meltblown. At the beginning of the pandemic, the Chinese government compulsorily purchased all locally produced masks in January and February, but exports resumed in March. From January to March 2020, Chinese output of face masks had expanded by a factor of 10. An OECD study estimated that the demand surge was a much larger contributor to shortages than any export restrictions.

Source: OECD (2020).

The global shortage in face masks and other goods produced abroad, combined with increased awareness and sensitivity to risk, has led some to argue that Australia should develop a stronger domestic manufacturing capability (box 1.2).

Box 1.2 The COVID-19 pandemic prompted calls for increased onshoring — but not everyone agrees

Andrew Liveris, former special adviser to the National COVID-19 Commission, is a strong advocate for onshoring:

> Australia drank the free-trade juice and decided that off-shoring was OK. Well, that era is gone … We've got to now realise we've got to really look at on-shoring key capabilities. (Greber 2020)

Similar sentiments were expressed by the Secretary of the Department of Home Affairs:

> … I think COVID has created a circumstance where we need to seriously think about both domestic manufacturing in limited and targeted ways, sovereign capability and, yes, stockpiles for those geo-strategic and geo-economic reasons. (Royal Commission into National Natural Disaster Arrangements 2020b, p. 2739)

In a report detailing how the Australian manufacturing sector could contribute to the Australian economy in the future, Stanford (2020, pp. 5–6) said:

> … this is an opportune moment to launch a new, multi-faceted effort to revitalise Australian manufacturing:
>
> - There is new public awareness of the importance of domestic manufacturing capability.
> - Previous global supply chains have been disrupted by health measures, trade policy interventions, and other factors, forcing us to re-learn how to produce more things at home.
> - The depth and speed of the economic contraction associated with the COVID-19 pandemic requires an ambitious strategy to rebuild national production and employment after the health emergency, and manufacturing could play a central role in that effort.
> - Global economic adjustments, including declines in resource prices and the exchange value of the Australian currency, have enhanced the cost-competitiveness of Australian manufacturing.
> - Continuing revolution in the technology and economics of energy is creating a new source of competitive advantage for Australian manufacturing: namely, our abundant resources of renewable energy, unmatched in the industrialised world.

But not everyone is calling for increased onshoring. Former Minister Craig Emerson argued that when thinking about improving the Australian economy, there are a few reform ideas worth considering and others that are not worth considering. The latter include:

> … tariffs to protect so-called strategic industries which, by the time the rent-seekers are finished, would be every industry under the sun. (2020b)

He also argued that:

> Trump-like tariff shelters for 'strategic industries' would shrink the economy and make genuine reform impossible to achieve. (2020a)

John Denton, the Australian Secretary-General of the International Chamber of Commerce argued:

> This policy distortion [increased protectionism], coupled with a resurgent discussion on industrial self-reliance, will if unchecked dramatically alter the landscape of global trade for the worse. It will lead to overall higher prices, reduced production and increased product scarcity. (2020)

Other countries are considering onshoring some manufacturing processes in response to the COVID-19 pandemic. Beyond that, firms and governments are looking to diversify production processes across regions and international borders.

Governments and firms responded to the COVID-19 pandemic in a variety of ways — some countries prevented the exports of goods and prioritised their own consumption. In Australia, some firms pivoted their production toward goods and services in shortage (box 1.3).

Box 1.3 Some Australian businesses were nimble in responding to shortages

Some Australian businesses increased their production of personal protective equipment and other products required to manage the COVID-19 pandemic, or pivoted production towards these products. Domestic production was important in resolving shortages in hand sanitiser, but played a much smaller role in personal protective equipment.

Company	Usual products	COVID-19 products
Free 3D Hands	Prosthetic hands for children with disabilities	Face shields for healthcare workers
Detmold	Food packaging	Surgical masks
Textor	Materials for nappies, sanitary pads and baby wipes	Personal protective equipment
Ford Australia	Automotive	Face shields for healthcare workers
Axiom Precision Manufacturing	Components, tooling and inspection services for defence, aerospace and other industries	Face shields for healthcare workers
Fella Hamilton	Women's clothing	Face masks, scrubs and gowns
Four Pillars, Archie Rose Distilling Co, Cape Byron Distillery	Gin	Hand sanitiser

Sources: Barndon (2020); Business News Australia (2020); DISER (2020c); Keating (2020); Knaus (2020); Marshall (2020); Masige (2020).

1.2 What was the Commission asked to do?

Against this backdrop, the Australian Government asked the Productivity Commission to examine the nature and source of risks to the effective functioning of the Australian economy and Australians' wellbeing associated with disruptions to global supply chains, identifying any significant vulnerabilities and possible approaches to managing them.

The terms of reference asked the Commission to consider Australia's part in global supply chains as an importer and exporter, and:

- consider the factors that make supply chains vulnerable

- develop a framework for identifying supply chains that are vulnerable to the risk of disruption and also critical to the effective functioning of the economy, national security and Australians' wellbeing
- use trade and other relevant data to identify supply chain vulnerabilities
- explore risk management strategies, including the roles of, and options for, government and businesses to manage supply chain risks.

The project has focused on a conceptual framework and data analysis, consisting of three main outputs:

- an analytical framework designed to identify goods and services that are critical to the functioning of the economy and to wellbeing. Part of this framework involves an outline of a methodology and process that could be used to identify goods and services that are vulnerable, essential and critical
  - the project outlines both data-driven and consultative approaches to identifying inputs that are critical to the functioning of the economy and to wellbeing (The consultative approach requires significant input from industry experts.)
- data analysis that operationalises the framework to identify imports of goods that might be vulnerable
- possible strategies involved in managing risks at the national level, rather than strategies that might be applied to specific firm-level supply chains or disruptions.

The final report will include additional data analysis to identify export markets that might be vulnerable to short-term threats such as reduced demand due to natural disasters, geopolitical reasons, or transport disruptions.

Due to security concerns and access to data, the report does not comment or analyse supply chains that relate to defence activities, beyond what is available in ABS data. That said, many of the principles discussed are likely to be transferrable to any sector of the economy.

1.3 How does this study relate to other reviews and government initiatives?

This study is designed to complement a number of current initiatives and studies:

- the Department of Industry, Science, Energy and Resources' Modern Manufacturing Strategy, which seeks to make supply chains more resilient to external shocks (DISER 2020d)
- Department of Home Affairs' Critical Technology Supply Chains Principles, which seek to assist government and businesses in making decisions about their suppliers and transparency of their own products (DoHA 2020b, p. 2).

The Commission has drawn on evidence from Australian and international sources and is based entirely on publicly available information. Recent Australian-based work that complements this report, includes:

- reviews by the Australian Competition and Consumer Commission's Agricultural Unit such as the *Cattle and beef market study*, the *Wine grape market study*, and the *Perishable agricultural goods inquiry* (ACCC 2017, 2019, 2020b)
- the *Inquiry into National Freight and Supply Chain Priorities* (DIRDC 2018)
- the *Royal Commission into National Natural Disaster Arrangements* (Royal Commission into National Natural Disaster Arrangements 2020a)
- the *Critical Infrastructure Resilience Strategy: Plan* and other resources from the Critical Infrastructure Centre (DoHA 2015)
- *Profiling Australia's Vulnerability* by the Department of Home Affairs (DoHA 2018)
- *Guidance for Strategic Decisions on Climate and Disaster Risk* from the Australian Institute for Disaster Resilience (AIDR 2021).

2 Supply chains and risks

Key points

- Supply chains are often complex networks across many firms and economies: they are not always a simple, single flow of goods, and can cross many borders across the globe. This increases the complexity of supply chains and decreases their transparency. Market-level supply chains (comprised of all the firms that supply similar goods) are even more complex.
- Improvements in technology and trade liberalisation have made it easier and cheaper to source goods and services from overseas. Increases in global trade bring large benefits such as cheaper and greater choice of goods and services for consumers. Industries also gain from specialisation and economies of scale.
- Supply chains are subject to many types of shocks, including:
  - geopolitical shocks, such as a trade war that might affect regional or global trade
  - environmental shocks, such as the 2019–2020 bushfires in Australia that affected transport and communication
  - economic shocks, such as the 1973 oil crisis that changed how firms and households use energy
  - societal shocks, such as labour disputes or pandemics that affect labour supply and demand
  - infrastructure-related shocks, such as cyberattacks or disruptions at a port or along a road.
- Characteristics of supply chains that increase firm-level risk include:
  - lack of flexibility (dependency on one firm for a critical input)
  - geographic clustering (if all the firms in an industry are in one location)
  - long supply chains (how many times goods change hands and countries).
- Policymakers are primarily concerned with market-level risk, rather than firm-level risk. Market-level risk is the risk that the supply of a whole category of goods is disrupted. A lack of flexibility and geographic clustering contribute to market-level risk.
- Risks have two components: the probability of an event occurring; and the effects of the event. Firms often underestimate the probability of negative events, and recent events tend to lead firms to overestimate the probability of them re-occurring. The effects of an event are summarised as changes in costs — an interruption in supply is equivalent to a very large or infinite increase in its cost.
- Risk management strategies aim to reduce the probability of an event occurring or the effects and cost of an event, including the costs of any recovery.

In 2020, bushfires and the COVID-19 pandemic tested Australia's supply chains. But there are many other scenarios that could disrupt Australia's supply chains, ranging from economic events, such as a global economic financial crisis or a trade war, to domestic

events, such as the recent labour dispute in the port of Port Botany or natural disasters such as bushfires and floods.

This chapter describes concepts in supply chain analysis and how characteristics of supply chains make them susceptible to risks and disruptions. The chapter also introduces the notion of market-level risk.

2.1 Supply chains are complex, and becoming more so

Supply 'chains' are actually networks

A supply chain is the process of transforming raw materials into goods that are delivered to final users, whether industries or consumers (figure 2.1). Although the concept of a supply chain is thought of mainly in the context of manufacturing, all industries, including services such as utilities, construction and hospitals, rely on networks of suppliers.

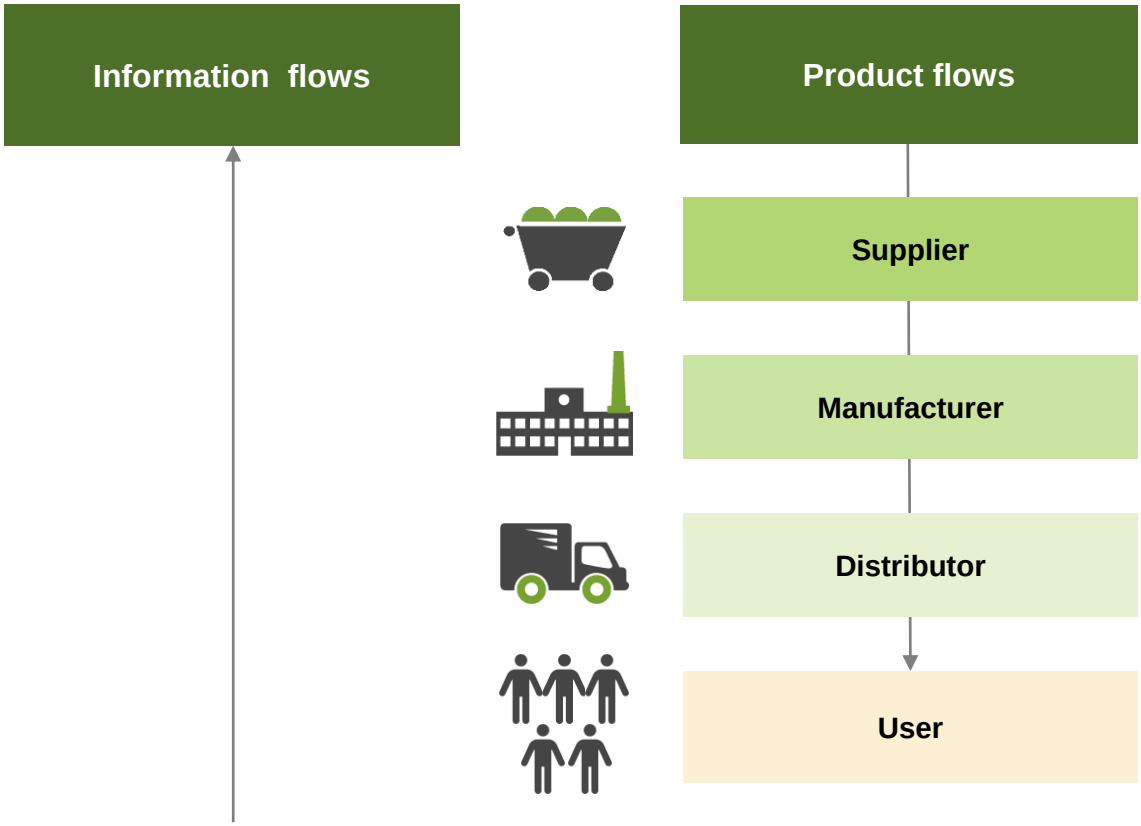
The term 'supply chain' implies a movement of physical goods along a simple path from the supplier to the user (figure 2.1). The reality is that most supply chains are networks of firms (Christopher 2018, p. 6) (figure 2.2, box 2.1). One reason for this is that several different types of inputs are combined in one stage of the production process; for example, making steel involves combining iron ore, coal and limestone. The other reason is that a firm might source the same input from several different firms (possibly for risk mitigation).

Box 2.1 **Supply chain terminology**

- Node — a node represents a stage in the production process occurring in one firm, in one geographic location. For example, if parts are manufactured in a plant and then assembled with other parts, these processes are all represented by the same node.
- Link — a link connects two nodes. It represents the process of transporting the input from one production site to another. For example, a link between a factory in Malaysia to an assembly plant in Melbourne might involve driving the part to the port, shipping through the Port of Singapore and the Port of Melbourne and rail transport to the assembly plant.
- Downstream/upstream — upstream refers to the part of the supply chain that is further from the end user. Downstream is the part of the supply chain that is closer to the end user, including the final distributor or retailer.
- Length — the length of a supply chain refers to the number of nodes that raw materials pass through before reaching customers.

There can also be multiple tiers in a supply chain. For example, a 'tier 1' supplier might supply Toyota directly, while a tier 2 supplier supplies a tier 1 supplier, and so on.

Figure 2.1 **From raw materials to the user**



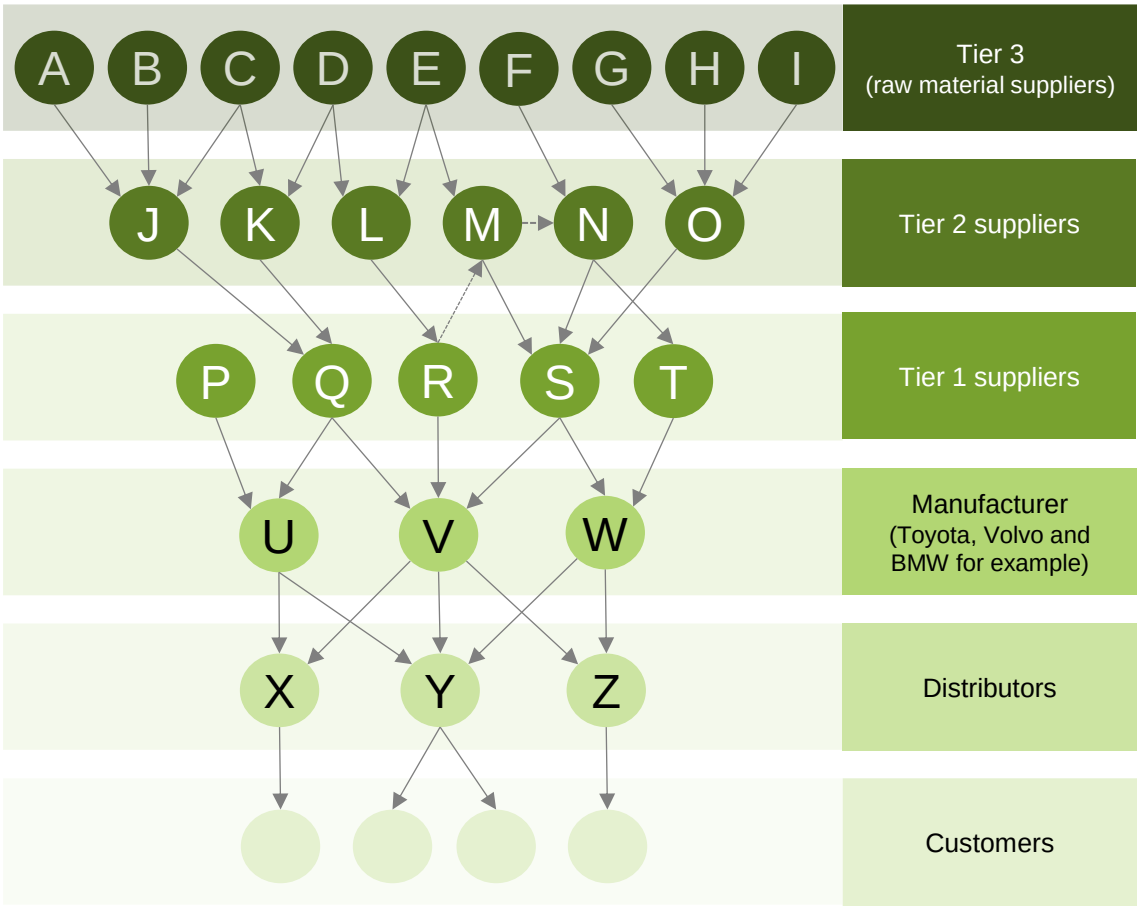
Supply chains can be very complex. Modern supply chains rely on inputs from across the globe, and can consist of thousands of firms. The Toyota supply chain is estimated to consist of 2192 suppliers (Kito et al. 2014, p. 7). Some supply chains are even larger: General Motors had 35 000 suppliers by 1986 (Milgrom and Roberts 1992, p. 566).

Even more complex are market-level supply chains (figure 2.2). This is the set of supply chains that supply a set of end product firms that sell competing end products in a market (firms U, V and W in figure 2.2). For example, there is a market-level supply chain for automobiles (the set of end product firms), which includes the global supply chains that produce all automobiles for sale in Australia. Some firms might have exclusive suppliers and exclusive dealers, keeping their supply chain separate from that of other firms. But more often in today's economy, firms share suppliers. For example, Dell and Lenovo are estimated to share more than 2250 tier 1 and tier 2 suppliers (Lund et al. 2020, p. 9). A disruption among any of these suppliers can affect the supply of the end products of both brands.

From an economy-wide perspective, it does not matter which downstream firm supplies a particular good or service. And if one brand is not available, the societal cost is not serious. So if the supply chain for a particular downstream firm is disrupted, this is not a serious cost to society; rather, it is costly if the entire system that supplies downstream firms is disrupted. For example, one brand of paracetamol disappearing from pharmacy shelves would not be a

problem; but the absence of all brands of paracetamol would be a significant problem for some health conditions.

Figure 2.2 **Market-level supply chain**



Note: Some firms can supply to firms within their own tier, and in tiers before their own. Suppliers in each tier may also supply firms outside of the supply chain. A supply chain is not always a simple flow of goods; for example, M in tier 2 supplies firm S in tier 1, but also supplies firm N in tier 2. Therefore, a disruption to firm M in tier 2 not only tier 1, but also tier 2.

Data source: based on a firm-level supply chain from Chandra and Kamrani (2004, p. 573).

Other inputs to a supply chain

Supply chains are more than just intermediate goods and have other key inputs into production, any of which could be disrupted. Components of supply chains include:

- labour:
  - a firm's workforce can be very diverse and more or less substitutable. For example, a pharmaceutical company might employ many technical assistants who might be easily substitutable, and researchers with specialised skills who are not easily

substitutable. Global transport, a key part of supply chains, relies on a large, relatively low-skilled workforce of drivers, but also on more skilled workers such as air and marine pilots and logisticians and on a few workers with highly specialised skills, such as helicopter pilots who ferry marine pilots to bulk carriers

  - customer support and administrative workers may be working in different locations to where goods are produced. Thus, for example, a lockdown in the Philippines could disrupt the functioning of an automobile dealership in Sydney, if their back-office functions take place in the Philippines

- services (produced from labour and other inputs), such as data processing and storage services, accounting and back-office services for financial institutions and communications, and call centre and other client services
- domestic and imported goods including:
  - raw materials, such as iron ore
  - intermediate goods, such as iron, steel, fertiliser, agrochemicals and seeds, manufactured goods and other inputs
  - final goods that have been produced from intermediate goods, and then are shipped to retailers and finally reach customers
- capital goods such as machinery
- logistics
- infrastructure, such as buildings, telecommunications, electricity, and road and rail networks. Infrastructure is crucial for both production at each node, and transporting goods and services to customers (adapted from WBCSD (2015, p. 9)).

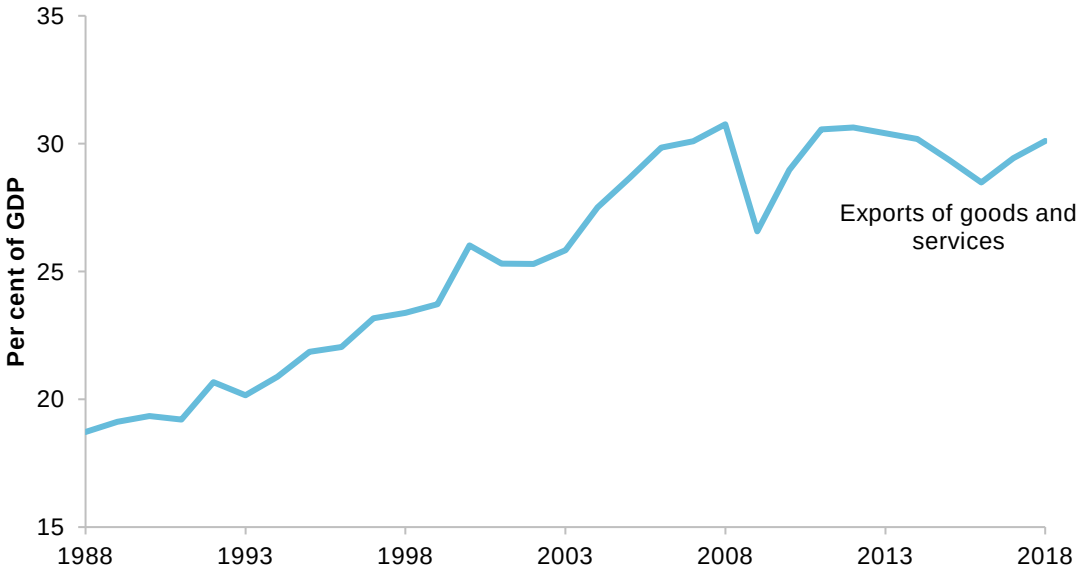
If there is a shortage of any of these components, then most firms in the industry are likely to be vulnerable to a disruption.

How trade and technology are transforming supply chains

Global trade has increased steadily over the last three decades (figure 2.3). And since the 1990s, the share of inputs (by value added) that cross international borders has greatly increased (Timmer et al. 2014, p. 100). For example, the iPhone X is assembled in Shenzen, China, with inputs sourced from Germany, the United States, Switzerland, and Japan (figure 2.4) (Costello 2020). That said, after 2008, the time of the global financial crisis, the growth in trade has slowed (figure 2.3).

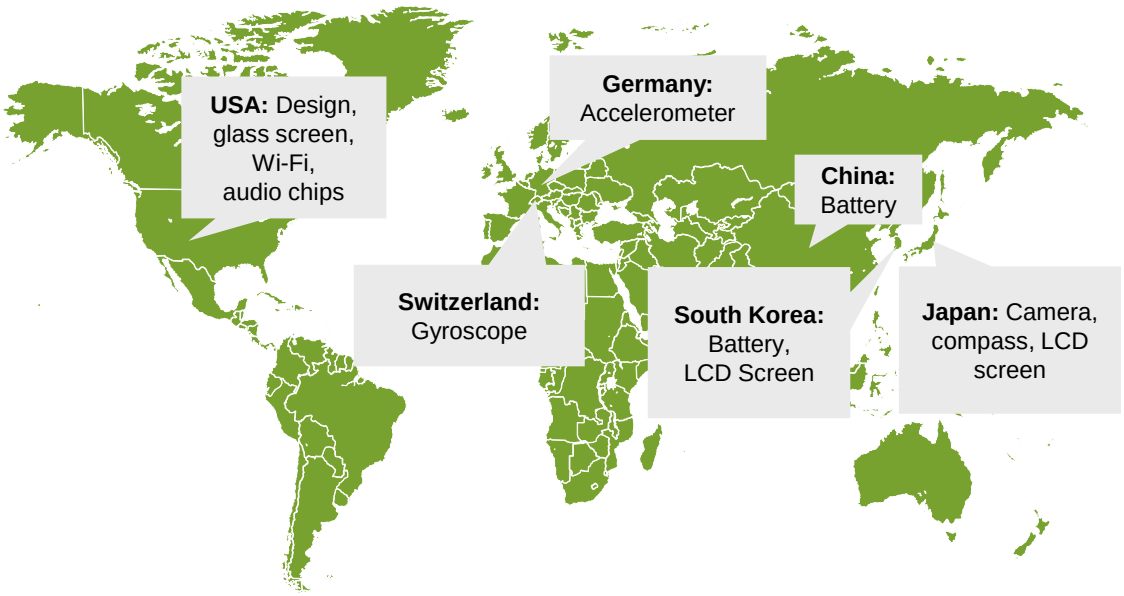
Figure 2.3 **Trade has grown over the last three decades**

World exports of goods and services, as a percentage of GDP, 1988-2018



Data source: World Integrated Trade Solution (*World Experts of goods and services, in % of GDP, 1988–2018*).

Figure 2.4 **The iPhone uses components from across the globe**



a Supplier locations are where each firm is based. They may have production sites across many other countries.

Data source: Costello (2020).

There are several forces acting on these developments: including declines in tariffs, quotas and other trade restrictions, driven by trade agreements between groups of countries (Krugman 1995, pp. 337–341).

Another cause is technological improvements in transportation and logistics that have resulted in cheap, fast and reliable transport, particularly containerisation. Improvements in computer systems and telecommunications have also led to large increases in services trade, such as financial services and customer support. Outsourcing these activities to overseas firms has become gradually more feasible (Krugman 1995, pp. 341–343; McKinsey & Company 2019, p. 34; Phillips 2014).

Finally, improvements in many technologies, both physical and managerial, have increased the reliability of supply chains and reduced delays and the amount of inventory that firms hold to keep production processes going. (In the extreme, these are just-in-time (JIT) production processes, where inventory is at an absolute minimum.) These improvements mean that a product can be moved across manufacturing sites several times, and even across countries, without too much time or expense. As a result, supply chains have been getting 'longer': a product will be transformed in several different locations (which may be in different countries) before the product reaches customers. That said, supply chains seem to have shrunk since the global financial crisis (McKinsey & Company 2019, p. 36).

Increases in global trade bring large benefits. A 2018 study argues that trade has strong dynamic effects on competition, which increases the purchasing power of consumers, reallocates resources toward more productive firms and encourages innovation (Impullitti and Licandro 2018b, p. 221). Conducting simulations based on data for the US economy, the authors conclude that:

> Due to the combination of these competition, selection and innovation responses to trade, the present value of long-run per-capita consumption (our measure of welfare) under trade is 50% higher than in autarky. (Impullitti and Licandro 2018a)

Trade contributes so much to income because each country has its own efficiencies and inefficiencies, and each country has abundant and scarce resources. Trade allows countries to specialise in producing the goods and services best suited to their resources and their capabilities. For example, India has an abundance of workers who are fluent in English, and faces some regulatory constraints in manufacturing, hence the development of its IT industry (Fernandes and Pakes 2009, p. 143; Pack 2009, pp. 66–68). The result is cheaper goods and services for consumers, and higher per capita income from exporting valuable goods and services. The expansion of trade with China, India and other countries in Asia has raised average income in both these and in Western countries (Krugman 2019).

Another benefit of trade is that countries gain from specialisation and economies of scale. By specialising in some goods and services, and producing for more than just their own country, firms can produce large quantities and become more efficient. And firms in the same industry tend to locate close together, which allows firms to have the same access to industry-relevant infrastructure, a specialised workforce and specialised suppliers; this is

known as an industry cluster. Importantly, proximity helps firms share knowledge and drives innovation (Roberts 2018). An example of the benefits of industry clusters is the technological advancements coming from the Silicon Valley, or the highly efficient automobile industry in Germany. Much of the gains from trade from the 1960s to the 1980s were from wealthy industrialised countries trading more with each other, achieving efficient scale and developing industry clusters (Leigh 2017, pp. 44–46).

At the same time, commentators have questioned whether long supply chains that cross international borders create too many vulnerabilities. A failure anywhere along a supply chain can jeopardise final output. And if most firms rely on one industry cluster for their supply, because it is the lowest-cost or highest-quality source of supply, a disaster in that location could jeopardise everyone's supply. For example, Wuhan, the epicentre of China's COVID-19 lockdown, is the world's largest producer of fibre optics (Clarke 2020).

2.2 Supply chain vulnerabilities

There is no consensus on how to classify supply chain risks, partly because of how complex risks are. However, some categorisation is useful, for understanding which risks threaten the functioning of a specific firm's supply chain, and which risks threaten the entire market.

Risk can be categorised as internal or external. Internal risks can be broken down into which internal processes are affected; such as supply, manufacturing, transportation, financial and information (Ho et al. 2015, pp. 5034–5035). External risks are any outside events that impinge on the functioning of the firm's supply chain.

All internal processes within a firm face risks of disruptions and poor performance. For example, a breakdown in an important machine might disrupt the manufacturing process, or a fault in the accounting software used might disrupt financial processes. Negotiations with a labour union could break down, or the firm could face delays when seeking to replace workers with unusual or different skill sets (specialist repair people, for example, or scientists). Quality control could fail and lead to faulty or dangerous products, causing serious reputational damage to the firm.

Categorising external supply chain risks

The following external risk categories have been adopted as they cover sources of risk identified in the literature:

- geopolitical
- environmental
- economic
- societal
- infrastructure-related (Ho et al. 2015, p. 5039; WEF 2020, pp. 86–87).

Geopolitical risks include trade wars, armed and other types of conflict, acts of terrorism and failures of political governance (WEF 2020, p. 87). There are a number of geopolitical risks facing the global economy and Australia, including: a trade war between China and the United States; Brexit; and an escalation of trade tensions between Australia and China (Alicke and Strigel 2020).

Environmental risks include natural disasters and weather events. Examples of significant natural disasters that have caused disruptions to supply chains, include:

- a volcanic eruption in Iceland in 2010 that grounded planes across large parts of Europe for nearly a month causing upheaval in supply chains across Europe and beyond (Choi 2012)
- an earthquake and tsunami in Japan in 2011 — among many other disastrous effects, this event disrupted a number of companies' supply chains including Toyota who experienced a 99 per cent drop in quarterly profits, and Apple who experienced a shortage of lithium-ion batteries produced in a factory damaged by the disasters (BBC News 2011; Sanchanta 2011).

Domestically, insurance losses from natural disasters have been increasing. This trend has been driven by severe weather events (PC 2014c, p. 279).

Experts also consider that environmental risks such as a geospatial event or a volcanic eruption are likely to cause significant global disruptions (The Economist 2020). Such events could be a threat to telecommunication networks and the global positioning system, both of which are critical to data transmission and freight, which in turn are critical to the smooth operation of supply chains — as well as to many other functions in modern societies.

Economic risks include fiscal crises, asset bubbles, severe inflation and energy price shocks (WEF 2020, p. 86). One of the biggest economic events to disrupt global supply chains was the 1973 oil crisis, which affected many aspects of life in the short term and long term as economies adapted to new conditions. More recently, the 1997 Asian financial crisis and the 2008 global financial crisis illustrate the types of economic disruptions that can occur; although they had a relatively small effect on Australia, they affected economies that play an important part in global supply chains.

Societal risks include social unrest, labour disputes, labour shortages due to an ageing population and epidemics. Epidemics and pandemics can lead to disruptions due to the workforce becoming sick, lockdowns and other major restrictions on operations or transport. Epidemics and pandemics can also lead to a surge in demand for specific goods (such as personal protective equipment), or a collapse in demand for specific goods (such as work clothing) if patterns of life change dramatically. There is evidence that demand shocks have been far more disruptive than supply shocks in the COVID-19 pandemic (Lynch 2021).

Infrastructure-related risks include any disruptions to critical infrastructure such as IT systems, transport systems and electricity. The 2016 South Australian blackout is an example of an infrastructure disruption.

Cyber security is also an infrastructure-related risk. One survey reported that concerns over data security were growing — 30 per cent of 1409 respondents in 2016 reported to be very concerned by this threat; the figure grew to 44 per cent of 1193 respondents in 2017 (SCM World 2016, p. 22, 2017, p. 46). Another survey showed that many are ill-prepared — of 400 managers surveyed from around the globe, about 75 per cent said cybersecurity was either a top priority or important, but only 16 per cent thought their company was well prepared (McKinsey & Company 2017, p. 5).

Importantly, although supply chain risks might be more evident in supply chains that rely on imports and global trade, some of the examples above illustrate that domestic supply chains are also at risk of disruptions. For example, the effects of bushfires and blackouts are reminders that parts of supply chains are also vulnerable to domestic infrastructure risk; however, supply chains that rely on overseas inputs are often highly dependent on a small number of ports, which increases vulnerability.

Firm-level risk and vulnerability to market-level risk

All supply chains are vulnerable to some form of risk. But there is an important distinction to draw between firm-level risk and market-level risk. Market-level risks are risks that can disrupt an entire market for a good or service; for example, a disaster could affect the supply chain of one automobile producer, for example Toyota in 2011; but if other automobile producers are unaffected, and can expand their supply, consumers will still be able to purchase automobiles. Other shocks could affect parts of a supply chain that affect all automobile producers. Policymakers should be concerned about vulnerability to market-level risk, rather than firm-level risk, and then only market-level risk for essential goods (chapter 3).

Firms and industries are vulnerable to different risks based on their characteristics and the characteristics of its supply chain. For example, labour-intensive industries are exposed to the effects of labour disputes, and industries that rely heavily on intellectual property, sensitive information, IT systems and communications are more likely to experience and are more sensitive to cyberattacks; agriculture is particularly susceptible to weather events. Industries that rely on specialised skills are more susceptible to disruption because they can be difficult to replace or substitute (Lund et al. 2020, pp. 27–30). But specialised skills are unlikely to lead to market-level risk: a global shortage of a skill would be a gradual problem, and one gradually resolved by education systems.

Different locations are more or less vulnerable to external risks. For example, a supplier from New Zealand is more likely to experience an earthquake-related disruption than a supplier in France. As will be discussed below, this only creates market-level vulnerability if most firms are clustered in one location.

In addition to the natural environment, local regulations and government preparations for natural risks will affect the likelihood of a disruption. Countries differed in their level of preparedness for the risk of a pandemic. For example Singapore and Taiwan experienced the

swine flu and SARS crises and seemed to be better prepared and able to contend with the COVID-19 pandemic (Lowy Institute 2021; Rogers 2020). Likewise, the level of geopolitical risk is quite different from one country to another (Marsh 2019).

Even internal risks are likely to vary by location. Labour disputes are more common in some countries. The risk of a serious failure in the quality or safety of inputs is more likely in an environment with many firms, rapidly evolving markets, and regulatory weaknesses; for example, in 2008 baby formula was contaminated in China (Puddy and Burnie 2018).

The architecture of the supply chain will also determine vulnerability to risk (figure 2.2). Although all supply chains are vulnerable to infrastructure-related risks, because they rely on transport systems, some supply chains characteristics can increase risks; such characteristics include:

1. limited flexibility — a supply chain that depends on a node or a link that is not easily substitutable
2. geographic clustering — if all the firms in one tier are geographically clustered, this increases the exposure to localised environmental risk, localised geopolitical risks and localised infrastructure-related risks
3. length — a long supply chain involving inputs changing hands between many firms.

The first two have the potential to create market-level vulnerabilities because they are more likely to affect all firms within a market. Long supply chains can also cause market-level vulnerabilities, but if there is flexibility in each supply chain and a spread in the location of firms, this diversifies the market-level risk.

Finally, operational decisions affect risk. If firms choose to operate with JIT processes, there is a lack of redundancy which increases vulnerability. JIT involves holding minimal inventory to reduce costs and waste — and promptly resolving any problems. However, this approach to cost minimisation does not leave much room for error, such as if a supplier misses a shipment, transport is disrupted, or if the firm experiences a surge in demand. Firms face trade-offs between efficiency and resilience (chapter 5). Lack of redundancy, if adopted by most firms in a market because of competitive pressure, raises market-level vulnerability.

Limited flexibility

Relying on a single supplier, a single production site, or depending on a particular supply route, a unique infrastructure (such as a port or IT system), or on a high-skilled workforce can contribute to inflexibility in a supply chain. Relying on a single supplier reduces costs and complexity. But in the event of a disruption, it can be difficult or impossible for such supply chains to replace that component of the supply chain in a short period of time.

If there are a small number of firms in the market and one supplier is disrupted, then others may not be able to replace the disrupted firm's output rapidly, because of capacity constraints. Market concentration (and capacity constraints) increase firm-level risk, and

create some market-level risk; there is a risk that a subset of market supply cannot be quickly replaced. In the extreme, there is substantial market-level risk if all firms have the same source. If there is a monopoly supplier for a critical input (one which cannot be easily substituted) there are no options if the monopolist is disrupted. Market concentration is a major source of market-level vulnerability.

Some supply chains can be thought of as being 'diamond' shaped, with the manufacturer at one end of the chain, multiple firms supplying the manufacturer, but the entire chain relying on a single firm upstream. Some pharmaceutical supply chains are thought to be diamond shaped, relying on a single producer for their active ingredients; and many of these producers are in China or India (Horner 2020). A firm may not be aware of how concentrated the market truly is, and may assume it has diversified its risk if it chooses several suppliers. Likewise, it can be challenging for policymakers to identify this market-level vulnerability, due to data constraints.

Lack of flexibility is also an issue in transport. Bottlenecks in transport links also increase the vulnerability of a supply chain as there may be limited substitute routes in the event of a disruption. Bottlenecks include reliance on a port or a specific maritime, land or air route. During the COVID-19 pandemic, some ports around the world experienced significant delays as they struggled with shortages of workers due to illness (Lynch 2021), and introduced infection-control protocols to ensure goods continued to move (UN ESCAP 2020, p. 5). In the case of air transport, the use of airspace is regulated through a network of mostly bilateral 'freedom of the air' agreements that define how airlines can use airspace for both passenger and freight transport, and therefore constrain flexibility in responding to changed conditions.

In terms of vulnerability to market-level risk, the closer the bottleneck infrastructure is to Australia, the more likely it is to affect most firms in the market. Imports into Australia are dependent on a small number of domestic ports, each with limited capacity, and thus are at risk of significant delay in the event of a natural disaster or infrastructure failure.

Geographic clustering

If all the firms that supply a critical input are clustered in the same location, any risks to that location become much more serious.

In 1999, an earthquake disrupted Taiwan's semiconductor firms; these firms supplied 17 per cent of the world's semiconductor chips which are used as inputs to electronic equipment. The resulting price increase affected some (but not all) personal computer producers, and their prices increased (Tomy 2020, p. 9). Had the earthquake been closer to the centre of semiconductor manufacturing and had Taiwan been a larger share of the industry, the computer industry would have been disrupted more seriously. Yet by 2017, Taiwanese foundries accounted for 66 per cent of the global semiconductor market (statista 2020).

Geographic clustering is a clear source of market-level vulnerability, because every firm in the industry is affected. Chapter 4 illustrates how indices of geographic concentration can be used as an indicator of vulnerability.

The length of a supply chain

When goods and services are transported across numerous regions, they are exposed to a variety of environmental risks (Stecke and Kumar 2009, p. 203). If a supply chain crosses many national borders, it is more susceptible to geopolitical and regulatory risks (changes in policy and in the application of policies).

Increasing the number of tiers makes a supply chain more complex, decreases transparency and increases the vulnerability of a supply chain. While a firm's managers have strong incentives to manage risk along its entire supply chain, they have less information about risk at another site, or in another country. This information problem is exacerbated when the other site is owned by a different firm. The supplier may have an incentive to hide information about their costs or the risks they face from the firm that buys their products.

A survey of firms found that 43 per cent had good level of visibility within their tier 1 suppliers only, 46 per cent within tier 1 and 2, and only 11 per cent for all tiers of suppliers (SCM World 2017, p. 46).

While this is a significant source of firm-level risk, it will not create market-level vulnerability unless most firms in the market have long supply chains, and one of the other two sources of risk also applies.

Dimensions of risk and risk management

Risk should be viewed along two dimensions: the probability of an event occurring; and the consequences or effect of an event (Ritchie and Brindley 2007, p. 305).

The probability of a disruption is estimated based on historical information about the occurrence of events. The likelihood of some external risks (environmental, geopolitical, and so on) may be difficult for firms or policymakers to accurately assess. However, based on historical information, it is still possible to assess the likelihood of a disruption at a particular node or link, independent of the underlying cause of the disruption.

Determining the probability of a risk can be difficult, but it is important that risk management includes events with low probability and with probabilities that are difficult to estimate as these risks can have severe consequences.

The effect of an event can be viewed in terms of cost. An interruption in supply might force a firm to find another, higher-cost source of supply; if no supply is available, the interruption is similar to an infinite increase in costs. This conceptualisation also accounts for some suppliers filling orders in the order that they are received, while others might sell to the

highest bidder (Sheffi 2020). So risks can be quantified in terms of their effects on costs along a supply chain. The duration of the cost increase is also relevant to firms and policymakers.

Other ways firms consider risk and risk management strategies is by thinking about:

- the **duration** of the event, such as how long the effects may last for
- the **lead time** of the event, this refers to whether a firm can anticipate an event occurring
- the **initial shock** and **contagion** of the shock, which can be considered from both a geographical perspective and an industry perspective. For example, the initial shock of the COVID-19 pandemic was felt by China, then spread to other countries. Likewise, for industries, initially only a few industries were affected (those that relied on production in the area of Wuhan) then this spread as the virus spread. (Lund et al. 2020, pp. 23–24)

Firms' risk management strategies aim to reduce the effects of a disruption. Firms can reduce the probability of some events occurring, for example, a cyberattack or poor supplier relations, but firms have little control over external risks. Management of these risks instead aims to prepare a firm to better respond or mitigate damage to a firm's supply chain.

Chapter 5 discusses risk management strategies in more detail and where government might play a complementary role.

3 A framework to identify vulnerable supply chains

Key points

- This chapter outlines a framework that is designed to identify supply chains that are vulnerable to disruptions *and* whose absence would jeopardise the functioning of the economy and hence Australians' wellbeing.
  - A distinguishing feature of the framework is the adoption of a 'wide net' by first identifying vulnerable product categories using a data-driven approach. Then it identifies which of these vulnerable products are used in essential industries, and then relies on expert assessment and other methods to determine which products are critical.
  - The framework is complementary to other approaches that begin with expert assessment.
- The approach embodies the notion of a resilient supply chain, as one that continues to function when exposed to disruption and adapts to changes.
  - Resilient supply chains are part of a well-functioning economy, which produces the income and goods and services that are the basis for Australians' wellbeing.
- The framework focuses on the short-term period after a supply chain disruption — a period of up to six months. This time frame was selected because in the long-run, well-functioning markets allow prices and quantities to adjust and supply chains to adapt.
- The notions of *vulnerable*, *essential* and *critical* goods and services are at the core of the framework.
- A vulnerable market-level supply chain is one that has characteristics which makes it susceptible to risk. These characteristics include: a lack of flexibility (where a supply chain depends on something not easily substitutable); geographic clustering; and having many nodes within a supply chain.
  - A market-level supply chain with a lack of flexibility is typically a highly vulnerable supply chain, and if a supply chain has more than one characteristic that makes it susceptible to risk this increases the vulnerability of the supply chain.
  - Data availability will shape the data exercise. No dataset can capture all dimensions of vulnerability.
- Essential goods and services meet the basic needs of Australians, and are part of the output of numerous industries, including food, water, health, communications, energy, transport, finance and government.
  - There are two views of essential — a narrow view which includes goods and services that meet Australians' primary needs, and a broad view which includes the list of goods and services from the narrow view, and any goods and services that provide income security to Australians.
- Goods and services that are deemed critical to the functioning of the economy and to the wellbeing of Australians cannot be substituted and are critical to the supply of an essential good or service.

This chapter outlines a framework that first uses a scan of data to identify supply chains that are vulnerable to disruptions *and* whose absence would jeopardise the functioning of the economy and hence Australians' wellbeing. The framework is applied to Australian imports in chapter 4 and will also be applied to Australian exports in the final report. It is also capable of being applied to whole supply chains, whether international or within Australia.

The framework is best thought of as a tool to gain insights into supply chain risks and to identify strategies to manage those risks (discussed in chapter 5). Typically firms apply a combination of strategies to insure against the risks of disruption, according to the costs of the strategies and their benefits in the case of a disruption.

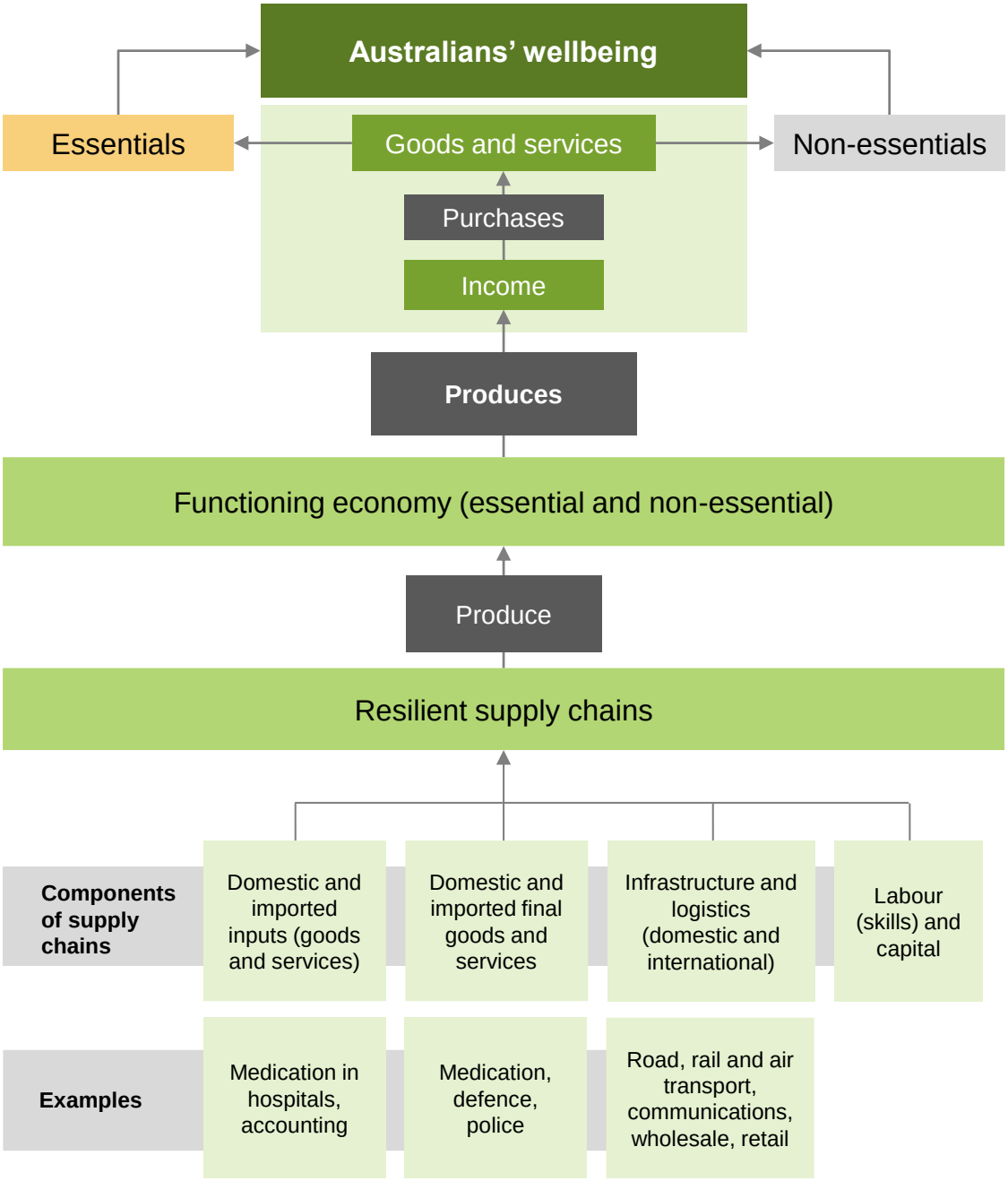
3.1 The links between wellbeing and supply chains

As outlined in chapter 2, goods and services are produced through supply chains, and all supply chains are subject to risk, to a greater or lesser extent. However, not all supply chains are essential to Australians' wellbeing. A disruption to the supply of American peaches, to Australia for example, is unlikely to have any marked effect on the wellbeing of Australians. (From this point onwards, we are discussing market-level supply chains, and the risk of disruption to an entire market.)

Figure 3.1 represents the role of supply chains in the functioning of the economy and the production of material wellbeing for Australians. Put simply, material wellbeing is a function of goods and services consumed, and some of these goods and services are *essential*. In turn, essential goods and services are those that support the basic needs of Australians; these needs are physiological, 'vital to survival', and take priority over other needs ('all needs become secondary until these physiological needs are met' (Maslow 1943; Mawere et al. 2016, p. 5)). This implies that essential goods and services are those that support the provision of health, water, food and shelter. That said, there are different views about what specific goods and services are essential, as discussed in detail below.

In the context of this study, distinguishing between essentials and non-essentials means that basic needs can be prioritised and risk management is focused on the resilience of the supply chains of essentials.

Figure 3.1 **The relationship between wellbeing, the functioning of the economy and supply chains**



Note: The green box surrounding goods and services and income represents the macroeconomic links between income (GDP_I) and expenditure on goods and services (GDP_E).

A well-functioning economy produces income that is used to buy essential and non-essential goods and services, and relies on resilient supply chains within the country and internationally. A resilient supply chain is one that continues to function when exposed to shocks and adapts to changes. Supply chains are comprised of many components which are

all vulnerable to shocks (chapter 2). As highlighted in chapter 2, some supply chains are more vulnerable than others, in that they have characteristics that make them more susceptible to risks. Chapter 5 explores how supply chain resilience can be improved and the role of governments.

3.2 The approach to identifying goods and services that are vulnerable, essential and critical

Consistent with this broader wellbeing framework, the Commission's analytical approach is designed to identify goods:

1. whose supply chains might be *vulnerable* to the risk of disruption
2. are *essential* to the wellbeing of Australians
3. are *critical* to the production of an essential good or service.

Identifying which goods and services are *essential* is the most subjective component of the approach. The formal analysis of supply chains in chapter 2 highlighted the sources of risk and characteristics of supply chains that render them more vulnerable. The notion of *critical* defines an input as critical when there is no available substitute for that input, and if it is not available, it would shut down a supply chain of an essential good or service.

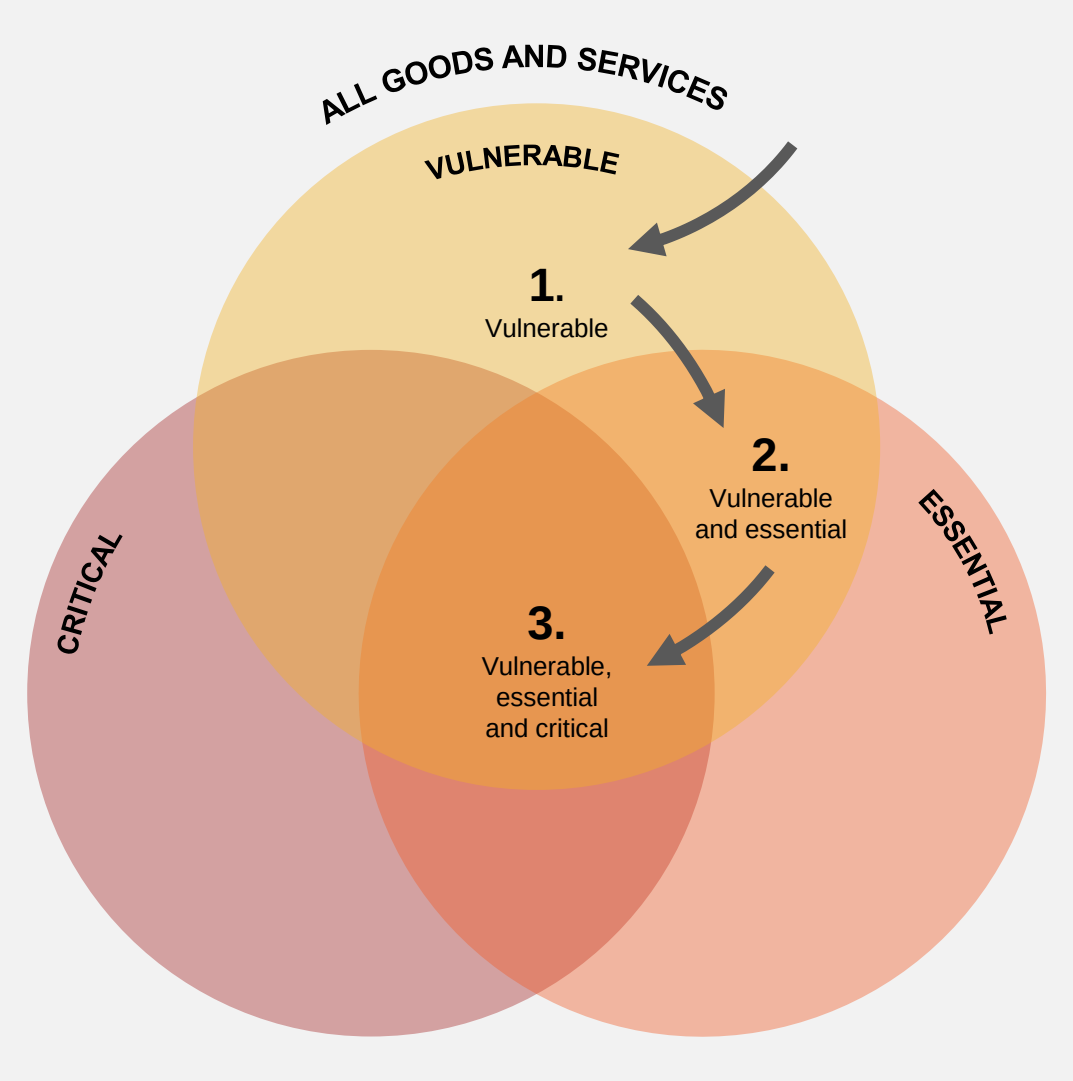
Many analyses of country-level risk begin by reversing steps 1 and 2 above and using, instead of a data scan, a process of expert consultation. The consultation approach engages with experts to identify the essential sectors and key inputs that may be at risk (box 3.1).

Box 3.1 The expert consultation approach — a recent example

The Department of Defence recently used an expert consultation approach to identify the effects of a collapse of global governance (Engineers Australia 2019). The report, based on a workshop with 17 engineers, outlines a timeline of effects from the collapse and the experts determine that the majority of effects, including an increase in cyberattacks, failure of water treatment systems, fuel shortages, food shortages, social unrest and wide-spread unemployment, would occur within three months.

The Commission's approach combines the use of data *and* experts. It starts with a broad scan of supply chains to identify those that might be vulnerable to shocks and uses filters to identify those goods and services that might be vulnerable and essential to the wellbeing of Australians (figure 3.2). This approach may be viewed as a data-with-experts approach.

Figure 3.2 **Analytical framework**



The scan is data-driven, and thus can only identify those vulnerabilities that will show up in the available datasets. The list of vulnerable supply chains is subsequently separated into those that are part of supplying goods and services that are considered to be essential. The resulting list of goods and services can then be used as a starting point to identify whether any of the vulnerable and essential items are *critical* to the supply of essentials. This stage of the approach is based on expert consultation.[1]

This data-based and relatively mechanical sorting can occur before exercising judgement as to what is an essential good. By first identifying vulnerabilities across supply chains that might affect parts of the economy, including essential and non-essential goods and services, the framework captures a large set of goods and services. The initial broad scan for vulnerability

1 The third step of the framework has not been implemented in this report due to time constraints.

allows for some flexibility in deciding on the breadth of the 'essential' step, as discussed below. A broad scan also means that the process is less prone to cognitive bias.

Although the framework might identify a good or service as vulnerable when it is not, akin to producing a 'false positive' (also known as a type 1 error), it is also likely to reduce the probability of missing a good or service that *is* vulnerable, therefore reducing the likelihood of a 'false negative' (also known as a type 2 error). The data part of the approach is complementary to an expert-based part, and is likely to reveal some vulnerabilities that might otherwise be overlooked.

The analytical approach used in this study is similar to processes that businesses use to identify critical goods and services (box 3.2). However, one of the main differences relates to the first step: this study concentrates on supply chains, which if disrupted might jeopardise the supply of goods or services that are essential to Australians' wellbeing, regardless of their size or value. In contrast, private sector supply chain risk management seems to concentrate on suppliers who provide goods and services over a defined value (box 3.2).

Box 3.2 Unilever's framework to identify critical suppliers

One method used by Unilever to manage supply chain risk is to identify critical suppliers. This process involves:

- starting with all suppliers
- identifying suppliers with spend over a defined threshold
- examining whether there is a 'unique dependency' on the supplier, that is, a default from the supplier would result in a capacity constraint
- assessing whether there are alternative suppliers
- engaging a third party to analyse and rank the risk of the supplier; if high, this supplier is determined to be a critical supplier.

After a critical supplier has been identified, Unilever develops a business continuity plan for that critical supplier, and puts in additional support measures.

Source: Unilever (2020).

Defining vulnerable supply chains

As outlined in chapter 2, a vulnerable market-level supply chain is one that has characteristics that make it susceptible to disruption. Primarily these relate to the architecture of the supply chain:

1. limited flexibility
2. geographic clustering
3. length.

Which of these vulnerabilities can be identified from data will depend on what data is available. In chapter 4 we outline an example using trade data.

Import and export data can help identify geographic clustering. If most imports in a category are sourced from the same country, that means that suppliers are geographically clustered. It may also mean that the imports are from a small number of firms, which is another source of limited flexibility. (The number of supplier firms could be verified with more detailed customs data.) But data on Australian imports and exports cannot identify where products were sourced further up the supply chain, or whether flexibility upstream is limited.

Defining essential goods and services

The second step of the framework is to separate essential goods and services from non-essential ones.

Not all vulnerable supply chains are essential for Australians' wellbeing (figure 3.2). As noted earlier, essential goods and services can be defined as those that support the basic needs of Australians such as food, shelter, water and health, but there are many ways to define essential.

Some jurisdictions within Australia define essential services in legislation (table 3.1). Typically the lists include electricity, gas, water and logistics services, but there are also notable differences, with NSW including health and more services generally than the other states.

Commonwealth departments and the Royal Commission into National Natural Disaster Arrangements have other definitions (table 3.2). Again, electricity, water and logistics services are included and there are other differences:

- the Critical Infrastructure Centre includes the Commonwealth Government (though interestingly, not state and territory governments)
- the COVID-19 critical sector list includes aged care
- the Royal Commission report did not explicitly list essential goods and services. Those shown in the table are the main goods and services mentioned in the Commission's report. The report has a section devoted to fire retardant being an essential good and the strain on its supply chain during the 2019–2020 bushfires (Royal Commission into National Natural Disaster Arrangements 2020a, p. 233) (appendix B).

Table 3.1 **State-level definitions of 'essential' vary**

Essential Services Act 1988 (NSW)	*Essential Services Commission Act 2001* (Vic)	*Essential Services Commission Act 2002* (SA)
The production, supply or distribution of any form of energy, power or fuel or of energy, power or fuel resources	Electricity industry	Electricity services
Public transportation of persons or the transportation of freight	Gas industry	Gas services
Provision of fire-fighting services	Ports industry	Water and sewerage services
Provision of public health services	Grain handling industry	Maritime services
Provision of ambulance services	Rail industry	Rail services
Conduct of a welfare institution	Water industry	
Conduct of a prison	Non-cash payment transaction industry	
Provision of garbage, sanitary cleaning or sewerage services	Commercial passenger vehicle industry	
Production, supply or distribution of pharmaceutical products		
Supply or distribution of water		

The scope of essential goods and services is affected by the time frame being considered and by their role in supporting the basic needs of Australians. If the time frame was longer than just the immediate response to a supply chain disruption, then other needs of Australians may be considered and the definition of 'essential' broadened. This study focuses on short-term disruptions to supply chains (up to six months) and their implications for the broader economy. A shock creates a large initial increase in price, reducing demand and providing incentives to increase supply. The reduction in demand reduces Australians' wellbeing. During the subsequent adjustments, supply increases and reducing prices return Australians' wellbeing to at or near the initial situation/equilibrium. In many markets for essential goods or commodities, such adjustments are likely to occur within a period of six months.

Table 3.2 **National-level definitions of 'essential' vary**

Critical Infrastructure Centre	Department of Home Affairs COVID-19 critical sectors[a]	Royal Commission into National Natural Disaster Arrangements
Communications	Medical technology	Electricity
Energy	Critical infrastructure	Communications
Water services	Telecommunications	Water
Banking and finance	Engineering and mining	Transport
Transport	Supply chain logistics	Fire retardant
Food and grocery	Aged care	
Commonwealth Government	Agriculture	
Health	Primary industry	
	Food production	
	Maritime industry	

[a] This list was used as eligibility criteria for non-citizens to receive a travel exemption during the COVID-19 pandemic. Specifically: non-citizens with critical skills required to maintain the supply of essential goods and services (as listed here) may be granted a travel exemption.

Sources: Critical Infrastructure Centre (2021); Department of Home Affairs (2020a) and Royal Commission into National Natural Disaster Arrangements (2020a, p. 227).

Selecting essential goods and services

When thinking about selecting a set of essential goods and services, it is useful to think of two views of different breadths:

- a narrow view might focus on basic needs; for example, food and drinking water and the services required to deliver them might be part of a narrow view (Often, only part of the output of an industry is considered to be essential.)
- a broader view might focus on which goods and services should be prioritised after those in the narrow definition. This subset might include goods and services that are essential to the functioning of the economy, especially as they affect the incomes of many Australians, nationally or regionally.

Exports are also included within the broader view of essential. Exports generate a significant proportion of Australia's income, which is required to purchase goods and services. For example, exports of iron ore, coal, natural gas and education are important sources of income, accounting for about 50 per cent of Australia's exports in 2019 (DFAT 2020). But while a disruption to the export sector can be significant for those employed in the sector, disruptions to the export sector would not affect Australians' basic needs in the narrow sense as defined above.

This study adopts the narrow view of essential goods and services, defined as those whose supplies are necessary to Australians' basic needs. That said, the list of essential goods and

services is broader than most of the lists reviewed above, because those lists reflect the focus of the study or institution that made them. The list in this study needs to cover all goods and services that are essential to the wellbeing of Australians. Some elements of the list are obvious in that Australians could not live without them for even a few weeks (water and medicines), while others are necessary to facilitate the transport and distribution of those types of goods (communications, energy, and transport). And some services support the functioning of the economy by providing essential services to firms (such as the payment system parts of the banking and finance sectors). Among government services, defence needs to be always operational and maintain a state of readiness to respond to security and safety emergencies. Further, most health infrastructure, social and related services, and services that support the tax and transfer system, ensure that Australians' basic needs are met. Supply chains that are part of the production of all these types of services need to be maintained to ensure the continued delivery of these essential goods and services. The list adopted for this study is found in chapter 4.[2]

While defence is essential to the wellbeing of Australians, it is not in scope for this study because the Commission does not have access to the information required due to national security reasons. That said, some of the economic and risk management principles in this study are relevant to the management of supply chains that support defence.

In the final analysis, the set of goods and services that are essential to the wellbeing of Australians is a matter of society's choice. That said, in the context of a study of this type, the set to be used is likely to vary depending on the purpose of the analysis. The potential for narrower or broader definitions of sets of essential goods and services illustrates the value of starting with a scan of supply chains and following that first step by a screen of varying 'size', depending on the focus of the analysis. For example, a study concentrating on the risks to Australians' health would have a very narrow focus, whereas a study on the risks to the Australian economy would have a broader focus.

Defining critical goods and services

The third step of the framework is to identify goods and services that are *critical*, in that they are required in supplying a good or service, cannot be substituted easily and cannot be designed out of the production process (within six months). This last screening relies on consulting with experts to identify (from the list of vulnerable inputs into the supply of essential goods and services) which ones might be critical. A good or service is substitutable if it:

- can be sourced from an alternative supplier
- can be replaced by another good or service.

2 Food is considered essential. That said, in Australia no disruptions to global supply chains are likely to affect access to food within the six month time frame under consideration so the remainder of the report excludes food.

Identifying such inputs requires consultation with experts who are familiar with the relevant production processes, such as engineers and warehouse managers. Experts can identify which goods and services are critical by answering the following questions.

- Are alternate sources of supply for the good readily available or can supply be increased quickly — from foreign or domestic sources?
- Can the input or good be substituted relatively easily by another (that is, with relatively little need to redesign)?

There are also data-driven approaches to identifying critical inputs. One is to measure the elasticity of demand for the input within the industry: if the world price of the input has undergone a large change, how did demand from the industry respond? A lack of responsiveness to changes in the price of an input is an indication that it is very difficult to substitute away from this input. That said, this approach would not fully capture the critical criterion: that is, if the good or service were unavailable, the supply of an essential good or service would be shut down. Appendix D shows how elasticities may be used to identify critical goods.

Once goods and services that are critical to production are identified, the next step in the framework is to identify appropriate risk management strategies; chapter 5 reviews such strategies. There are some conditions under which governments might intervene or facilitate some risk management strategies. Conditions under which that might be required are investigated in chapter 5.

Before that, chapter 4 applies the first two steps of the general framework developed here to Australian imports as an illustration of how it works.

4 Applying the framework to Australian imports

Key points

- The analytical framework developed in chapter 3 can complement existing processes for identifying supply chain risks. It also provides a methodology for suggesting whether inputs are likely to be critical, but criticality is best determined together with industry experts.
- The Commission has applied this framework using detailed data for goods trade. Applying the first step of the framework revealed that:
  - one-in-five imports is predominantly sourced from one country
  - global trade data suggest that for many of these products, alternative sources of supply exist and could be utilised should the need arise
  - one-in-twenty Australian imports (292 products) might be vulnerable to concentrated sources of global supply (worth A$20 billion)
  - the main supplier of vulnerable imports is China, accounting for about two thirds of those products.
- The second step of the framework examined how reliant the Australian supply of essential goods and services is on vulnerable imports. Applying this step revealed that:
  - essential industries used 130 of the 281 vulnerable imports in production
  - use of essential goods and services account for almost half of total household and government final consumption. Most of these goods and services are produced locally. Vulnerable imports play a limited role in meeting final demand either directly (as final goods) or indirectly (as inputs into production).
- Taken together, the results suggest that the main supply chain disruption risks arise from relying on concentrated imports of some basic chemical products and some personal protective equipment.
- Vulnerable imports are a small proportion of the cost of inputs for producing essential goods and services, which suggests that in many cases they may not be critical. But this evidence is not conclusive and industry experts are required to determine criticality.

The analytical framework developed in chapter 3 is intended for scanning data as a first step in identifying supply chains that are vulnerable to disruption *and* where their absence would jeopardise the functioning of the economy and, hence, the wellbeing of Australians.

This chapter applies the first two steps of the analytical framework to Australian imports to identify:

- which Australian imports are more vulnerable to disruption
- whether these imports play a material role in the delivery of essential goods and services in Australia.

It does not apply the third step in the framework to identify whether these imports are *critical* to the delivery of essential goods and services, although some of the evidence used in assessing whether vulnerable imports are essential does point towards factors that may be important in determining their criticality. Industry experts are best placed to determine criticality using their knowledge of production processes and the extent to which substitute products can be used in the event of any disruption (chapter 3).

The chapter begins by outlining the importance of imported goods to Australian economic activity (section 4.1). It then applies the first step of the analytical framework to ascertain how vulnerable Australian imports are to disruption (section 4.2). It then applies the second step of the analytical framework to examine how reliant the Australian *production* of essential goods and services is on vulnerable imports (section 4.3) and how reliant the *use* (that is, final demand by households and government) of essential goods and services is on vulnerable imports (section 4.4). The chapter then identifies some extensions that could be made to this work (section 4.5).

Applying the framework involves linking data on Australian imports, global trade, and Australian production to determine which industries use each product (appendix C). The analysis focuses on data from 2016-17, the latest year from which data are available from all three sources, to enable their linking.

No comparable dataset exists on Australian imports of services, and therefore it is not possible to assess the vulnerability of supply of imported services.[1] However, imports of services are susceptible to disruption in much the same manner as imports of goods. The COVID-19 pandemic, for example, has restricted the movement of people across domestic and international borders. Supply chain disruptions may occur where these people have specialist skills that Australia or its particular states may lack. Supply chain vulnerability to imported services and the movement of skilled labour should also be assessed using the best available information.

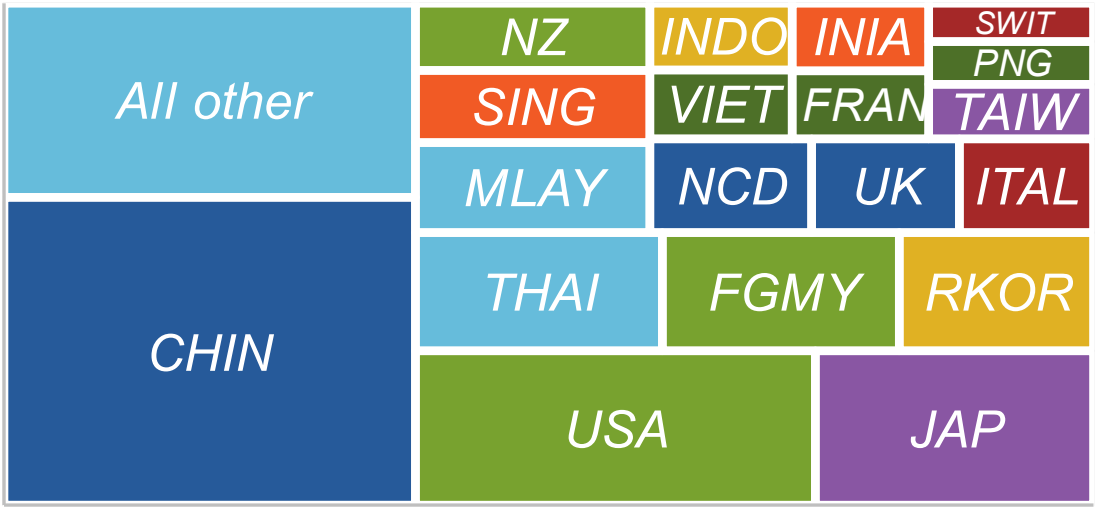
[1] Hereafter, imports refers to merchandise (goods) imports. It does not include imports of services. Services trade is inherently more complex to record than goods trade. The OECD-WTO Balanced Trade in Services dataset (BaTIS) collects global trade flows of services, but only records flows in 12 broad categories.

4.1 How important are imports to economic activity?

Australia imported 5950 different products in 2016-17.[2] The value of these goods imports was A$272 billion, or around 16 per cent of gross national income.

These imports came from 223 countries.[3] China and the United States were the primary suppliers, collectively accounting for just over one-third of the value of all imports (figure 4.1). Other notable suppliers included Japan, Thailand, and Germany (all over 5 per cent). The ten largest suppliers accounted for A$197 billion of imports (70 per cent of all imports). This indicates that, although imports came from 223 countries, most came from a relatively small number of countries. This may suggest a higher susceptibility to disruption.

Figure 4.1 **Australian imports are sourced from many countries**
Each country's share of Australian imports by value, 2016-17[a,b]



The area of each tile represents the value of imports from that country as a proportion of Australian imports .

[a] CHIN: China; USA: United States; JAP: Japan; THAI: Thailand; FGMY: Germany; RKOR: Republic of Korea; MLAY: Malaysia; NCD: no country details supplied; UK: United Kingdom; ITAL: Italy; SING: Singapore; VIET: Vietnam; FRAN: France; NZ: New Zealand; INDO: Indonesia; INIA: India; TAIW: Taiwan; PNG: Papua New Guinea; SWIT: Switzerland. [b] The ABS confidentialises imports of certain products to protect the confidentiality of the transactions involved. Confidentialisation prevents the products (and/or supplying country) from being identified.

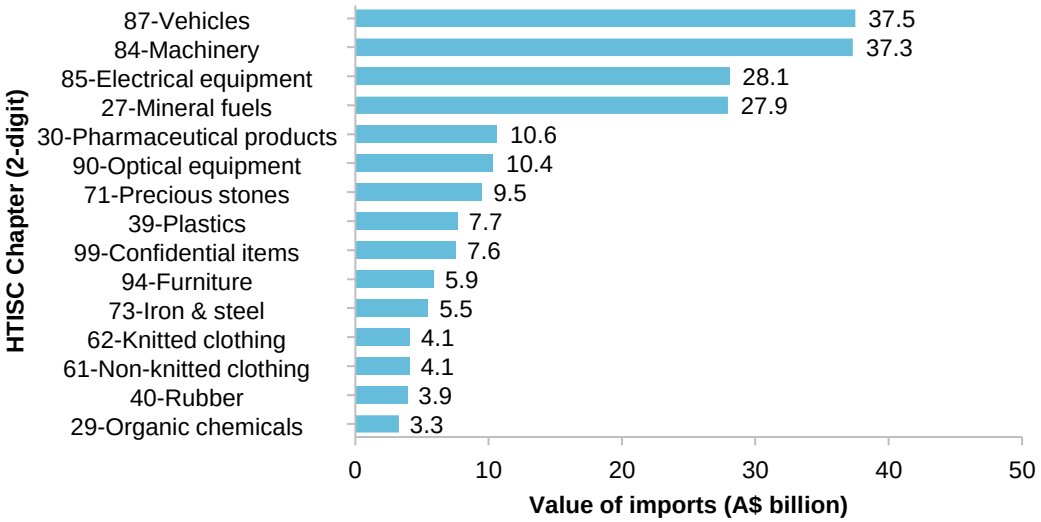
Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

2 The term product refers to each HS Subheading (8-digit) under the Harmonized Tariff Item Statistical Code (HTISC) classification unless otherwise stated (see appendix C for product classification details).

3 The definition of country used reflects that used in the Australian imports data to record the origin of the goods entering Australia. The geographic classifications used in the data is a mixture of sovereign countries (such as Papua New Guinea and Thailand) and geographic regions (such as Antarctica and the Channel Islands). Countries such as China, France, and the United Kingdom consist of multiple regions.

The main imports by value were: motor vehicles and parts; electrical, optical and other specialised equipment; fuel; pharmaceuticals; and chemicals (figure 4.2).

Figure 4.2 **Imports are dominated by vehicles, machinery, and fuels**
Top imports by value, 2016-17[a]



[a] The ABS confidentialises imports of certain products to protect the confidentiality of the transactions involved. Confidentialisation prevents the products (and/or supplying country) from being identified.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

Not all imports are of similar importance to Australian industry, the Australian economy, and the national interest. The consequences of any disruption to imports of clothing apparel, for example, would be less than the consequences of a disruption to the imports of fuels and pharmaceuticals.

4.2 How vulnerable are Australian imports to disruption?

Supply chain vulnerability may arise from the reliance of Australian producers (and consumers) on goods sourced from overseas, as their supply chains will be more susceptible to certain sources of disruption than those sourced locally. Imported goods are, for example, more susceptible to geopolitical events (such as trade disputes), and disruptions to transport corridors that they may pass through (such as the Strait of Hormuz). If most of the supply is from one location, vulnerability is greater: a natural disaster or other shock in that location can disrupt supply. The degree of vulnerability would generally increase when the number of *actual* and *potential* suppliers decrease, and when suppliers have market power. In the language of chapter 2, vulnerability is greater if there is geographic clustering, or limited flexibility.

As an extreme case, some Australian industries may cease production if there were to be a sustained disruption to the supply of a critical imported input. Consumers may also suffer if products that are integral to their welfare are unavailable, for example some medicines or chemicals for water treatment.

This section assesses supply chain vulnerability arising from sourcing imports from concentrated global markets. That is, it focuses on imports with high levels of market concentration. By implication, well-developed and diversified trading networks (networks of supply from multiple countries) are one way of mitigating any such risks.

Applying the framework to determine potential import vulnerability

As described in chapter 3, the process for identifying vulnerable imports is mechanical and data driven. The mechanical sorting involves progressively applying filters to assess whether:

- a single country accounts for a large share of Australian imports. This considers vulnerability arising from existing suppliers and trade flows, which provides an indication of *actual* supply risk
- there are limited alternative suppliers that Australia could access in the event of any disruption to existing suppliers. This considers vulnerability in terms of *possible* sources of supply, which provides an indication of *potential* supply risk.

The imported products that remain after applying these filters may be more susceptible to disruption, as Australia is reliant on limited sources of supply.

Australian imports data and global trade data for 2017 are used in the application of these filters (box 4.1).

Box 4.1 Trade data and classifications

The trade data used in this chapter is classified according to the international Harmonized System (HS), or its Australian extension known as the Harmonized Tariff Item Statistical Code (HTISC) (appendix C).

All trade data classify products at different levels of detail, ranging from highly aggregated to highly disaggregated categories (with more digits indicating progressively more disaggregated data). The analysis in this chapter assesses:

- Australian imports at the 8-digit level (known as the HS Subheading level). This level of detail is fine enough to enable vulnerable products to be identified, but not so fine that many substitute products are separately classified
- the global trade data at the 6-digit HS (which is the same as the 6-digit HTISC). This is the most disaggregated product classification available in global trade data.

Filtering process and results

Three filters are applied to the trade data to identify vulnerable imports, with supply chain risks progressively increasing with the application of each filter.

Filter one: Concentrated Australian imports

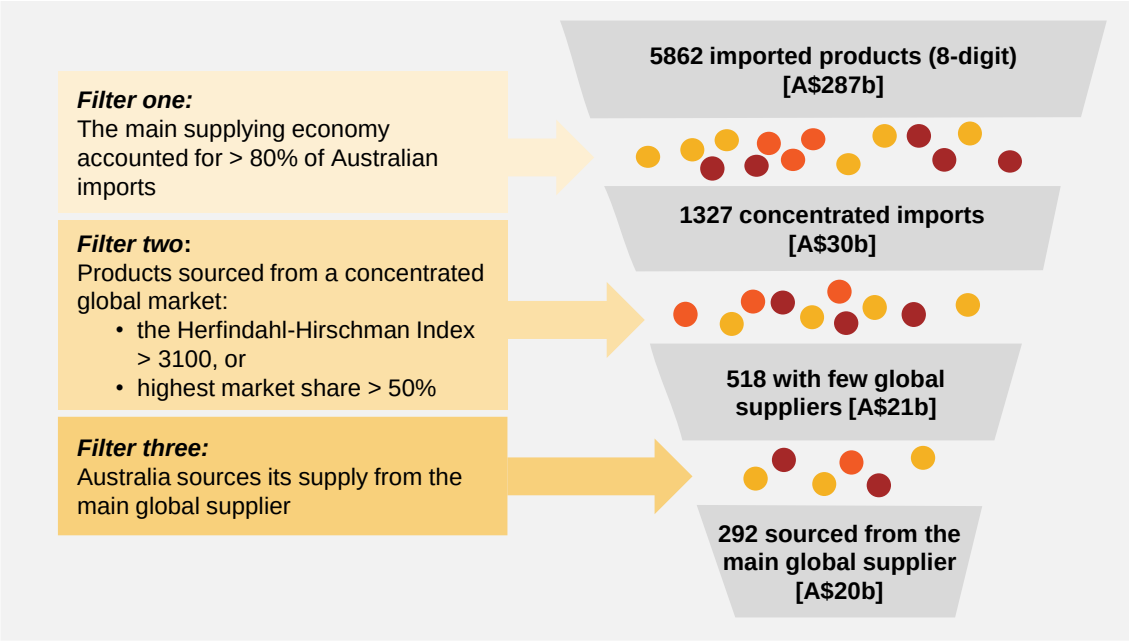
The first filter determines whether the market for each product that Australia imports is highly concentrated, as concentrated sources of supply entail additional risk. Australian imports are considered concentrated when the main supplying country accounted for over 80 per cent of imports of a product (appendix C).

The first filter indicates that 1327 products (worth A$30 billion) of the 5862 products (A$287 billion) that Australia imported in 2017 came from concentrated local import markets (figure 4.3). That is, the market was concentrated for one-in-five imports.

The number of concentrated imports identified is sensitive to a number of decisions made during the analysis including the threshold used to identify concentrated imports (80 per cent), the level of analysis (product aggregation), possible minimum value thresholds, and the exclusion of product groups (2-digit Chapters) that are less likely to be critical to national activities. (Sensitivity testing to gauge the robustness of the analysis to these assumptions is reported in appendix C.)

Figure 4.3 **The filtering process to identify vulnerable imports**

Number and value of products at each stage of the filtering process



Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished) and UN *Comtrade*.

Most concentrated imports relate to chemicals (both organic and inorganic), iron and steel, and different types of equipment. Imports of some other products, such as seafood and particular types of clothing apparel, were also highly concentrated. Agricultural products also accounted for many of the concentrated imports. These imports often complement Australian production by maintaining year-round supply out of the Australian growing season (such as imports of peaches from the United States).[4]

Concentrated products are found across many product groups, including: chemicals, fuels, pharmaceuticals, minerals, metals, fertilisers, plastics, transport parts and equipment, and military equipment.[5]

Other products might be vulnerable but may be missed in the analysis due to limitations inherent to trade classifications (box 4.2).

Box 4.2 Limitations with trade classifications

There are limitations in the trade data that may point to areas of vulnerability that cannot be identified in the present analysis.

- Import data is confidentialised for some products, suggesting that a product might be sourced from a limited number of suppliers. It is likely that products that are under patent (such as some medicines) are confidentialised given there are few producers, or one producer in the extreme case.
- The coarseness of product classifications may lead to groupings of vulnerable and non-vulnerable products. Active ingredients, for example, may be grouped with other chemicals that are not critical to the production of medicines that might be essential to the material wellbeing of some Australians.

These limitations also apply to production data, which has even coarser product classifications than the imports data. For example, the more aggregated nature of production data makes it difficult to determine the exact local and imported sales shares for each of the products covered in the trade data.

Filter two: Concentrated global markets

The second filter determines whether global trade in a product is also concentrated, as fewer potential sources of supply exist that could be utilised in the event of any disruption to existing supplies. Global markets are considered highly concentrated when the main supplying country accounted for over 50 per cent of global exports or when the Herfindahl-Hirschman Index (HHI) is greater than 3100 points (box 4.3).

4 The number of concentrated agricultural imports also reflects the fine-grained categories used to classify imports that differentiate between effectively similar products.

5 Although some military equipment appear in the imports data, it is only a partial view as other items are not recorded. This study does not analyse supply chains that relate to defence activities in depth (chapter 1).

Box 4.3 The Herfindahl-Hirschman Index

The HHI is the most commonly used measure of market concentration. It is popular because it summarises information about both the number of exporters and their respective market shares. It is calculated as the sum of the square of the market shares of each exporter (limited to the largest 50 exporters). The HHI ranges from 0 (not concentrated) to 10 000 (extreme concentration).

In US antitrust law dealing with firm-based concentration, a HHI between 1500 and 2500 is interpreted as moderate concentration and over 2500 indicates high concentration (US Department of Justice and Federal Trade Commission 2010).

Since the global trade data describe flows between countries, rather than firms, a HHI above 3100 is used to indicate that a global market is concentrated (appendix C).

The second filter reduces the number of concentrated imports from 1327 to 518.[6] This represents 9 per cent of the total number of products imported and about A$21 billion of value. This reduces the number of imports sourced from concentrated markets to one-in-ten.

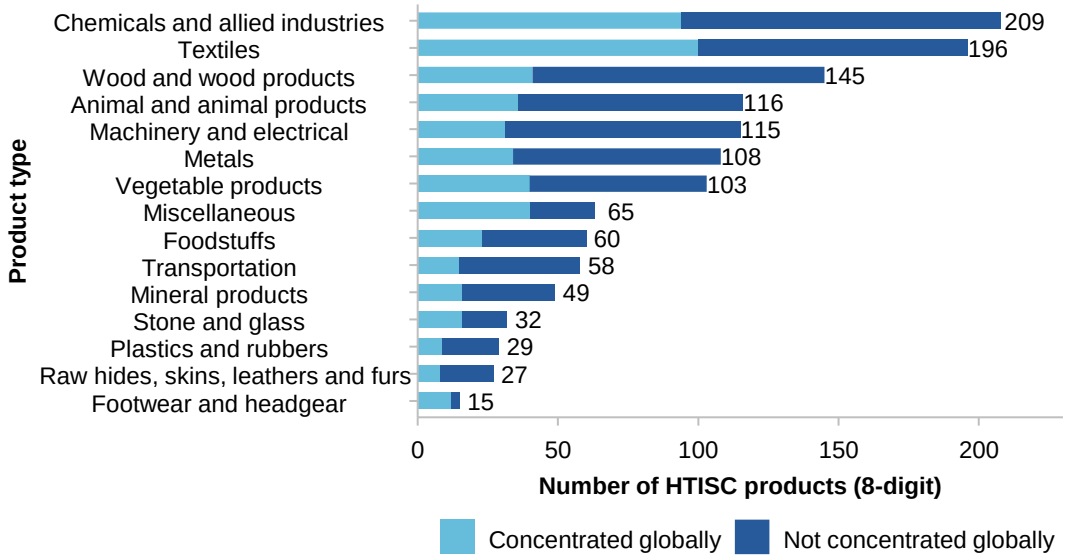
This indicates that alternate sources of supply exist for well over half of all concentrated imports that could be utilised in the event of any disruption to existing supplies. For example, Australia sources chlorine primarily from China, but the global market for chlorine is not concentrated and China is not the leading exporter of chlorine. This suggests that Australia could source chlorine from another country in the event of a disruption to Chinese supply.

The 809 products removed by the second filter indicate that many agricultural, food, wood, chemical, textile, and mineral products (such as fuel) have alternative sources of supply that could be utilised if the need arises (figure 4.4). However, the presence of biosecurity and other domestic restrictions may reduce the number of markets potentially accessible to Australia, such that they may, in reality, be effectively more concentrated than the mechanical data processing indicates.

6 Since the global trade data are available at a higher product aggregation than the Australian imports data (6-digit versus 8-digit), each concentrated import is linked to measures of global market concentration which are constructed at more aggregated product levels.

Figure 4.4 **The analysis of global trade data identified alternative suppliers for 809 of the 1327 concentrated imports**

Concentrated imports by product type[a] and whether global supply is concentrated. Products defined at the HS Subheading level (8-digit)



[a] Product type is based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act* (Cwlth) aggregated to 15 groups. 'Miscellaneous' includes products like: clocks and watches; musical instruments; bedding and lighting; toys; arms and ammunition; and works of art, collectors' pieces.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished) and UN *Comtrade*.

Filter three: Australia sources concentrated imports from the main global supplier

The third filter determines whether Australia sourced its concentrated imports from the main global supplier in a concentrated market. This filter works on the assumption that if Australia sourced a product from the main global supplier in a concentrated global market then, in the event of a disruption to the main supplier, there may be few alternative suppliers with the capacity to meet the shortfall in global supply, and more importantly Australian demand. Such products may be more susceptible to supply disruptions and global demand spikes, such as what happened with the supply of face masks and personal protective equipment (PPE) during the COVID-19 pandemic.

The third filter reduces the 518 concentrated imports to 292 vulnerable imports. This represents 5 per cent of the total number of products imported by Australia and about A$20 billion of value. The filter reduces the number of imports sourced from concentrated markets to one-in-twenty.

FINDING 4.1

One-in-five products imported by Australia is considered highly concentrated; however, the global trade data suggest that for many of these products alternative sources of supply exist and could be utilised should the need arise. The result is that one-in-twenty Australian imports might be vulnerable to concentrated sources of global supply.

Characteristics of the vulnerable imports

Vulnerable imports are classified by their *main* end-use, notwithstanding that some products are likely to have multiple end-uses. Most vulnerable imports are classified as either consumption or intermediate goods, with fewer capital goods (figure 4.5).

Consumption goods comprise of mostly textile, miscellaneous, food, and clothing products (figure 4.5a). A closer inspection of textile, and plastic and rubber products reveals that PPE (which suffered some supply chain disruptions during the COVID-19 pandemic) is included. While this provides some validation of the filtering approach, the labelling of products in trade data makes it difficult to precisely identify where the PPE products are in the HTISC product classification without detailed knowledge of the HTISC.[7] Further, there are products within textiles that are unlikely to materially affect the wellbeing of Australians if imports were disrupted (such as other clothing items).

Intermediate goods are likely to be inputs into Australian production and tend to encompass chemical, wood, metal, machinery and electrical, stone and glass, and mineral products. Many imports of chemicals and those from allied industries (such as fertilisers, pharmaceuticals, explosives, and soaps) were used as intermediate inputs. For example, disodium carbonate is identified as a vulnerable import used in the treatment of drinking water.[8]

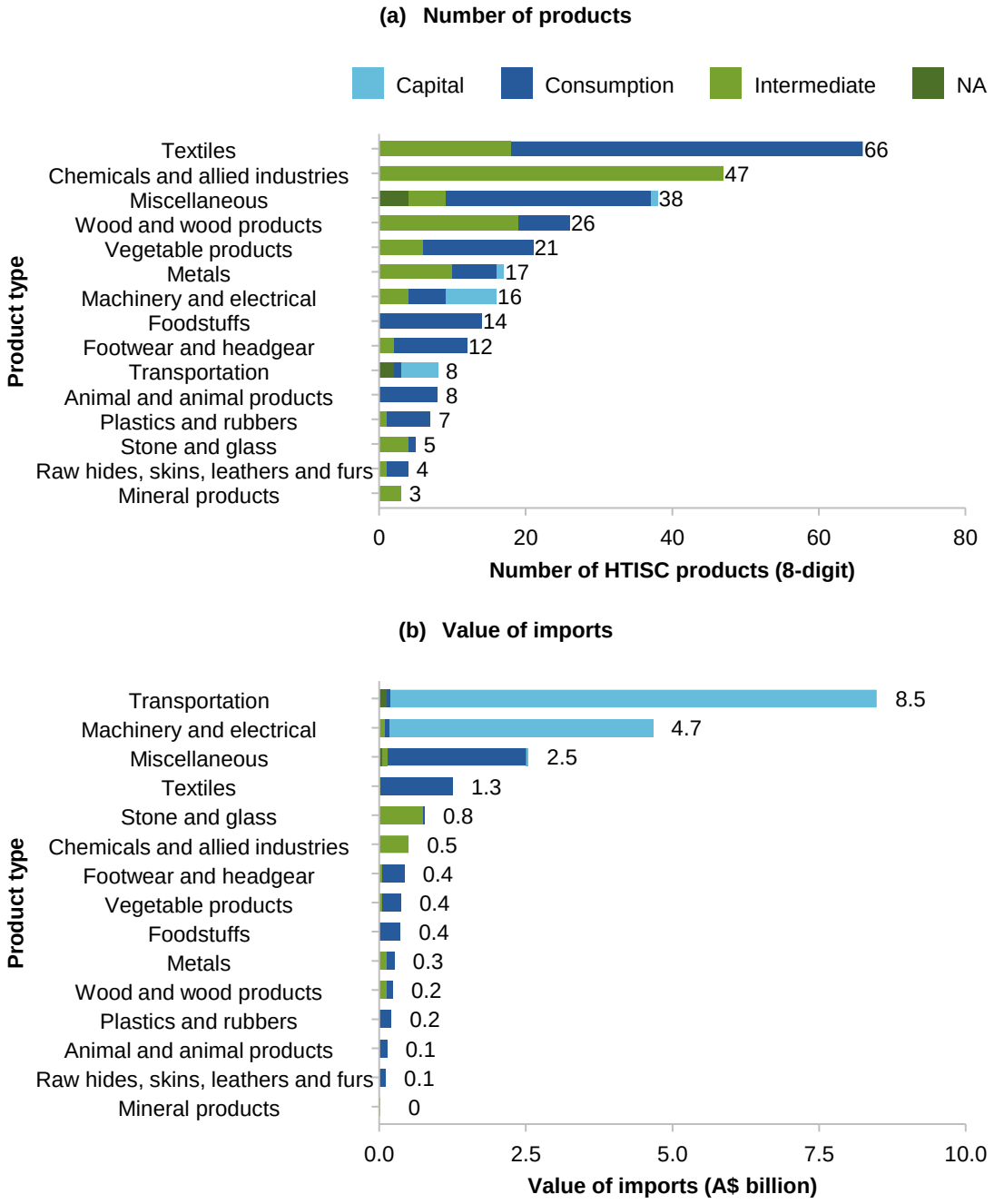
Capital goods typically form the highest share of vulnerable imports by value. These goods include transportation equipment (for which the value changes year-to-year depending on economic activity and infrastructure projects) and machinery and electrical equipment (primarily laptops and computers) (figure 4.5b). Imports of natural gas drilling platforms accounted for A$8.1 billion of the transportation category. This is an example of an irregular import; removing this product would reduce the value of vulnerable imports by almost half to A$12 billion.

7 PPE products that are identified as vulnerable imports are classified under HTISC codes 39262029 and 62101090.

8 That said, analysis in appendix D suggests that there are several alternatives to disodium carbonate; and there are many non-essential uses from which it could be diverted for some time.

Figure 4.5 **Characteristics of vulnerable imports**

Vulnerable imports by product type and main end use.[a,b] Products defined at the HS Subheading level (8-digit)



[a] Product type is based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act* (Cwlth) aggregated to 15 groups. 'Miscellaneous' mainly includes products like: clocks and watches; musical instruments; bedding and lighting; toys; arms and ammunition; works of art, collectors' pieces. [b] NA's have no main end-use classification and are imports of defence products typically from the United States.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished) and UN *Comtrade*.

The value of chemical imports is generally small, but chemicals are likely to be important in the production of goods that rely on imports of active ingredients (such as those used in domestic production of pharmaceutical products). The value of such imports may not be a good indicator of the importance of these products in production. Nevertheless, the value used does provide a natural way to rank the relative importance of products and for flagging the starting point for further investigation.

FINDING 4.2

Most vulnerable imports are classified as either consumption or intermediate goods, with fewer capital goods. But by value, capital goods typically form the highest share of vulnerable imports. Though important in the long run, disruptions to the supply of capital goods that might appear vulnerable are unlikely to affect wellbeing in the short run.

The majority of vulnerable imported products are sourced from China (68 per cent of vulnerable imports) (figure 4.6). China was the main supplier of most vulnerable textile (which includes PPE), chemical, metal, and machinery and equipment products to Australia in 2017 (worth a total of A$9.6 billion). The United States and India were the next largest suppliers of concentrated imports, many of which are not involved in the supply of essential goods and services.

FINDING 4.3

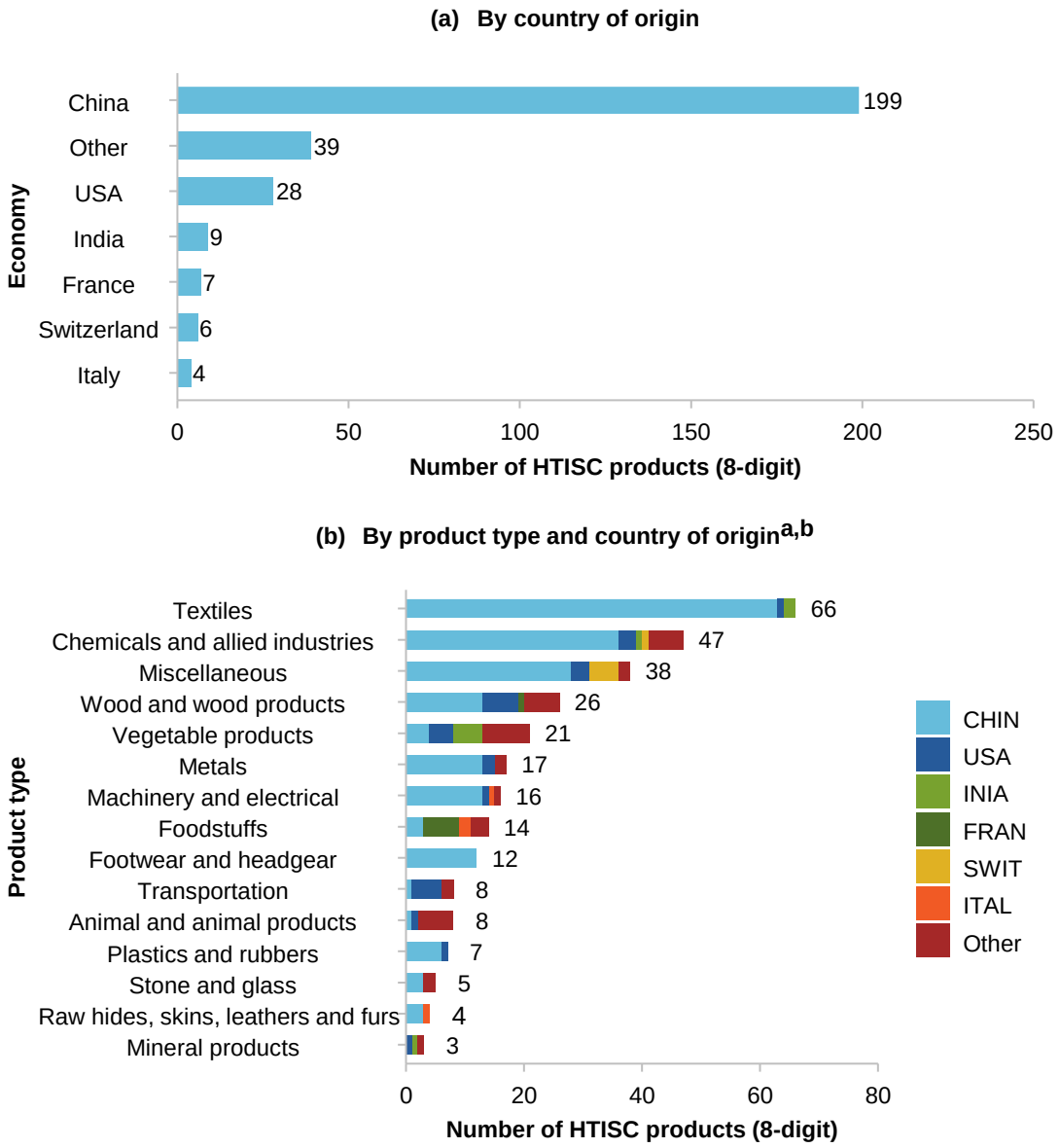
For many products, the main supplier of vulnerable imports is China, accounting for roughly two-thirds of those products. Notwithstanding this, the main source of supply varies by product.

The broad-based data scan identifies many products that, while having high import concentrations, are unlikely to be essential — either directly or as an input into the production of essential goods and services — for the material wellbeing of Australians. Examples of such products include festive decorations, certain types of alcohol, clothing items, and toys.

However, numerous other products are more likely to be inputs into essential industries. These include laptops, some chemicals, some PPE, and some products used in drilling for oil and refining iron and steel. A supply shock to laptops may not result in any short-term (six months) supply chain disruptions, but a supply shock to chemicals used in water treatment or in pharmaceuticals could have severe short-term impacts on supply chains (if no substitutes are available and no reallocation of supplies is possible).

Figure 4.6 **Most vulnerable imports come from China**

Number of products, defined at the HS Subheading level (8-digit)



a CHIN: China; USA: United States; INIA: India; FRAN: France; SWIT: Switzerland; ITAL: Italy. **b** Product types based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act* (Cwlth) aggregated to 15 groups.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished) and UN *Comtrade*.

FINDING 4.4

The list of vulnerable imports consists of a variety of products that are used in production or consumption, but many of them are not essential to the wellbeing of Australians.

4.3 How reliant is the production of essential goods and services on vulnerable imports?

The narrow definition of essential goods and services captures the basic needs of Australians, as defined in chapter 3: the provision of water, communications, energy, defence, health, medicines, logistics, transaction banking services, and government services. The essential goods and services are linked to the industries that produce them (table 4.1). The production of these goods and services account for roughly one third of all Australian production (in value-added terms).

Table 4.1 **Mapping of essential goods and services to Australian production data**

Essential good or service	*Input-Output group*[a]
Banking	Finance
Health	Human Pharmaceutical and Medicinal Product Manufacturing Veterinary Pharmaceutical and Medicinal Product Manufacturing Health Care Services Residential Care and Social Assistance Services
Water services	Water Supply, Drainage and Drainage Services
Communications	Broadcasting (exc Internet) Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing Telecommunication Services
Energy	Coal Mining Oil and Gas Extraction Petroleum and Coal Product Manufacturing Electricity Generation Electricity Transition, Distribution, On Selling and Electricity Market Operation Gas Supply
Logistics	Road Transport Rail Transport Water, Pipeline and Other Transport Air and Space Transport Transport Support Services and Storage Wholesale Trade Retail Trade
Government	Public Administration and Regulatory Services Defence Public Order and Safety

[a] These industries form part of the 114 industries categorised in the Input-Output tables (see appendix C).

Australian production of these goods and services are potentially susceptible to disruption where vulnerable imports play a significant role in their delivery or are a critical input to their production.

This section focuses on the application of step two of the framework to assess whether any of the vulnerable imports identified in section 4.2 are inputs into the Australian production of essential goods and services.

Applying the framework to the production of essential goods and services

Australian producers of essential goods and services may source their inputs locally or from imports. Some of those imports will be vulnerable.

This section links trade data with data on production to ascertain the extent to which the production of essential goods and services relies on vulnerable imports.

Conceptually, this process involves:

1. identifying those industries that produce essential goods and services
2. assessing whether any vulnerable imports are inputs into the production of these industries
3. assessing the degree to which these industries rely on vulnerable inputs, as a share of total inputs.

Linking the datasets indicates which vulnerable imports are used in which industry but it does not indicate whether the vulnerable imports are *critical* to the functioning of the industry. As a preliminary step toward assessing criticality, the share of inputs to an industry that are imports is measured, and what share of those imports is vulnerable. (An industry that primarily uses imports, and vulnerable imports, is more likely to be significantly affected by a disruption in the supply of imports.)

Data used

The analysis draws on Australian production data from the ABS Input-Output (I–O) tables. The I–O tables provide detail on the production and final use of goods and services in the Australian economy in 2016-17, covering 114 industry and product groups.

The list of essential goods and services (as defined in chapter 3) are mapped to the 114 industry and product groups (table 4.1). These include: health, energy, water, logistics, communications, banking, and government. Generally, multiple industry classifications make up an ‘essential industry’ (similarly, multiple products make up an ‘essential good or service’). For example, ‘communications’ is comprised of three detailed industry classifications: broadcasting, internet, and telecommunications.

The Commission used the published I–O tables to separate the use of imported products in production and final use from those sourced locally (appendix C). This disaggregation enables the identification of whether inputs into essential industries are mostly sourced locally or from imports. Industries that source the same input locally and from imports will be less susceptible to any disruption in the supply of imports. The Australian imports data (5950 products) are then mapped to the more aggregated products used in the Australian production data (114 products) to indicate the use of vulnerable imports by essential industries.

The ABS does not publish a concordance or mapping from the HTISC classifications used in the trade data to the classifications used in the I–O tables. The absence of such a concordance impedes the analysis of supply chain vulnerability. To overcome this, the Commission has used publicly available and historical mappings (for 2004-05) to construct a concordance from the trade data (HTISC) to the I–O tables. This process is not straightforward, and hampered by widespread changes to the trade and production classifications over time (appendix C).[9]

How reliant are essential industries on imported inputs?

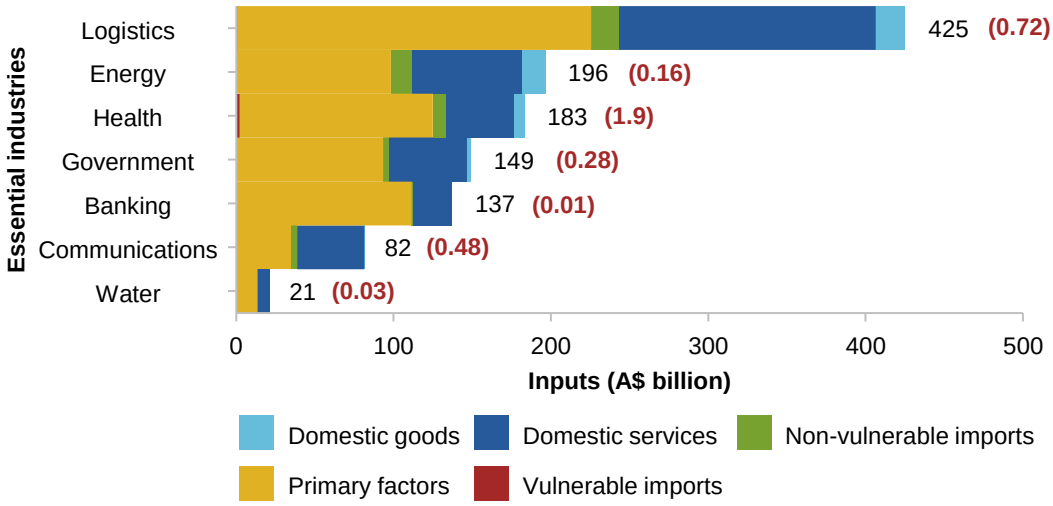
For each industry, the I–O tables indicate the value of each input into production, including goods, services, and payments to labour (wages) and to capital owners. For example, the I-O tables list the value of basic chemicals (domestic and imported, separately) used by each industry. Given that disodium carbonate is identified as a vulnerable import and classified as a basic chemical (according to the concordance), an essential industry that uses disodium carbonate will be assigned a share of the value of the import (from the 2016-17 trade data) based on the shares of imported basic chemicals that each industry uses. So only part of the value of the imported basic chemicals product group will be classified as vulnerable — the part that corresponds to disodium carbonate imports.

Imported inputs form a very small part of the cost structures of the essential industries that produce essential goods and services (figure 4.7). Payments to domestically-sourced labour and capital (primary factors) were generally significantly larger than essential industries' use of *all* goods and services in 2016-17. Inputs of domestically-sourced services were also substantial. Imported products, especially those that are vulnerable, played a very small role in the production of essential goods and services. For example, the health industry had the greatest use by value: almost A$2 billion of vulnerable imports, but all other industries used less than A$800 million each.

9 Timing differences between the global trade (2017) and Australian imports and production data (both 2016-17) meant that 11 vulnerable imports could not be mapped to the I–O tables. The primary reason for this is that roughly A$8 billion of vulnerable imports occurred in the second half of 2017. This meant that vulnerable imports in 2016-17 were in the order of A$12 billion, and indicates that irregular imports can have a material impact on the magnitudes involved.

Figure 4.7 **Imported inputs form a small part of essential industries' cost structures**

Input use by essential industries, 2016-17[a,b]



[a] Primary factors are domestic and include payments to labour, the owners of capital, and taxes on production. [b] The value (in billions) of vulnerable imports used by each industry are in parentheses.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); ABS (*Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); and UN *Comtrade*.

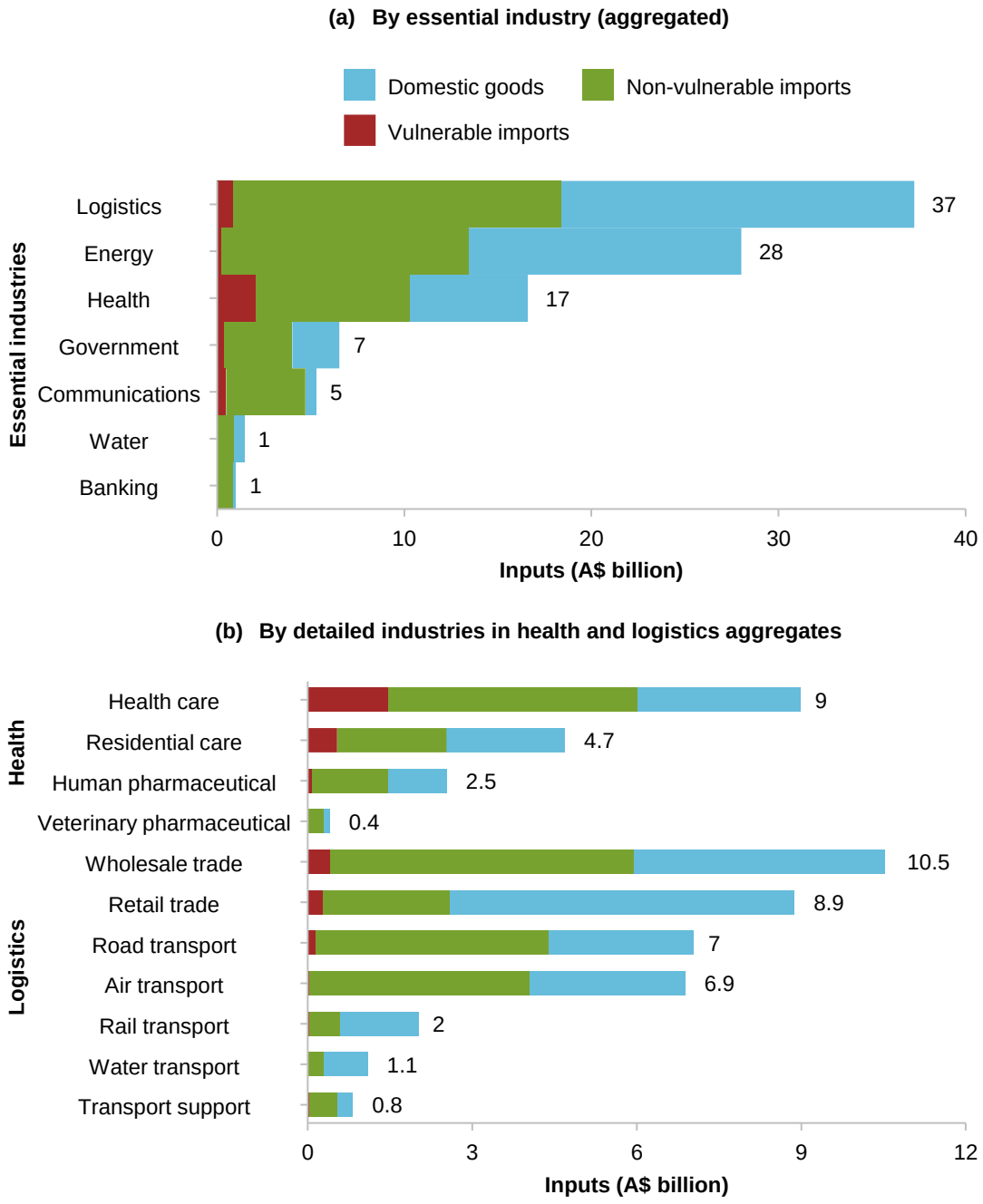
Inputs of goods were the smallest component in the production of essential goods and services, but varied across industries (figure 4.7). This is because the essential industries largely consist of service industries, rather than manufacturing industries that use relatively more goods. For example, health is predominantly a service industry; it is comprised of health care and residential care, which are both large service industries, and the much smaller human and veterinary medicine manufacturing industries.

The cost of goods was largest for energy, health, and logistics industries when compared with communications, government, and water industries (figure 4.8a).

Typically, around half of the goods used in production by an essential industry were sourced from within Australia, but the relative importance of imported goods varies across industries (figure 4.8a). For example, the domestic production of petroleum products (such as crude oil, diesel, and petrol), human medicine manufacturing, and air transport were relatively more reliant on the use of imported inputs than the production of other essential goods and services. This makes these industries potentially more susceptible to disruption if the supply of these imports were disrupted, particularly if the goods are also vulnerable and critical inputs (that is, there are no substitutes).

Figure 4.8 **Vulnerable imports are a fraction of essential industries' costs**

The use of goods inputs, 2016-17[a]



[a] Imports may include some services as a result of the mapping of HTISC imports to I–O industries.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); ABS (*Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); and UN *Comtrade*.

Further, the industries of health, logistics, and to some extent communications, energy, and government, used vulnerable imports in their production — although these imports represent a fraction of the cost of all imported inputs (figure 4.8a). A more detailed inspection of the industries that make up health and logistics reveals that health services, residential care, and wholesale trade use the highest value of vulnerable imports (figure 4.8b).

The finding that vulnerable imports are a very small share of the goods used in essential industries is significant, but not conclusive. If the results had shown that 99 per cent of goods used in the health industry were vulnerable imports, this would suggest a significant vulnerability, but the results show the opposite. The small share of vulnerable imports is suggestive evidence that vulnerable imports may not be critical to the production of essential goods and services. That said, the analysis used very broad industry categories, and it is still possible that, for example, an active ingredient for the production of medicine critical for the treatment of one condition is vulnerable (see box 5.3 for a discussion of medicine shortages).

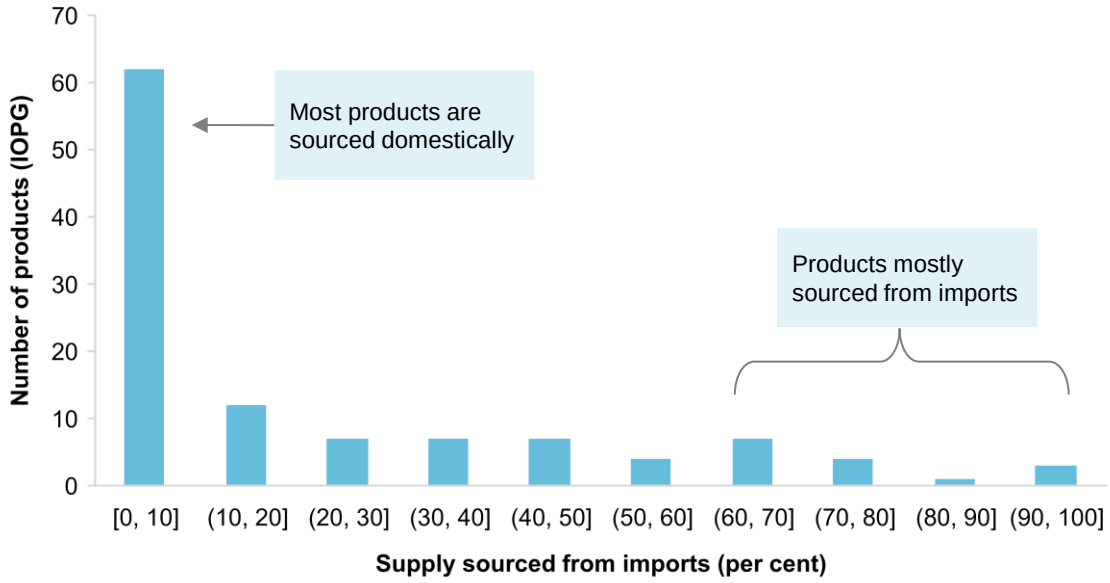
FINDING 4.5

Vulnerable imports are a small share of the goods used in essential industries, by value. This is suggestive, but not conclusive, evidence that vulnerable imports may not be critical to the production of essential goods and services.

While essential industries used imported goods as inputs into production, many products could be sourced domestically (figure 4.9). There were 15 products for which imports accounted for over 60 per cent of Australian supply. If products within this product group were vulnerable, their supply chain would be more susceptible to disruption, as there is limited local supply to alleviate disruptions. (These product groups are much broader than those used to assess vulnerability in the trade data.)

Figure 4.9 **Most inputs used by essential industries are locally sourced**

Share of Australian use of each product sourced from imports, 2016-17.
Products defined using Input-Output Product Group (IOPG) classification.



Data source: ABS (*Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001).

Which vulnerable imports were used in production by essential industries?

Returning to the finer-grained import categories used in the trade data (HTISC), essential industries used 130 of the 281 potentially vulnerable imports[10] identified using the mechanical processing.[11] The remaining vulnerable imports were used by 'non-essential' industries.

Use of vulnerable products varied widely across essential industries (figure 4.10). Health and logistics used more than all other essential industries, with each using around 100 products. In contrast, banking and water used the least.

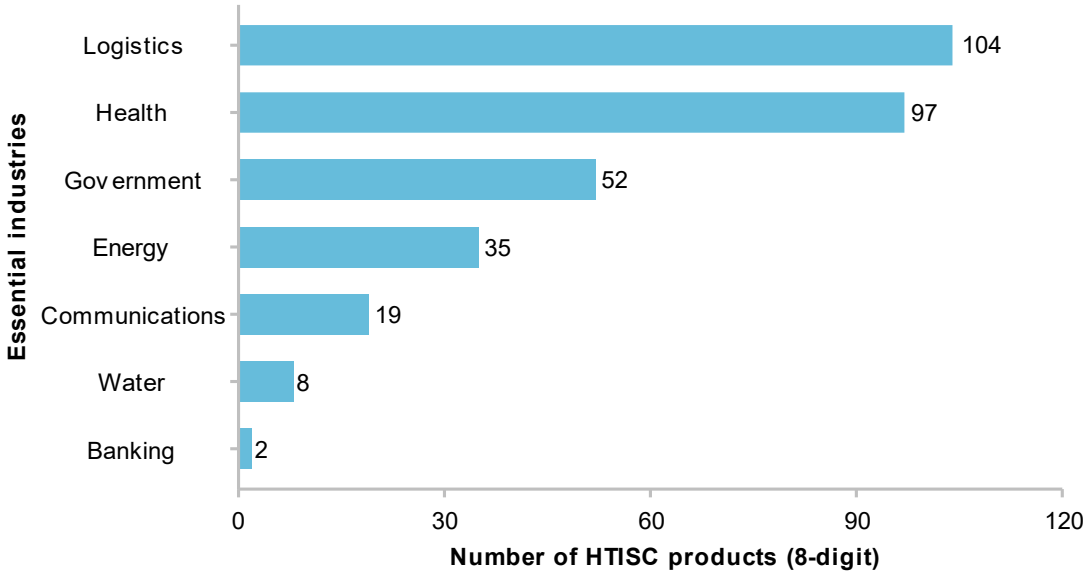
Many of the 130 products identified by the mechanical processing are unlikely to constitute critical inputs into these (or other) industries. Examples of such products include women's swimwear from China and watches from Switzerland.

10 Only 281 of the 292 vulnerable imports identified in section 4.2 could be mapped to product groups in the production data (IOPGs).

11 A minimum value filter of A$1 million is used here to screen out products that otherwise met the criteria for being considered a 'vulnerable import used by essential industries'. Very small import values arise for some products as a result of the coarser nature of the mapping of imports and production classification changes over time (as the I–O products are at a higher level of aggregation than the imports data). Given the small values involved, these products are unlikely to constitute critical inputs even if they are used by the industry.

Figure 4.10 **Health and logistics are the greatest users of vulnerable imports**

Number of vulnerable imports used in essential industries, 2016-17[a]



[a] Products identified as vulnerable if the imports used by an industry were more than A$1 million.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); ABS (*Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); and UN *Comtrade*.

Laptops and computer equipment were common inputs across most essential industries. Some products (such as disodium carbonate) were used by a handful of industries (such as water, health, and energy). Others were only used by a single essential industry. An example of a vulnerable product used by a single industry is the use of some PPE by the health industry.

Disaggregating the vulnerable imports used in the production of essential goods and services by product type reveals that essential industries use many vulnerable imports of textiles and miscellaneous products (table 4.2). Most of these products, however, are unlikely to be critical inputs (such as electric blankets, camping gear, and toys). This suggests that the number of vulnerable imports used by an essential industry does not always reflect a higher degree of vulnerability to supply chain disruptions.

The analysis of import vulnerability presented here is based on past production data. Changes to Australian production capabilities may make Australia more or less vulnerable to supply chain disruption than is currently the case. This implies that the analysis needs to be periodically updated.

Table 4.2 **Essential industries use many vulnerable imports of textiles and miscellaneous products**

Number of vulnerable imports used in essential industries, by product type. Products defined at the HS Subheading level (8-digit)

Product type[a]	*Logistics*	*Health*	*Govern-ment*	*Energy*	*Commu-nications*	*Water*	*Banking*
Animal and animal products	4	3	1	0	0	0	0
Chemicals and allied industries	4	7	0	5	0	3	0
Foodstuffs	4	1	2	0	0	0	1
Footwear and headgear	5	8	2	3	1	0	0
Machinery and electrical	6	4	2	8	5	2	1
Metals	3	1	2	3	0	2	0
Mineral products	0	0	0	0	0	0	0
Miscellaneous	23	20	16	4	6	1	0
Plastics and rubbers	4	4	2	2	0	0	0
Raw hides, skins, leathers and furs	3	2	3	0	0	0	0
Stone and glass	5	4	1	1	0	0	0
Textiles	31	36	16	7	5	0	0
Transportation	4	2	2	2	0	0	0
Vegetable products	4	5	1	0	0	0	0
Wood and wood products	4	0	2	0	2	0	0
Total	**104**	**97**	**52**	**35**	**19**	**8**	**2**

[a] Product types based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act* (Cwlth) aggregated to 15 groups.

Sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); ABS (*Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); and UN *Comtrade*.

FINDING 4.6

Since the narrow definition of essential industries used in this study comprises mainly service producing industries, locally-sourced services are primarily used in their production, rather than locally-sourced or imported goods. Consequently, vulnerable imports are a small share in their production costs. Furthermore, many of the vulnerable products identified, such as textile products, are unlikely to be *critical* to the production of these services.

Vulnerable imports that are inputs into the goods-producing industries of petrol refining and medicine manufacturing are more likely to be critical.

4.4 Direct and indirect contribution of vulnerable imports to the consumption of essential goods and services

The narrow definition of essential goods and services are those that are necessary to meet the *basic needs* of Australians (chapter 3).

Meeting the basic needs of Australians is about the *final consumption* of essential products by Australians (households) or by government (which provides goods and services on behalf of households). That is, it is about the use of essential goods and services by, or on behalf of, consumers.

The wellbeing of Australian consumers will be materially impacted by a sustained disruption to the supply of imports if:

- they *directly* consume imports of essential goods and services (that is, imports form part of final demand) or
- they consume Australian-produced essential goods and services whose production relies on imported inputs (imports are consumed *indirectly*).

The I–O tables enable the users of essential goods and services to be identified at a relatively high level (such as individual industries, households, and government).

Importance of essential goods and services in meeting the wellbeing of Australian consumers

Australian households and government used A$600 billion in essential goods and services in 2016-17, collectively accounting for almost 56 per cent of the use of all essential goods and services.[12,13]

Put another way, household and government consumption of these essential products accounted for almost half of their consumption of all products (which was A$1.3 trillion).

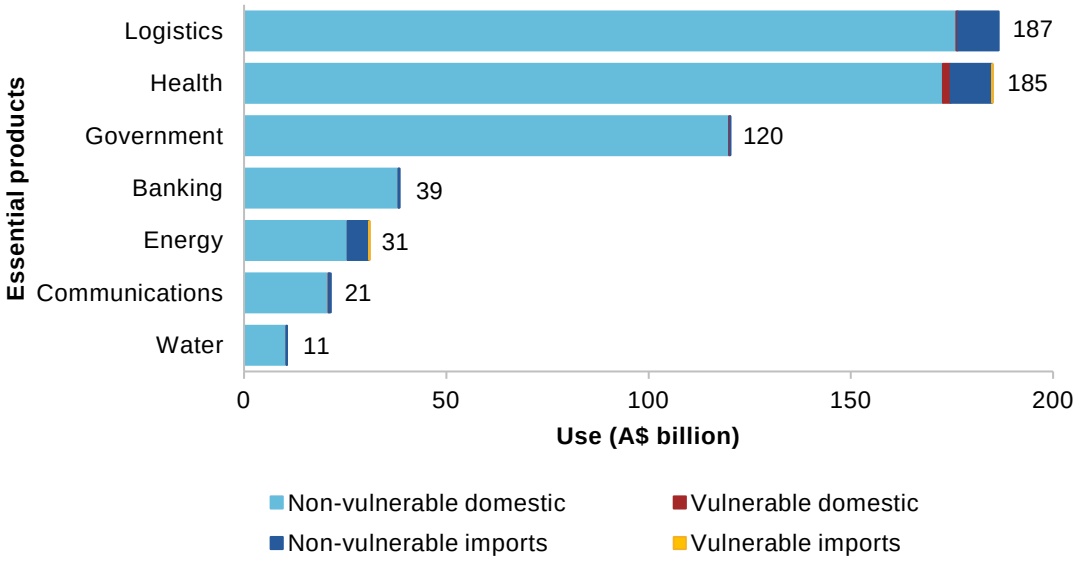
Health and government services accounted for almost half of household and government consumption of essential products (figure 4.11). Households and government accounted for the bulk of the use of these products, in contrast to banking, communications, and energy, where industry was the main user. The use of water and logistics was evenly divided between household/government and industry use.

12 The coarse nature of these product categories, however, overstates their importance for the wellbeing of Australians, as the categories also implicitly include other goods and services that go beyond those needed to meet the basic needs of Australians.

13 Total use of each product is the total supply of that product in the I–O tables less exports.

Figure 4.11 **The vast majority of essential goods and services used in Australia were produced in Australia**

Household and government use of essential products by source, 2016-17[a]



[a] Essential products are either produced domestically or sourced from imports. The value of vulnerable imports used in the domestic production of essential products is shown in red (covered in section 4.3). The value of vulnerable imports used to directly meet final demand for essential products is shown in yellow.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); ABS (*Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); and UN *Comtrade*.

The vast majority of essential goods and services used in Australia in 2016-17 were produced in Australia — 96 per cent of total use (figure 4.11). This high share reflected, among other things, the high proportion of services among the list of essential products. Imported final goods and services played a small role in meeting household and government demand for essential goods and services, and vulnerable imports played an even smaller role.

Households *directly* consumed some imports of energy, health, and logistics products. For example, some households filled their car using petrol refined in Singapore and consumed medicines manufactured in Belgium and the United States. Notwithstanding this, the share of these imports found to be vulnerable in 2016-17 was tiny (A$20 million).

As outlined in section 4.3, the *indirect* use of vulnerable imports in Australian production in 2016-17 was also found to be very small (figure 4.11). As Australian households used only a share of this Australian production, their indirect use of vulnerable imports is A$2.7 billion.

While the shares of expenditure on vulnerable imports in aggregate Australian consumption might be tiny, this does not mean that a disruption to their supply would necessarily result in a negligible impact on wellbeing. For example, the absence of lifesaving medicines jeopardises the wellbeing of Australians whatever the value of these medicines or their share in consumption or production.

Overall, the low share of essential goods and services that Australians use and that are sourced from imports is suggestive evidence that most supply chain disruptions may not have a material and sustained impact on the basic wellbeing of Australians. Moreover, the fact that most essential products — whether used by households or by industry — were produced locally points to alternative (domestic) sources of supply that could be accessed in the event of a disruption to imports, or whose production could be ramped up (if not immediately, then over time). This is not, however, conclusive evidence because the industry categories and products considered are broad; in some very narrowly defined essential industries, imports could be critical. Further, where an import is critical, and its absence would jeopardise the supply of an essential good or service, then wellbeing would be affected.

FINDING 4.7

Combining imports and production data suggests that the supply of essential goods and services in Australia is not highly susceptible to a short-term disruption to the supply of imported goods. Vulnerable imports represent a small fraction of the value of essential goods and services consumed by Australians — whether that consumption be direct (final goods, A$20 million out of total consumption of essential goods and services of A$593 billion) or indirect (as inputs into Australian production, A$2.7 billion). But this evidence is not conclusive and industry experts are required to determine criticality.

4.5 Possible extensions to this work

The application of the framework presented here could be extended in a number of ways.

First, and most importantly, further work is needed to conclusively determine which vulnerable imports are *critical* to essential industries. Industry experts are best placed to determine which of the concentrated inputs identified and used by essential industries are critical in the sense that production would not occur without them. These experts have detailed knowledge of the production processes involved and what substitute products, if any, could be used in the event of a disruption. There are data-driven methods that could complement experts' advice if suitable data is available (appendix D).

Second, the analysis could be improved with a closer inspection of product classifications to ensure substitute products are grouped together. For example, for some agricultural products a higher product aggregation is adequate, but for specific chemicals a finer classification would improve the analysis.

Third, extending the analysis to other years would improve the robustness of the analysis. Imports in any one year will be influenced by factors specific to that year, and can affect the analysis. This may particularly be an issue where the items are large and ad hoc in nature. Examples of such imports may include aeroplanes, ships, trains, military equipment, and

natural gas platforms. Preliminary analysis suggests that 2016-17 appears to be a reasonably representative year, but confirming this requires additional work.

Fourth, the analysis only considers tier 1 suppliers (that is, countries that directly supply a good to Australia, chapter 2), but it could be linked into work on global supply chains. This would help to better gauge the potential for supply chain disruption arising from our foreign suppliers being at risk of disruption themselves (that is, consider tier 2 suppliers and above). These risks could arise from many sources, including:

- disruption to their own input suppliers (whether local or from a third country)
- when different stages of production are located in different countries
- where our suppliers are owned by another firm in a third country, such that, if the parent firm experiences financial or other difficulties, it may flow through to the subsidiary that supplies Australia
- where global supply comes from similar parts of the world (such as from the Middle East, South East Asia, North America or Europe).

Finally, the fact that the ABS confidentialises production and import details for numerous products suggests limited sources of supply and, hence, may indicate potential vulnerability to disruption. These products should be investigated further.

5 Supply chain risk management

Key points

- Supply chain risk management balances the trade-off between the costs of a disruption — that is, a potential increase in the cost of purchasing goods and services upstream — with the opportunity cost of investing in risk management. Risk management is costly, much like buying insurance to protect against other types of risks is costly.
- To make an effective decision on the level of risk to manage, firms need to understand the nature of the potential disruption (likelihood, size etc.), and its potential impact to their supply chains. But this is not always straightforward. Supply chains can be long, complex and opaque, and information on a firm's supply chain can be difficult to obtain.
- Biases can also affect the decisions of firms to invest in risk management. For example, because of their experience with the COVID-19 pandemic, firms focusing on the risks to their supply chains from a future pandemic, may over-invest in strategies that seek to mitigate this risk, when other risks may be more probable and imminent.
- Firms will employ risk management strategies, such that the perceived net benefit of their mitigation exceeds the potential costs of a disruption. Key mitigation strategies used to prepare for supply chain risks include: no action, stockpiling, supplier diversification, contingent contracting, and developing domestic capability. These strategies complement other actions firms take to prevent the risks of a disruption, or respond and recover from one. Different strategies will perform better under different types of disruptions and contexts, and firms will likely have to employ a range of strategies to effectively manage risk.
- Risks are best managed by those who have direct incentives to mitigate against them. Government has responsibility, like any firm, to manage risks in supply chains for which they purchase and deliver goods and services directly.
- There may be conditions where government intervention in private sector risk management is justified, such as where the private and public net benefits of risk management diverge. In these cases government could implement a range of options — from providing better information to taking more direct ownership of risk management (such as maintaining government stockpiles, mandating or subsidising private stockpiles, or maintaining domestic production capacity). But higher levels of government intervention impose higher costs on the community, and also decrease firms' incentives to invest in risk mitigation. Even where an in-principle case for government intervention exists, any case for intervention needs to demonstrate that the benefits of intervention outweigh the costs.
- Governments should also focus on ensuring firms do not face unnecessary constraints in how they plan and respond to disruptions. This includes maintaining a respected, rules-based and low-cost trading system, and a responsive regulatory environment.

Firms operate in a world of uncertainty, taking risks to pursue their objectives. With risks come the possibility of success but also failure, and adverse events can have significant cost implications for firms and the community. This chapter establishes a framework to better understand risk management of a firm's supply chain (section 5.1), and then explores the key elements to managing risks, including:

- understanding risk (section 5.2)
- identifying how to best manage supply chain risks (section 5.3)
- identifying who should manage risk, including the role of government in managing supply chain risks (section 5.4).

5.1 A framework for managing risks

Many firms rely on complex supply chains made up of many products, customers, channels, and geographies. While these firms decide to operate this way to improve supply chain efficiency and drive higher revenues, this also carries risks (chapter 2).

Risks of a disruption can be characterised by the probability of an event occurring and its consequences. There is uncertainty about what, when and where disruptions will occur (for example, they could be geopolitical events, natural disasters or economic crises), as well as their intensity and impact. Firms manage routine disruptions that cause small impacts through hedging, forward and other contract types, and by maintaining small inventories. For example, Dell Inc. keeps some inventory of low-cost components in the United States in an effort to minimise the effects of delays in the deliveries of some components to the United States (Chopra and Sodhi 2004, p. 55).

Other disruptions can have larger impacts on a firm's operations if not managed effectively, and some will have market-level implications that threaten the supply of essential goods and services to the community. This study focuses on these latter types of disruptions that could impact the functioning of the economy, national security and Australians' wellbeing.

Managing risks in a supply chain

Risk management can be used to mitigate the costs of disruptions, and better manage their consequences once they occur. Broadly, risk management involves three steps:

- understanding risk — identifying which risks are faced and their likely consequences (section 5.2)
- treating risk — making decisions on how to best manage risks, such as reducing exposure to risks through diversification or investing in capacity to recover from a disruption (section 5.3 and box 5.1)

- owning risk — determining who is responsible for managing risks that affect a supply chain; as well as monitoring and reviewing risks — regularly reassessing risk management arrangements to ensure they are still fit for purpose (section 5.4).

The impacts of certain disruptions can be lessened by improving how a firm anticipates, reacts to and recovers from a disruption. It is useful to think about the various stages of building supply chain resilience — from prevention through to recovery (box 5.1) — although many risks will likely be treated in multiple stages and strategies. Some risks (or impacts from certain disruptions) will not be managed because they cannot be foreseen. Others will not be managed because the cost of mitigation is too high relative to the potential impact. (Risk mitigation strategies are covered in section 5.3.)

Risk management does not mean that all disruptions identified by a firm can be avoided, but their effects can be reduced. Earthquake proofing a building does not mean that it would be completely protected from earthquake damage, but will likely reduce the amount of damage that occurs in the event of an earthquake. The initial cost of risk mitigation would be borne regardless of whether an earthquake occurs, but this form of physical insurance (and minor repairs) would be chosen when it is cheaper than the expected costs of major building repairs if an earthquake occurs and no mitigation activities are undertaken.

Trade-offs must be made

A supply chain disruption effectively causes a sudden increase in the cost of supply. When a source of supply disappears completely, its cost can be thought of as having increased prohibitively. Although it might be possible to obtain supply from another source, it is likely to be at a much higher cost.

But managing risks also has costs. People take steps to protect their health, income and assets against risks by buying insurance but have to pay a premium based on what is insured and the risks being insured against. Likewise, investing in strategies to manage supply chain risks (such as diversifying supply, stockpiling, or bringing manufacturing onshore) involves costs — the investment is equivalent to paying insurance premiums. Thus, firms accept higher costs in good times in order to lower costs in the event of a shock.

Resources, such as the time, money or effort needed to understand, manage and deal with risks, have opportunity costs — that is, they cannot be devoted to other uses. These costs are part of all the other costs of supplying goods and services; they contribute to the price of goods and services, and fall eventually to households and taxpayers.

Box 5.1 Stages of supply chain risk management

Risk management strategies can be thought of in a prevention, preparedness, response and recovery (PPRR) paradigm, sometimes used in emergency and disaster management. In the context of this study, strategies seek to improve supply chain resilience by:

- preventing a disruption (or lowering the likelihood of a disruption occurring)
- preparing the rest of the supply chain to avoid the costs of the disruption
- improving the speed and effectiveness of the firm's response
- facilitating a firm's recovery from a disruption.

Firms make decisions about investing in each of these stages before a disruption, but naturally some strategies will only come into effect after a disruption has occurred (response and recovery).

Different risks are better treated in different stages. For example, a predictable risk (such as the potential impacts of the United Kingdom withdrawing from the European Union) might best be treated in the prevention stage. However, an unknown, highly uncertain risk (such as a large storm) might be better treated through response and recovery (or in preparatory actions that will help more effective response or recovery after a disruption). A combination of different strategies used at different stages is likely the most effective approach to managing risks.

The figure below outlines some of the different strategies available to firms.

Prevention Reduce the likelihood of a disruption	**Preparedness** Prepare the rest of the supply chain to mitigate costs of the disruption	**Response** Improve the speed and effectiveness of the firm's response	**Recovery** Recover from the disruption
Locate factories, suppliers or warehouses in areas that are less prone to disruption	Hold additional buffer stock	Invest in early detection systems	Develop post-disruption recovery plans
Choose suppliers that are less vulnerable to disruptions	Have additional capacity among other suppliers	Have contingency plans in place ahead of a disruption	
Invest in risk management for critical suppliers	Diversify supply network and geographic footprint	Have flexible manufacturing processes	
	Delayed product differentiation	Use dynamic pricing and promotion	
	Use contingent contracting		
	Take out insurance		

Sources: Hopp et al. (2012, pp. 24–26) and PC (2014b).

Effective risk management involves purchasing the right amount and type of insurance given: the benefits of the different strategies; the probability of a disruption; the estimated costs of a disruption; the firm's degree of risk aversion; and the opportunity costs of the resources needed to manage risks.

A key part of making the appropriate trade-off is to identify an acceptable degree of risk aversion — the willingness to bear some risk of loss rather than devoting additional

resources to reduce the risk. At some point, people choose to live with some exposure to risk so that they can continue to use their resources in other ways. Where that point is depends on a firm's aversion to risk, the cost of risk management, and the probability and cost of disruptions. It also depends on firms being able to understand their risks. However, firms operate in an environment of uncertainty, where they have imperfect knowledge of future events, or where it may be impossible or too costly to estimate the probability or consequence of such events occurring. In this environment, it may not always be possible for firms to make effective trade-offs in managing supply chains risks. That said, firms still manage this type of uncertainty by making provisions for contingencies about which they might have little information on.

In the context of this study, we care about effective risk management from a community perspective — that is, balancing trade-offs given the impact of a disruption to the community and society's degree of risk aversion. This means choosing the balance of risk management strategies that maximises community wellbeing over time.

While 'insurance' provides a useful analogy to highlight the costs of risk management strategies that need to be traded off against an uncertain benefit if a disruption occurs, there are some important distinctions between risk management strategies covered in this study relative to a common insurance product. First, this chapter focuses on risk management strategies that provide firms physical restoration of their supply chains, rather than a pure financial compensation in the event of a disruption. Firms can purchase business continuity insurance to protect themselves financially from supply chain risks, but this form of insurance does not protect the community from losing access to essential goods or services when a disruption occurs. Second, while pooling of risks is commonly used by insurers to manage risks, some firm-level risk management strategies (such as stockpiles or domestic production) do not involve diversification of risk.

Effective risk management is hard to do in practice. First there are a broad range of supply chain risks (chapter 2); and second supply chains are complex and opaque to assess for risk, and there are many possible strategies available that are suitable to address different types of risks. That said, some principles can help. In particular, management strategies are best implemented by those who are close to the risk, have the best information required to manage it, have incentives to do so, and face few impediments.

5.2 Understanding risk

For firms to manage risks effectively, they need to understand their supply chains and how risks make them vulnerable. Things that may make a supply chain vulnerable (and therefore should be understood) include: its flexibility, its length, and its geographic clustering (chapter 3).

Gathering information to better understand risks is not costless. This may be particularly problematic for small firms, who lack scale to benefit from large investments required to

better understand the full set of their upstream suppliers. Survey data indicate that small firms were far less likely to 'assess and record' changes in their supply chain as part of their supply chain risk management activities (17 per cent for businesses with 0-4 employees, compared with 42 per cent for businesses with 200 or more employees) (ABS 2017).

Understanding supply chain risks can be difficult. For example, for Unilever's network of nearly 60 000 suppliers (Unilever 2020), the costs of understanding what each supplier does and what risks they face rises with each additional node. Firms may only have a murky view of their supply chain beyond the first tier of suppliers. This can lead to problems when disruptions occur further upstream. For example, in 2007 Menu Foods Corp., a producer of pet food, had to recall more than 60 million cans and pouches of dog and cat foods, following a number of reported deaths. The deaths were linked to contaminated wheat gluten, which was procured from ChemNutra, who, unbeknownst to Menu Foods, had outsourced its production to Xuzhou Anying Biologic Technology Development Co. Ltd (Yang et al. 2009, p. 192).

A firm may not necessarily need to understand their entire supply chain to effectively manage their risk. If each firm in a chain recognises the risk from 'one level up' and takes appropriate action, then the need to understand risks deeper into a firm's supply chain may be unnecessary. For example, if Menu Foods was reasonably assured that ChemNutra was managing their supply chain risks, they would not have to worry about understanding risks beyond their first tier of suppliers. Well-designed contracts (with damages, for example) can encourage suppliers to manage and share information about their risk. However, this is not always possible in practice. One reason for this is asymmetric information — that is, where a supplier has access to private knowledge of their own financial status, state of operations, or input sources that is not known by the purchaser (Yang et al. 2009). The supplier may not be willing to share the information where it is proprietary or would hurt their commercial interests, such as appearing riskier to prospective purchasers. This risk was highlighted in the case where Land Rover was unaware of, and therefore unprepared for, the looming bankruptcy of UPFThompson — the sole provider of chassis for their Discovery model (Yang 2009, p. 5).

Finally, cognitive and behavioural biases can affect how people and firms perceive risks. Cognitive biases mean that firms can underprepare for low probability events, and overprepare for events that have occurred recently. During a long period of relative stability, the probability assigned to disruptions declines. This can lead to firms under-investing in risk management strategies. Cognitive biases also mean that firms can over-estimate the probability of a disruption for a period following the occurrence of an event, leading to firms over-investing in strategies designed to deal with that specific type of disruption (to the detriment of investing in strategies to deal with other types of disruptions). Such biases mean that firms may not always make full use of available information, or may evaluate the information inadequately.

Many firms, especially large ones, have sophisticated structures to overcome such biases, such as risk governance committees, and frameworks to systematically assess, plan for, and manage risks. Despite this, there is evidence that firms do not always respond rationally to risk. For example, a number of studies have shown that investments to guard against

cyber- and IT-security threats have declined just as these threats have become more frequent and severe (Gaudenzi and Siciliano 2018, p. 87).The pharmaceutical industry showcases how different factors can impact an industry's understanding of a single supply chain (box 5.2), for example:

- pharmaceutical supply chains are becoming longer and more complex as manufacturers source ingredients offshore from cheaper sources of production (mainly China and India)
- asymmetric information exists between manufacturers and wholesale purchasers, where manufacturers have more detailed knowledge of their quality control and risk management processes
- smaller pharmacists may lack scale to understand supply chains in depth
- the COVID-19 pandemic's effect on the supply chain has likely been overemphasised, making it difficult to determine what is a normal shortage and what is caused by the COVID-19 pandemic.

How do firms understand supply chain risks?

Firms, as part of their usual risk management practices, gather information on risks facing their supply chains. To better understand risks, firms work collaboratively with suppliers to understand, and regularly report and review potential risks, and invest in technology and data analytics to help identify risks deeper into their chain of suppliers. For example: Unilever has developed a systematic approach to identify critical suppliers (Unilever 2020); Toyota has developed a supply chain database that maintains information on parts and identifies vulnerabilities across its 650 000 supplier sites (Webb 2016); and GM has an information system combining information from suppliers and logistics hubs to monitor incidents (Lund et al. 2020, p. 77).

The Critical Infrastructure Centre, within the Australian Government Department of Home Affairs, also conducts risk assessments to monitor market-level vulnerabilities of key assets to espionage, sabotage and coercion risks. They consult with state and territory governments, regulators, and private owners and operators to understand:

- a company's cyber security and physical security
- security audits undertaken by a company
- emergency management plans
- redundancies
- offshoring and outsourcing of operations
- existing regulatory regimes and controls (DoHA 2020c).

Box 5.2 Pharmaceutical supply chains

Pharmaceutical manufacturing involves two main stages. First the production of active pharmaceutical ingredients (APIs), and second, formulations production — where the APIs are transformed to turn the drug into tablets, capsules, creams, etc. (Horner 2020). Once the drug is manufactured, pharmacies buy medication from wholesalers, sell them to consumers, and are then (in many cases) reimbursed by the government under the Pharmaceutical Benefit Scheme (as well as receiving a nominal mark-up and dispensing fee).

At the beginning of the COVID-19 pandemic, many raised concerns about Australia's reliance on imports for APIs and other pharmaceutical inputs. Australia imports most of its pharmaceutical goods from Europe and the United States. However, the United States and Europe are increasingly relying on APIs manufactured in India and China (Butler and Sorrell 2020). As of 2017, China produced 40 per cent of global APIs and India supplied 20 per cent of global exports of generic medicines by volume (UK MHRA 2017, p. 10).

During the COVID-19 pandemic, disruptions to Indian and Chinese production of APIs led to concerns of shortages in Australia (ABC 2020). Panic buying and stockpiling ensued and the Australian Government implemented purchasing limits to ensure equitable access to medicines (PSA 2020, p. 6). Despite concerns, the pharmaceutical supply chain functioned well and 'demonstrated significant resilience', according to Medicines Australia (Davey 2021). This was helped by Chinese manufacturing recovering quickly and India removing export bans. However, many companies also had risk management strategies in place, such as emergency stocks of ingredients, and had manufacturing capacity in multiple locations (Mullin 2020). The Therapeutic Goods Administration also worked with industry through the Medicine Shortage Working Party to manage medicine shortages (TGA 2020a, p. 5).

However, a lack of transparency did lead to confusion about whether there were actual shortages of medicines. As noted by the Pharmaceutical Society of Australia (2020, p. 6) in their submission to the Senate Committee on COVID-19:

> While pharmaceutical wholesalers may have been in contact with the Therapeutic Goods Administration about supply issues, [information on shortages and wholesale limits] were often not shared more broadly with practitioners at the coalface, such as pharmacists and doctors.

Shortages of other medicines caused by the COVID-19 pandemic have also been reported, such as some hormone replacement therapies and antidepressants (Ross 2021). However, this does not appear to be out of the ordinary. According to the Therapeutic Goods Administration, the average monthly total of national medicine shortages published on the Therapeutic Goods Administration website in late 2020 was comparable with the average in 2019 (Davey 2021).

Medicine shortages were common even before the COVID-19 pandemic, affecting patients, doctors and pharmacists (Tan, Moles and Chaar 2016). The combination of intense price competition (especially in the generics market) and a lack of transparency in supply chains hampers the ability of firms to accurately assess (and therefore reward) good quality management and supply chain resilience, leading to shortages. The pharmaceuticals industry is also highly regulated, making entering the market, or modifying existing facilities to respond to a crisis, a slow and costly process (US FDA 2019).

Technological advances have made it easier for firms to understand their supply chains (box 5.3). Advances in tracking technologies, data analytics and machine learning have made it easier to predict where and when disruptions might occur. These advances have also made it easier to access real time information about disruptions, facilitating a quicker

response and recovery. For example, consumer goods manufacturer Procter & Gamble has integrated multiple types of real-time data for its suppliers and distributors, including inventory levels, road delays and weather forecasts. It also runs scenarios in the event of a disruption to identify effective solutions (Lund et al. 2020, p. 76).

Box 5.3 **Supply chain technological advancements**

The internet of things (IoT)

IoT allows for the tracking of location, weather conditions, environmental status, traffic patterns and more. This allows supply chain managers to monitor assets throughout the logistics journey, track shipments and inventories, and whether anything needs to be remedied. One of the risks and costs associated with the use of IoT is the increased vulnerability of a chain to cyber-attacks.

Blockchain

Blockchain is a distributed ledger technology, in which a record of an asset or transaction is maintained in multiple locations. Records of transactions can be used to track the origin of goods and establish trust in shared supplier information.

AI, machine learning and analytics

AI, machine learning and analytics are increasingly used to automate many aspects of supply chain management, including warehouse operations, transport and logistics, and inventory management. These technologies are particularly useful: as supply chains become more complex, as data processing capacity increases, and to the extent that decision-making can be automated.

Source: Stackpole (2020).

FINDING 5.1

Effective risk management requires a good understanding of a firm's risks to ensure that the net benefits of any investment to mitigate the costs of disruptions is matched by their potential effects and costs.

Supply chain risk management is similar to buying insurance for any other types of risk. In effect, a firm pays an insurance premium upfront to invest in a range of strategies such as, stockpiling, supplier diversification, contingent contracting, and domestic capability, to insure itself against potentially large cost increases if a disruption occurs. The focus of these risk management strategies is on the physical restoration of supply chains, rather than taking out insurance for a pure financial compensation in the event of a disruption.

5.3 Managing supply chain risks

Risk management strategies

While it may not be possible to foresee all potential risks facing a firm, those that take action to understand their supply chain risks will work to effectively mitigate their impacts — that is, firms use risk management strategies, such that the net benefit of their mitigation activities outweighs the expected costs of potentially foreseeable disruptions.

This section focusses on supply-side risk management strategies that firms use to mitigate the impact of a shock that has the potential to disrupt their supply chain. (Particularly focused on strategies that physically restore access to goods and services, rather than provide financial compensation to secure a firm's future operations.) In the typology of box 5.1, these are prevention/preparedness strategies, which support the ability of firms and economies to respond and recover following a disruption. These strategies complement those that firms use to prepare for a more predictable disruptive event affecting their supply chain.

Firms are more adept at handling the 'uncertainties that businesses face on a day-to-day basis, such as delays in product deliveries, fluctuations in consumer demands, and product shortages' (O'Neil 2016). For example, at its Kooragang Island ammonia plant, Orica maintains stockpiles of ammonium nitrate that it uses primarily to manufacture explosives for mining, which it describes as 'just-in-time inventory'. That is, it maintains a small stockpile of about 6000 to 12 000 tonnes of ammonium nitrate, while mining operations take about 8000 tonnes from its site every seven to ten days (Orica 2020).

The rest of this section focuses on the costs and benefits of efforts to deal with unexpected but highly disruptive supply chain events.

Supply-side strategies for unexpected (and large) disruptions

No action

As a baseline for our analysis of risk management strategies, it is important to recognise that 'no action' can be an effective strategy. This is where firms accept that some residual risk is always present, and that it would be too costly to mitigate its effects. In other words, where the upfront investment needed to mitigate is too high given the expected cost of the disruption (and the relative risk appetite of the firm), the firm will adapt its operations and live with some risk. For example, McKinsey & Company noted that many firms have accepted the likely impacts from the United Kingdom leaving the European Union ('Brexit').

> For many companies, the UK market is simply not large enough to dedicate significant resources to prepare for Brexit. They believe that the consequences of Brexit will be short-lived operational issues that will ease within a few weeks or months. … Other companies are simply ready to accept the risk of longer lead times due to customs, stating that they 'don't care; customers will simply have to wait longer and pay a bit more; it affects the entire industry.' (Alicke and Strigel 2020)

This shows that when firms assess mitigation actions to be too costly relative to the expected size of the disruption, they will accept the potential consequences and adapt their business accordingly.

Decisions on whether to mitigate (and to what extent) rely on firms being able to understand their risks and estimate their consequences. In most circumstances, firms operate in an environment of uncertainty, where they have imperfect knowledge of future events. In others, it can be impossible or too costly to estimate the probability or consequence of such an event occurring. In these situations it is difficult for a firm to undertake effective mitigation at reasonable cost.

Accepting risk, however, may not be an effective strategy where better information would have predicted large impacts or identified a more cost-effective mitigation strategy.

Stockpiling

Stockpiling refers to firms holding inventories of goods in storage that can be made available when supply chains are disrupted. Stockpiling here refers to inventories larger than would otherwise be maintained under purely cost-minimising, just-in-time sourcing practices (as per the Orica example above). Stockpiles can be part of an alternative to just-in-time that is sometimes referred to as a 'just-in-case' approach to production and inventory management. Stockpiles are best suited to address shorter-term interruptions to the supply of critical goods, while other sources of supply are found or existing supply chains are restored.

The costs of maintaining a stockpile can vary depending on the good, but in general includes storage and maintenance costs, such as rotating materials and disposing of expired products. For goods with a relatively short shelf life, stockpiling is either not possible or very expensive. For example, the Australian Government acquired over 10 million units of a COVID-19 testing kit (the acquisition was funded by the private Minderoo Foundation), which has a shelf life of only six months. Given the slower than expected need for testing in Australia and the availability of a number of other testing kits, there was a risk that some of those kits subsequently might be wasted (Knaus and Smee 2020). Swabs used for RT-PCR testing (one of the most accurate laboratory methods for detecting, tracking and studying the COVID-19 coronavirus) have a relatively short shelf life of 15-36 months, which may also make them costly to stockpile (Johnson 2020).

In order to be effective, a stockpiling strategy relies on firms making good assessments of future vulnerabilities to their supply chains. For example, prior to the COVID-19 pandemic, the National Medical Stockpile (NMS) held very limited stocks of personal protective equipment (PPE). The ANAO noted that pre-pandemic replenishment planning for the NMS 'set out procurement priorities that were focused on chemical, biological, radiological or nuclear (CBRN) threats and an influenza pandemic and did not address other potential health threats' (ANAO 2020, p. 8). The ANAO also noted that procurement planning was not adequately coordinated with states and territories, who have primary responsibility for the supply of PPE (ANAO 2020, p. 8). Stockpiles provide limited capacity to respond to an

unexpected disruption. In effect, a small stockpile provides a small amount of insurance, which might be an effective part of a strategy that relies on a stockpile in the very short term, while responses are put in place. In the case of the COVID-19 pandemic, the NMS stockpiles could not meet Australia's needs for PPE beyond the very short term, but it was quickly able to use its contacts and knowledge of suppliers to source more PPE (box 5.4).

Box 5.4 The National Medical Stockpile

The Australian Government National Medical Stockpile (NMS), managed by the Department of Health, provides strategic reserves of pharmaceuticals, vaccines, antidotes and personal protective equipment (PPE) for use during the national response to a public health emergency which could arise from natural causes (risks) or terrorist activities (threats). It is intended to supplement state and territory supplies in a health emergency.

Prior to the COVID-19 pandemic the NMS held a small stock of PPE (12 million P2 masks and 9 million surgical masks) because state and territory health agencies have primary responsibility for equipping public hospitals and other health facilities. By 30 September 2020, the NMS had significantly increased its purchasing of PPE equipment, including 166 million P2/N95 and 595 million surgical masks, and distributed around 21 and 56 million of these masks respectively. (Previously, around 3.5 million P2 masks were distributed during the bushfire emergency in January 2020, and around 2.1 million pieces of PPE were distributed during the 2009 swine flu pandemic.)

Procurement was guided by estimates of expected usage of PPE and other medical products. This was based on assumptions about the rate of spread of the virus, the level of interventions, hospitalisation rates and how products are used. This information changed. The ANAO (2020, p. 58) for example, noted 'an initial estimated demand of 800 million to 1.2 billion surgical masks was reduced in April to less than 200 million due to the status of COVID-19 at that time.'

The quantities held prior to the pandemic needed to be expanded significantly beyond the small initial stockpile to meet expected demands, and the NMS (working closely with other government agencies) demonstrated strong capability as a bulk purchaser of these essential products by being able to secure supplies during a period of high international demand. The Australian Government's 54 contracts (as at 31 August 2020) secured sufficient PPE, medical equipment and COVID-19 test kits to complement the small stockpile that could not meet Australia's needs, but offered a short term buffer.

At the outset of the COVID-19 pandemic, the NMS was valued at $123 million. The Australian Government provided around $3.23 billion to the Department of Health to bolster reserves of PPE and other medical equipment between March and May 2020.

Sources: ANAO (2020, pp. 6–7; 58; 61); Department of Health (2020, p. 1); Doggett (2020).

Supplier diversification — sourcing goods from a range of suppliers across firms and around the globe

Diversifying suppliers is about improving the reliability of supply by spreading risks across many possible sources. Different suppliers are exposed to different risks and disruptions, and respond to them differently, so relying on a range of suppliers — not just on the lowest-cost supplier — will likely mitigate the cost of disruptions affecting certain suppliers.

Diversification also helps firms deal with uncertainty. Where risks are difficult to anticipate and probabilities of disruption difficult to estimate, having access to a range of suppliers is likely to cover firms against a wide range of potential risks (essentially pooling risks). For example, if there is an unexpected geopolitical event between Australia and another country, access to goods from a third country supplier could be ramped up to make up any shortfalls from this disruption.

Cochlear, for example, used outsourcing to solve potential capacity constraints in its manufacturing of hearing implants. According to Raz and Stonecash (2004, p. 2):

> [Cochlear] undertook to enter into a number of outsourcing arrangements with various firms around the globe. At one stage, the company had over 250 outsourcing contracts. To ensure security of supply, the company often outsources each component from two or three different suppliers.

Investing in relationships with several suppliers means that they can be available to bolster supplies when disruptions to other suppliers occur. The level of investment will likely depend on the confidence firms have about the suppliers in their chains, or the limited risks in not having full transparency. Greater confidence can also be developed with contractual obligations set on suppliers along the chain.

The importance of diversifying suppliers was highlighted in 2000, when a fire at a Philips semiconductor plant in the United States disrupted supplies of a crucial component in the production of Nokia and Ericsson mobile phones. Nokia officials noticed a glitch in supply even before Philips told the company and acted quickly to find alternative sources across Europe, Asia and the United States. 'They redesigned chips on the fly, sped up a project to boost production, and flexed the company's muscle to squeeze more out of other suppliers in a hurry' (Latour 2001). Ericsson moved more slowly.

> Unlike Nokia, [Ericsson] didn't have other suppliers of the same chips, known as RFCs, for radio frequency chips. In the end, Ericsson came up millions of chips short of what it needed for a key new product. Company officials say they lost at least $400 million in potential revenue, although an insurance claim against the fire may make up some of it. (Latour 2001)

The effectiveness of a diversification (or any other mitigation) strategy is limited when it applies to a 'diamond-shaped' chain. This is where 'a firm uses multiple tier 1 suppliers who in turn use a limited number of tier 2 suppliers, who all use the same upstream source … From the firm's point of view, the supply chain may appear to be composed of a diverse set of suppliers, often in different countries. However, the reality is that one firm, or a limited number of firms, provides critical materials to all the suppliers' (Slowinski, Latimer and Mehlman 2013, p. 21) This reinforces the importance of understanding the supply chain (section 5.2).

The costs of diversifying suppliers include developing and maintaining commercial relationships across multiple potential supplying firms or countries; and where multiple suppliers are established before a disruption, incurring average costs that are higher than if using the minimum cost provider. Diversification typically forgoes economies of scale in production and in shipping. Purchasing larger quantities, more consistently, from a single

supplier can also increase a firms' ability to influence the supplying firms' risk management strategies and ability to recover from disruptions.

Robust supplier relationships

In 1997, Toyota (and its suppliers) relied on just-in-time production, and maintained limited inventory of each of the over 30 000 components used in the production of a vehicle. While such inventory management was sufficient to deal with a minor supply chain disruption, it was not adequate to mitigate the impacts of a major fire to its sole supplier of a small but crucial brake-related part. This event threatened to halt production for several weeks as Toyota only held 2 to 3 days' worth of stock of this part. Toyota was, however, able to overcome that disruption by collaborating with over 200 firms in its established network of suppliers to produce the crucial component (around 70 firms took direct responsibility for production — some producing the part for the first time) (Nishiguchi and Beaudet 1997, pp. 1–2; 15).

Toyota's strong relationship with its suppliers has been extensively studied as a source of strength for Toyota. Suppliers demonstrate flexibility and commitment to Toyota, because Toyota is committed to retaining and rewarding its suppliers (Nishiguchi and Beaudet 1997). The experience of Toyota in 1997 showed how its investment in its supplier networks was crucial in overcoming a supply chain disruption. The various capabilities Toyota developed through institutionalised problem-solving activities within its group of suppliers also helped ensure the effectiveness and rapidity of the collaboration effort across its supplier networks, including the sharing of intellectual property, and human and physical capital (Nishiguchi and Beaudet 1997, p. 2).

While it may be possible to establish new relationships when a disruption occurs, a crisis makes this more difficult and more costly than if the relationship exists already. For example, during the pandemic, travel restrictions made it difficult to meet with new suppliers. Moreover, firms were unable to inspect products or the supplier to assess quality, and were competing with other firms seeking to repair their own supply chains. Further, alternative suppliers may not have capacity to expand production for new customers.

Contingent sourcing

Firms can enter into option contracts with alternative suppliers. This type of contract specifies the cost of reserving a number of units of a good that the firm would have the option to purchase. Under an option contract, the price of the reserved units is higher than the price of committed units under a regular purchasing contract. This means that rather than bearing a higher average cost of supply from relying on many suppliers, a firm would only bear additional marginal costs when disruptions occur (Tomlin 2006, p. 642).

Many countries have entered into advanced purchasing agreements to secure access to vaccines against COVID-19, some of which stipulate an option to buy additional units of a vaccine. For example, the United States signed a supply agreement with Moderna to provide

100 million doses of their vaccine candidate for US$1.525 billion (which includes a US$300 million incentive payment if emergency use authorisation is obtained by 31 January 2021). The U.S. Government also has the option to 'purchase up to an additional 400 million doses at a fixed price of US$1.65 billion per 100 million doses by specified dates in the agreement'(Moderna, Inc 2020, p. 30).

This form of contracting is particularly common in high-tech industries that face price fluctuations as demand and technology change rapidly. Hewlett-Packard, for example, has designed a customised option contract for memory chips, where the firm pays suppliers a premium for the option to buy a fixed quantity of memory devices at a fixed price, and will exercise this option if the market price increases above the fixed price, but would let the option lapse and buy in the open market when the market price is lower (Fu, Lee and Teo 2010, p. 2).

This strategy requires upstream firms to be flexible, that is, to have the capability and capacity to expand or contract their production volumes to meet changing demands. It may also require the firm to have some flexibility to be able to adapt to critical inputs that might not be exactly the same as those from the primary supplier. These arrangements involve additional costs, for example, requiring changes to machinery to be able to use parts of different dimensions. Firms can reduce these costs by postponing the point of product differentiation (that is, keeping production in a generic form as far down the production line as possible) to ensure they can use different components from other suppliers (as Nokia could, in the example above, by reconfiguring its generic mobile phone quickly so it could accept a slightly different component from other suppliers in the United States and Japan (Tang 2006, p. 38)).

Contingent sourcing also relies on the enforceability of contracts. If the shock is sufficiently disruptive, it may raise other issues that interfere with the normal enforcement of contracts. For example, in early 2021, the European Union disputed whether AstraZeneca was meeting its contractual 'Best Reasonable Efforts' over obligations in manufacturing and delivering the required number of doses of COVID-19 vaccines. AstraZeneca underdelivered on the number of doses it was contracted to produce for the European Union as it dealt with operational issues in some of its EU plants and faced large demands for its vaccines from around the world (O'Connor and Kirton 2021). Other contracts may stipulate force majeure conditions, which recognise that some events might be outside the supplier's control, and sufficient cause to relieve them from their contractual obligations (such as 'acts of God' or 'government actions or interference') (Borgese et al. 2020).

Domestic capability

Firms may choose to build their own domestic factory for a critical input, or to pay a premium to be supplied by an Australian firm. This insulates firms from supply chain disruptions that might affect overseas suppliers, causing shortages or large (and sometimes prohibitive) increases in costs.

For example, as a result of the COVID-19 pandemic, many telecommunications providers and some banks had to reassess their reliance on call centres located mainly in India and the

Philippines after they were unable to meet customer demand when these centres closed due to lockdowns. Crummy (2020, p. 1) observed that:

> In many cases, businesses had to quickly decide whether to replace now-defunct South-East Asian [call] centre operations with another offshore provider or provide additional resources to over-stretched Australian [call] centre teams while concurrently migrating agents to a working-from-home (WFH) scenario, or urgently find a new local [call] centre partner to move customer conversations onshore.

In July 2020, Westpac announced it would be reshoring up to 1000 call centre jobs back to Australia, at a cost of $45 million a year (although it expects productivity gains would help mitigate some of this cost increase) (Yates 2020).

An onshoring strategy does not necessarily involve moving an entire supply chain but rather assessing the parts of the supply chain that are most vulnerable to disruption, and onshoring those parts that still allow firms to remain competitive. Realistically, onshoring cannot eliminate risks associated with exposure to global supply chain disruptions. Complete insulation from disruptions is unlikely because most domestic production also relies on some imported inputs.[1]

In addition, onshoring does not eliminate all supply chain risks, as domestic production facilities and transport networks are vulnerable to onshore risks. Recent natural disasters and state-based health regulations during the COVID-19 crisis slowed and jeopardised the movement of goods around Australia. Moreover, large disruptions to global supply chains may still mean domestic production capacities are insufficient to meet demand. For example, despite producing half of the world's protective face masks before the pandemic, even China found itself importing masks during the pandemic, as it was unable to meet its initial needs despite its large local production (OECD 2020, pp. 5–6).

The costs of onshoring include maintaining higher costs of production, due to higher input (particularly labour) costs and to foregoing economies of scale. According to Logistics Bureau (2020), production in China results in significant savings for some industries:

> With significant reductions in labour and capital investment expenditure, production costs can be slashed by some 20 to 40 percent, and for labour-intensive products, up to 50 percent and beyond. The main reason for these savings is the availability of cheaper labour — manufacturing labour costs in China average US$5.5 per hour against the Australian average of US$15 per hour.
>
> An added factor is that Chinese companies produce in bulk for global consumer markets and therefore import raw materials, e.g. plastics and resins, in quantities so vast that they attract significant discounts from suppliers.

This local production cost premium was also identified by manufacturers of motor vehicles in Australia. For example, Ford and Holden/GM's manufacturing costs in Australia were approximately twice as high as those in Europe and four times greater than in Asia for a

[1] For example, across the veterinary pharmaceuticals and medicinal production manufacturing sector as a whole, every $100 of domestic output is associated with $50 of imports (ABS 2020).

comparable manufacturing operation. Holden noted that $2000 of this cost gap was due to Australian input costs (of which approximately 80 per cent was due to labour costs), $1500 was due to buying components from local suppliers, and $250 was due to the logistics costs for imported components (PC 2014a, p. 61).

Depending on the industry, demand in Australia (and any potential export demands) may be well below what could support a factory of efficient scale domestically. For example, much of the world's fire retardant is produced by one American factory (appendix B). Australian demand for fire retardant would also be highly variable (depending on how severe the bushfire season was), but country-level spikes in demand will smooth out for a global producer. This applies particularly to goods and services likely to be identified as essential under the Commission's proposed framework (chapter 3). Given the potentially narrow list of goods that would be identified under the framework, it may be that the goods cannot be produced locally (such as oil), or that Australia does not have the expertise or scale to produce them well or competitively relative to the rest of the world (such as chemicals).

But this does not mean there are no opportunities for firms to consider onshoring to improve resilience in their supply chains. Labour and other costs in some traditional offshore manufacturing centres have increased (including in some sites in China), and technology and automation have reduced labour-intensity and labour costs in many industries; these trends present opportunities for business to recalibrate their production choices.

The COVID-19 pandemic also provided a limited number of examples of firms pivoting their production to high-demand medical goods and services, where previously they may have found it difficult to overcome higher costs of production (box 1.3). For example, some craft breweries and distilleries pivoted their production to hand sanitisers during the beginning of the COVID-19 pandemic to help meet higher domestic needs. By April 2020, domestic production as a share of Australia's total hand sanitiser supply had grown from 50 per cent to around 70 per cent, with total domestic production capacity increasing from approximately 10 to 54 million litres per year (DISER 2020c, p. 4).

How the strategies compare

Firms have a number of risk management strategies to choose from, and some strategies will be more suitable than others depending on the disruptions that firms are likely to face and the nature of the vulnerabilities in the supply chain. A combination of strategies will likely be needed to mitigate the costs of potential supply chain disruptions.

Table 5.1 outlines some of the key elements that these strategies can be assessed against, and shows the relative strengths and weaknesses of each. For example:

- the less frequently a disruption is expected to occur, the worse a stockpiling or domestic capability strategy would likely perform relative to other strategies
- contingent contracting with alternative suppliers and supplier diversification share some of the same advantages, except if the more reliable (likely higher cost) suppliers have

more limited capacity to expand or contract production. In this scenario, contingent contracting would likely perform less well than a diversification strategy

- the longer the duration of a disruption, the less reliably we would expect stockpiling to perform, relative to other strategies. We see this, for example, in the performance of the NMS in supplying P2 masks for the 2020 Australian bushfires, relative to the pandemic. In the case of the pandemic there were millions more masks required than were held by the stockpile, and other strategies needed to be deployed.

This table is not exhaustive, and does not indicate the magnitude of strength and weakness of each strategy relative to others. Each disruption (such as a natural disaster, logistic failure, or pandemic) will have its own unique set of circumstances — and each will present opportunities or difficulties for different risk mitigation strategies.

Table 5.1 **Indicative impact of supply-side mitigation strategies**
Performance of strategy against nature of disruption and supplier[a]

	Do nothing	*Stockpiling*	*Supplier diversification*	*Contingent contracts*	*Domestic capability*
Nature of disruption					
Infrequent	+	−	+	+	−
Longer duration	−	−	+	+	+
Impact localised domestically[b]	?	+	+	+	−
Nature of disrupted supply					
Less flexible in production[c]	−	+	+	−	−
Goods are more perishable	?	−	?	?	+
Lower reliability of preferred supplier	−	+	+	+	+

[a] + Strategy likely to perform better than other strategies; − Strategy likely to perform worse than other strategies; ? Unclear how the strategy would perform under this characteristic. [b] Localised disruption affecting domestic supplies, rather than localised overseas or global disruptions. [c] Difficult for producers to respond quickly due to obstacles, such as capacity constraints or large investment requirements.

5.4 Risk ownership and the role of government

Firms are mainly responsible for managing risks in their supply chains

'Good risk management allocates risk … to the party best able to manage it' (OECD 2008, p. 49), where 'best able' relates to parties with the incentives and capabilities to reduce,

respond to and deal with residual risk. Supply chain disruptions can result in lost sales, profits and reputational damage, and possibly closure; firms thus have strong incentives to manage and respond to risks in their supply chains.

Firms up and down the supply chain can also share in managing risks. For example, a supplier may be reliant on the final producer for a majority of their revenue, which would be an incentive for them to help respond to any disruption in the supply chain (for example, as happened with suppliers of Toyota and Nokia discussed earlier). And contracts can be structured to give suppliers strong incentives for reliability, such as by including damages clauses.

While firms will not always manage supply chain risks effectively — due to unforeseen risks or inadequate preparation or response to a disruption — this does not mean government should take ownership of private sector supply chain risks. Governments make mistakes too. And all government interventions involve some combination of making: firms undertake certain activities; taxpayers fund firms' risk management; or the community as a whole bear certain risks. Such interventions thus need to be justified to ensure the benefits of the intervention outweigh the costs.

Government is directly responsible for managing supply chain risks where they deliver or procure goods and services on the community's behalf, including in delivering health services, national security and many other public services. Governments have a direct responsibility in many of the supply chains that would be considered essential as part of the framework proposed in this study — such as water, health, communications (provision of broadband internet and the telecommunications universal service obligation), and government (chapter 3). In doing so, governments, like any firm, invest in risk management strategies (as described in section 5.3).

The rest of this section explores whether there is a case for government involvement in the private sector's risk management, and if so, how it might be involved without crowding out the sector's investment in risk management.

FINDING 5.2

Risks are best managed by those who have direct incentives to mitigate against them. Firms are primarily responsible for managing risks in their supply chain.

Governments have responsibility, like any firm, to manage risks in supply chains for which they purchase and/or deliver goods and services directly, particularly when these are essential goods and services.

Each strategy has costs and some will perform better under different types of disruptions and contexts. Firms will employ a range of strategies to effectively manage risk.

Where might direct government intervention be justified?

Government intervention could be justified where private firms might under-invest in supply chain risk management or might otherwise be unable to effectively respond to disruptions, whether due to government or other impediments. It might also be justified where the amount of residual risk that results from the market exceeds the amount of risk that the community might be willing to accept, that is, where firms' risk appetite exceeds that of the community.

This implies that a socially optimal level of investment in risk management might diverge from what private firms deliver (that is, where the social cost or benefit of mitigation does not align with the firm's private cost or benefit). This divergence could come about for several reasons.

- Disruptions could have 'contagion' effects. Even if each firm individually managed the disruption effectively, these firms (and the community) may still be left exposed to large disruption costs. If firms understood the potential impacts of contagion to their business, they may seek to reach agreements with each other to internalise its effects, or governments may impose such measures. Bank deposit guarantees partially fulfil this role as a form of insurance to prevent large-scale bank failure that could spread to the banking system, and consequently, the broader economy.
- Consuming certain goods and services at times of disruption, such as face masks during the COVID-19 pandemic, may provide benefits to a broader group than those who directly consume them. This could lead to private undervaluation in the need to secure the supply of such goods and services.
- In some essential industries (such as in utilities or health provision), regulated prices may not provide sufficient financial incentives for firms to invest in risk management despite their importance to society. For example, pharmacies might choose not to stockpile additional amoxycillin to prevent a shortage, if they could not charge a premium when a shortage occurred. (Some providers of essential goods and services, such as supermarkets, can face social pressures that also limit their ability to charge more when there is scarce supply.)
- Even in markets with unregulated prices, firms may under-invest in risk management. For example:
  - a monopoly will take into account potential loss of profits from a disruption, but the damage to profits would be less than the damage to wellbeing.[2]

[2] Firms in a perfectly competitive market will make the socially efficient investment in risk management. However, firms with limited market power may under- or over-invest in risk management. The intuition is derived from Mankiw and Whinston (1986), who showed that an oligopoly market with free entry can lead to excess entry because a new firm does not take into account that it is stealing market share from existing firms. Investing in risk management is equivalent to investing to 'enter' the market in a state in which many firms are disrupted. A firm is insufficiently incentivised to invest in case it might be the only firm operating (the monopoly effect) but has a strong incentive to invest if many firms might be operating (the market-stealing effect). Either effect can dominate.

– if risks are large but infrequent, firms that do not invest in risk mitigation will gain a cost advantage. In a highly competitive market, firms that make this investment could be driven out. While firms may be able to credibly signal their risk management activities, customers might buy from cheaper providers and plan to switch providers when a disruption occurs (although this would only be a concern where individual private valuation diverges from social valuation).

Even where investment in risk management may not be adequate (and this itself is difficult to measure) due to government or other impediments, this is not sufficient to warrant government intervention (other than maybe correcting the impediment). Government taking over ownership of risk from firms could reduce private incentives to invest in risk management. Governments may also not have access to information held by private firms, which may make them less effective at managing risk for any given level of risk appetite.

To ensure government intervention is effective, governments need to demonstrate that the expected benefits of government investment in mitigating private sector supply chain risks outweigh the expected costs, and that the intervention is the best solution to the identified problem. (A potential assessment framework is outlined in figure 5.1.)

What role could government play in prevention and preparation?

Helping to better understand risk through the provision of information and expertise

Firms are usually in the best position to understand risks in their supply chains (even if they are unaware of details in all tiers of a chain). But governments also hold certain expertise and knowledge which can make them well placed to disseminate information that would improve a firm's understanding of risks in their supply chain.

The Australian Government, for instance, has science and research agencies that can directly support firms to improve the understanding of risks in their supply chains. The Bureau of Meteorology offers expertise in forecasts, warnings, monitoring and advice that assists Australians to deal with 'the harsh realities of their natural environment, including drought, floods, fires, storms, tsunami and tropical cyclones' (BOM 2021). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has expertise in science and technology, and can collaborate with government and industry to improve resilience in supply chains (box 5.5).

Box 5.5 CSIRO work relating to supply chains

- The CSIRO, supported by industry and state and territory governments, developed the Transport Network Strategic Investment Tool (TraNSIT). TraNSIT is a model that maps millions of vehicle trips across thousands of supply chains between production and domestic and export markets. It has been used to analyse the sensitivity of the road and rail network to natural disasters or other disruptions and their impact on freight access to markets.
- Through the Science and Industry Endowment Fund (which is supported by the CSIRO), researchers have developed a prototype of an automated system for fish species identification, counting, size estimation, colour measurement and tagging of catch to provide information to improve traceability along the supply chain.
- The Australian Department of Agriculture funded work by the CSIRO and academics to investigate how climate change might impact different agrifood supply chains in Australia, and how they can adapt.
- The CSIRO has other partnerships with industry to support supply chains via imaging and sensor technologies, autonomous robotics, new materials, and manufacturing processes.

Sources: CSIRO (2018, 2020); Lim-Camacho (2016); Science and Industry Endowment Fund (2020).

Several government agencies offer trade and international relations expertise by leveraging off the Australian Government's extensive diplomatic, trade and security networks (such as Austrade, and the departments of Foreign Affairs and Trade, Defence, and Home Affairs). These agencies gather information on geopolitical and security threats that might affect global supply chains, and identify and establish opportunities for trade links. While some firms will have access to some of this information through their own networks, governments may have greater access and reach to foreign governments and their security agencies.

As a regulator, governments also gather critical information, which can help identify risk in specific supply chains. For example, the Therapeutic Goods Administration (TGA) coordinates the national Medicines Shortages Working Group, which comprises key medical peak bodies and organisations, in addition to Department of Health staff.

> In Australia, medicines sponsors (companies) are required by law to report current and anticipated shortages of prescription medicines and certain over-the-counter medicines. The TGA publishes shortage notifications for the information of health professionals and consumers. If there are any medicine shortages relating to COVID-19, including information about expected duration and the supply of potential alternative products, details will be published on the TGA web page and also communicated more widely to healthcare professionals. (TGA 2020b)

Gathering this information and expertise is not costless for governments, and such initiatives to support firms need to demonstrate a net benefit to the community. Governments may often face economies of scale in obtaining expertise and insights, relative to individual firms. They may also have access to information in the course of providing a public good or service, which is of value to the community but would otherwise be under-produced if not delivered by government.

Mandating or subsidising investment in risk mitigation

Governments can compel or support firms to invest in risk mitigation to reduce the impacts of supply chain disruptions. In terms of supply-side risk mitigation strategies, governments could require firms in essential industries to hold stockpiles, compel or support firms to diversify their supply links, and/or subsidise local production or onshoring.

The most prominent example of direct government intervention in private firms' mitigation of supply chain risks in Australia is the minimum stockholding requirements for liquid fuels — although this requirement also supports the Australian Government in meeting its international stockpiling obligations (box 5.6).

While not specifically aimed at protecting firms from disruptions to global supply chains, some regulations require firms to invest in understanding their supply chains; for example, the Australian Government requires firms to report on how they monitor and manage other forms of risks through legislation:

- under the *Modern Slavery Act 2018* (Cwlth), entities with consolidated revenue of at least $100 million per financial year are required to report annually on the risks of modern slavery in their operations and supply chains, and the steps taken to address those risks
- under the *Security of Critical Infrastructure Act 2018* (Cwlth) owners and operators of critical infrastructure assets are required to provide information to the Register of Critical Infrastructure Assets to help the Australian Government work with them to identify and manage the national security risks of espionage, sabotage and coercion.

Other jurisdictions have provided direct subsidies to support firms to diversify their sources of production. For example, Japan, and later South Korea, introduced subsidies to onshore manufacturing and to diversify supply chains (primarily relocating production away from China to other economies across Asia). Japan provided subsidies of US$2 billion to onshore manufacturing and US$200 million to expand supply chains to South Asia (Editorial Board, East Asia Forum 2020). As Denton and Bruckard (2020) noted, nativist policies are likely to undercut competitiveness, raise consumer prices, concentrate risk and make industries 'more vulnerable to smaller, localised and more frequent shocks like floods, blackouts or social upheaval.' Moreover, it is unclear whether these subsidies facilitated additional investment, as noted by the Editorial Board, East Asia Forum (2020):

> Many Japanese multinationals have been reorganising their supply chains in Asia regardless of the 'China-exit' subsidy. Japanese companies have been restructuring their supply chains in Asia and investments over time due to rising labour costs in China. The 'China plus one' strategy of diversifying investment has been common practice for years. The subsidies may distort decisions and concentrate risk, or simply be a form of corporate welfare or privileging.

Setting requirements on firms to invest in supply chain risk mitigation raises the question on whether some form of taxpayer subsidy is appropriate, particularly if the additional investment supports a community-wide objective, rather than purely a private one. This may be relevant, for example, in regulated industries, which may be subject to price, rate of return

or similar regulation. There is a risk that regulation sets the price (or rate of return) too low to account for the costs of risk management.

Box 5.6 Minimum stockholding requirements for liquid fuel

Australia, as a member of the International Energy Agency, is a party to the International Energy Program and treaty that requires that member states maintain oil stocks equivalent to at least 90 days of the previous year's daily net oil imports. The purpose of this requirement is to ensure that oil-importing countries can withstand disruptions to supply by releasing stockpiled oil.

Oil supplies face many geopolitical and natural risks. For example, members of the Organization of the Petroleum Exporting Countries (OPEC) can work together to decrease oil production and create supply risks, but these efforts require members to co-operate with OPEC directions, which does not always occur (Iraq, for example, supplied record volumes of oil in August and September 2019, which went against an earlier OPEC decision to decrease production). And, although OPEC covered a large proportion of global oil production in the 20th century, it now accounts for only some 40 per cent of production.

The issue of how disruptions in global oil supplies could impact Australia was addressed in the *Liquid Fuel Security — Interim report*:

> Initial findings from testing of disruption scenarios show that the global market is generally robust enough to balance out supply and demand. The global oil price will spike in response to a disruption, and this will be an incentive for companies to bring new supplies of oil to the international market. (Department of the Environment and Energy 2019, p. 43)

Even so, in 2020 the Australian Government bought $94 million worth of oil to store in the United States' Strategic Petroleum Reserve for an initial period of 10 years. By storing crude oil in the United States, Australia meets some of its international treaty obligations, but its role in supporting Australia's physical or strategic oil reserve is less clear. In addition to possible geopolitical risks, time delays in shipping and refining the oil once in Australia are also a risk.

The Australian Government also created minimum stockholding obligations on industry for key transport fuels, to be accompanied by a $200 million grant for the construction of new storage facilities.

Sources: DISER (2020a); Department of the Environment and Energy (2019, pp. 25; 43); Laidlaw (2020, pp. 4–5); Turak (2019).

There are limited circumstances in which governments might take greater ownership of risk mitigation, for example by maintaining their own stockpiles, such as the National Medical Stockpile, in which the Australian Government maintains a national stockpile of PPE to be used by private medical practitioners and state-run health systems. The main advantage of a central stockpile (relative to directing firms to hold stockpiles) is the ability to rapidly direct supplies in the event of an emergency. If firms do not all experience shortages at the same time a central stockpile could be more efficient — smaller than if each firm had to maintain its own stockpile, because a pool of resources would be used to accommodate the shortages, similar to pooled insurance.

As with the many risk management strategies available to firms, governments have the choice of investing in one strategy or many, depending on the type of risk facing the supply

chain. For example, Australia relies on private and public stockpiles of liquid fuels. Japan, facing risks to rare earths supplies, has also opted for a multi-pronged strategy, involving:

- expanding the stockpile of most minerals from 60 days of domestic consumption to 180 days
- extending debt guarantees to firms to purchase existing refineries or to build their own facilities (for oil and other minerals), as well as to aid firms that wish to invest in mining operations overseas
- investing in the search for rare earth minerals in waters off Japan. (In late 2018, scientists from the University of Tokyo and the Japan Agency for Marine-Earth Science and Technology announced that an area of seabed 2000 km south of Tokyo contained millions of tons of rare earths.) (Ryall 2018, 2020)

Direct taxpayer assistance to help private firms invest in risk mitigation can be costly. For example, as noted in section 5.3, local cost premiums to produce domestically can be significant. But beyond the financial costs, there could be other costs.

- Setting expectations of taxpayer support, and with government acting like an insurer who charges no premiums, reducing the incentive for business to manage their own risks (i.e. crowding out). For example, drought assistance programs have been found to benefit recipients, but not to help farmers improve their self-reliance, preparedness and climate change management (PC 2009, p. XX).
- Government project financing instruments can distort the allocation of resources, and impose hidden costs on taxpayers, for example through risks of non-repayment of debt and concessional financing subsidies (that extend loans to firms on terms substantially more generous than are available through the market) (PC 2020, p. 20).
- Costs on other sectors of the economy, that do not directly benefit from government assistance. For instance, to fund the subsidies, governments must increase taxes and charges, cut back on other spending, or borrow additional funds. Funding provided to a single firm can also discriminate against its competitors (PC 2018, p. 2). Moreover, investment and economic activity could be diverted away from more highly-valued uses and sectors of the economy, due to an artificial increase in rates of return in the sector of the economy that received the industry assistance (PC 2014a, p. 94). And this could exacerbate supply chains risks in those industries that miss out on assistance.
- Resources that firms waste on rent-seeking behaviour to secure government assistance, rather than focusing on things that they could do themselves to improve the reliability of their supply chains (PC 2014a, p. 94).

These costs do not preclude government intervention, but any case for taxpayer-funded risk mitigation needs to demonstrate how the associated costs are outweighed by the benefits to the public, and that the intervention is the best solution to the identified policy problem (PC 2020, p. 20).

Direct government intervention in risk mitigation to protect the supply of essential goods and services should not be used to support broad industry policy objectives, unless the link

can be clearly established (and the intervention is found to be a net benefit to the community). Government supporting advanced manufacturing capacity in 3D printing or advanced robotics could be seen as important to allow firms to pivot when faced with a supply chain disruption. And indeed, there were a few examples where this capacity assisted in government and firms working together to pivot domestic production to produce essential PPE during the COVID-19 pandemic (box 1.1), although it is worth noting that many firms did not pivot. But government support in establishing general manufacturing capacity will not be suitable in mitigating many types of disruptions (for example, disruptions in fuel supplies), and the investment will likely crowd out more profitable forms of private investment in these technologies.

Government should also be cautious about intervening in private sector risk mitigation because firms' preparations for, and responses to, disruptions are usually effective. These responses are why most people are completely unaware of the myriad supply chain disruptions that happen every year. As McCloskey (2020) pointed out, 'you can depend on it that businesspeople will think up methods of insurance against future plagues better than government-imposed restrictions on whom you can buy from.' Although no system is likely to be foolproof, and disruptions in vaccine production in Europe have occurred (Goenka 2021), Australia's pharmaceutical supply chains were able to take measures to manage disruptions as they arose — box 5.2:

> Pharma and biotech companies with manufacturing facilities in Australia such as CSL, GSK and AstraZeneca have diverse supply chains and redundancies built-in to be able to accommodate a pandemic. As a result, there was not a significant interruption to the ability to either export medicines to international markets or import medicines from offshore manufacturing. (MTPConnect 2020b, p. 14)

What role might government play in response and recovery?

Ideally, governments would anticipate and prepare for future disruptions to ensure that policy responses during a crisis are measured and outcomes focused. The reality, however, is that it is not possible to anticipate all eventualities, and governments will be required to develop policy responses after a crisis occurs. Below are several principles to guide such a response.

First, as noted earlier, if a government is responsible for directly providing or purchasing essential goods or services, then it should manage risks in the supply chain. If that supply chain fails, then the responsibility for resolving a shortfall in supply belongs to the government. Disruptions may also require new policy priorities for governments to support communities respond to unanticipated cost increases. (Under circumstances where risks have not been effectively mitigated prior to a disruption, the community is likely to bear the higher costs associated with responding to and reducing the impacts.)

Many facets of the COVID-19 pandemic required rapid action from governments to understand and respond to new developments as part of their responsibilities in providing public health services. For example, governments secured supplies of PPE to hospitals and

government-owned aged care facilities, as well procuring vaccines, and testing supplies. In terms of vaccine procurement, the Australian Government decided that, for a premium, it would fund domestic production capacity to help secure access, in addition to making purchasing arrangements with overseas manufacturers of other vaccine candidates. Having a domestic manufacturing capacity seeks to avoid relying on global supply chains, some of which were assessed to be at greater risk of disruption than local supply chains:

> Both [AstraZeneca and Pfizer] have experienced global supply challenges but we are in a fortunate position as a country because of the decisions that have been taken … [including] the decision to pay a pay premium for an onshore, secure, sovereign vaccine manufacturing capacity via CSL. (Morrison 2020)

Local production, however, is not the only approach to overcoming potential barriers to supply such as export bans and spikes in global demand. In fact, it can raise other issues if domestic supply risks are not effectively managed, such as where local vaccines fail or prove to be less effective. This is why Australia and other countries have signed supply agreements with multiple manufacturers and through global collaboration efforts, including the COVAX Facility.

Governments can also have an important coordinating role in the aftermath of major disruptions to insulate the community from its worst effects. With respect to protecting vulnerable supply chains during the COVID-19 pandemic, several government agencies established taskforces and initiatives to coordinate a response to supply chain disruptions affecting essential industries (box 5.7).

Regulators can also play a key role in helping the community respond to unexpected disruptions. As the Medical Technology Association of Australia noted, the TGA:

> … has been a key partner in the government-industry collaboration, providing rapid engagement with the sector and developing an accelerated approvals process. As an example, rapid approval of ventilator design variations allowed Australia to get earlier access to new products on the production line which may have otherwise gone to other countries. In addition to rapid approvals, the TGA took on a heavy workload around preparing and publishing regulatory and non-regulatory advice and guidance to industry. The TGA reports that over 2200 new manufacturers entered the market from February to April this year, all requiring guidance. (MTPConnect 2020a, p. 8)

The Australian Competition and Consumer Commission also made determinations to temporarily allow conduct that would normally be considered anti-competitive. This included allowing the Australian Institute of Petroleum and major oil refiners to coordinate with one another to 'facilitate the efficient use of refining and fuel storage capacity during the pandemic' (ACCC 2020a). It also authorised supermarkets to take a coordinated approach to best ensure grocery supply. And the Australian Pesticides and Veterinary Medicines Authority provided support and guidance to holders and manufacturers of veterinary medicines to demonstrate compliance with Good Manufacturing Practice, while scheduled inspections and audits could not take place due to COVID-19 social distancing measures and travel restrictions.

Box 5.7 Examples of government responding to the COVID-19 pandemic

The Department of Industry, Science, Energy and Resources worked with industry and the Department of Health to secure supplies of personal protective equipment to the National Medical Stockpile:

> The Government supported local manufacturers by providing grants (such as $4 million to Shepparton-based company Med-Con to increase its production of face masks), reducing regulatory barriers, facilitating supply chain connections, and purchasing equipment for the [National Medical Stockpile] (such as the contract with a consortium of over 30 companies led by Grey Innovation to supply ventilators). (DISER 2020b, p. 4)

In collaboration with the Advanced Manufacturing Growth Centre, the Department of Industry, Science, Energy and Resources also supported Australian manufacturers and suppliers of critical medical and protective products to identify collaboration and market opportunities through the Growth Centre's COVID-19 Manufacturer Response Register.

The Department of Defence provided defence personnel to support domestic manufacturing of medical personal protective equipment under Defence Assistance to the Civil Community arrangements. For example, around a dozen engineering maintenance specialists were deployed to Med-Con Pty Ltd to assist the company's existing staff on production, maintenance and warehousing tasks. The Department's Defence Science and Technology Group helped to design new face shields, and worked with South Australian defence industry company Axiom Precision Manufacturing to assist with rapid production.

AUSTRADE administered the International Freight Assistance Mechanism to help accelerate delivery of agricultural and fisheries exports and re-establish global supply chains during the COVID-19 pandemic. A network of 15 air freight service providers were established to deliver regular freight services in the absence of commercial passenger flights.

The Department of Foreign Affairs and Trade established a COVID-19 Coordination Unit, which became the principal point for: coordinating the Department's COVID-19 response; whole-of-government policy coordination on implementing COVID-19 policy responses; and facilitating the delivery of personal protective equipment and other medical imports to Australia.

The National COVID-19 Coordination Commission was established to coordinate advice to the Australian Government on actions to anticipate and mitigate the economic and social effects of the global coronavirus pandemic. It formed a working group to work with manufacturers 'to ensure supply of essential products, such as personal protective equipment, and solve supply chain issues to keep critical goods flowing to Australian communities.'

The Prime Minister established the National Cabinet to ensure a 'coordinated response across the country to the many issues that relate to the management of the coronavirus'. It comprises the Prime Minister and the leaders of the states and territories, and is advised by the Australian Health Protection Principal Committee.

Sources: DISER (2020b, p. 4); DPS (2020); Reynolds and Andrews (2020).

In making these decisions, governments make an assessment that the net benefits of certain policy objectives, such as avoiding collusion or having greater certainty over the quality of regulated goods, are lower than the cost of major disruption.

Second, a government could also assist firms respond to disruptions in private sector supply chains but, as noted earlier, this runs the risk of crowding out more effective responses by private firms and dulling their incentives for future preparedness. For example, taxpayers supported firms to overcome disruptions in their freight channels through the International Freight Assistance Mechanism. While this support would have provided relief to many firms that faced fewer (and higher cost) freight options given the reduced availability of passenger flights as a result of border closures, it may also affect a firm's incentive to invest in managing for this risk in the future. Although there might be calls for governments to support the economy during a crisis, the costs of government intervention need to be considered. As with natural disaster funding, governments should not create a cycle of under-investing in mitigation and insurance, and over-investing in post-disaster recovery, which reduces incentives for firms to manage risks ex ante (PC 2014b, p. 2).

Providing an open trading environment is vital

Most fundamentally, governments can facilitate more effective responses to supply chain disruptions by creating a regulatory and policy environment that avoids unnecessary impediments to domestic and international trade. An open trading environment in particular allows firms to deal with operating uncertainties or unanticipated risks in their supply chains, as they face lower costs in adapting their production or their supply chains in response to a major disruption.

Trade is beneficial for managing and responding to supply chain disruptions

The Australian Government plays a critical role in supporting a rules-based global trading system. It signs up to these rules of trade between nations (based on the principles of non-discrimination, transparency and reciprocity) primarily through the World Trade Organisation (WTO).

> The system provides predictability and mechanisms to avert or resolve trade disputes and gives all nations and businesses regardless of their size the confidence that success in international trade depends on the merits and competitiveness of the goods and services they provide, not their political clout. It has proven effective in progressively lowering trade barriers, which has been a source of economic growth, lifted living standards and contributed to poverty reduction within and across nations. (PC 2019, p. 38)

The Australian Government supports this rules-based trading system by ensuring markets are open to trade and investment. The Commission has previously identified three areas that could continue to drive this, including: periodically reviewing the design and adequacy of foreign investment screening processes; bolstering government efforts to explain how and why the community benefits from trade liberalisation; and lowering remaining trade barriers (PC 2019, p. 51). Opportunities to free up trade barriers are found in box 5.8.

The Australian Government can also support the rules-based trading system by working with other countries to resolve long-standing and escalating challenges facing the WTO. This

includes reinvigorating its negotiation function, strengthening compliance with notification procedures, and refreshing the rules to handle issues relating to state-owned enterprises, regulatory co-operation, digital trade and intellectual property, amongst others.

Having minimal constraints on international trade allows firms to diversify their suppliers in preparation for global supply chain disruptions, and to find alternative suppliers when a disruption affects a specific location in a firm's supply chain.

A strong and reliable trading system is particularly important during a crisis. By April 2020, around 80 countries had introduced export prohibitions and restrictions to mitigate shortages at the national level of medical supplies (facemasks and shields), pharmaceuticals and medical equipment (ventilators), and other products, such as foodstuffs and toilet paper (WTO 2020, p. 1).

Agreements under the WTO (based on the *General Agreement on Tariffs and Trade 1994*) broadly prohibit the use of export bans and restrictions, unless the member country can justify that a measure is required to prevent or relieve critical shortages of foodstuffs or other essential products, or to protect human, animal or plant life and health (WTO 2020, p. 4).[3] These provisions regulate how the measures can be applied (for example, they cannot be discriminatory), and establish notification and dispute resolution mechanisms. (That said, few countries were transparent in how they implemented the measures during the COVID-19 pandemic (WTO 2020, p. 2).)

The WTO noted that such actions are not costless. For example, exporters risk losing out in the long run:

> … lower domestic prices will reduce the incentive to produce the good domestically, and the higher foreign price creates an incentive to smuggle it out of the country, both of which may reduce domestic availability of the product. On the other hand, restrictions initiated by one country may end-up triggering a domino effect. If trade does not provide secure, predictable access to essential goods, countries may feel they have to close themselves from imports and pursue domestic production instead, even at much higher prices. Such a scenario would likely result in lower supply and higher prices for much-needed merchandise. The long-term effects could be significant (WTO 2020, pp. 1–2).

[3] The *General Agreement on Tariffs and Trade 1994* sets out carve outs and exceptions to the general prohibition to export bans and restrictions under Articles XI:2(a) and XX:b respectively (WTO 2020, p. 4).

Box 5.8 Potential areas to remove barriers to trade

- Address the 'noodle bowl' of rule of origin requirements that need to be navigated to benefit from tariff and quota preferences in preferential trade agreements.
- Undertake a targeted review of certain technical barriers to trade (usually erected for product safety or biosecurity reasons). Evaluating these barriers can take time so is better suited for prevention against the impacts of supply chain disruptions and for building preparedness to respond to disruptions. Local businesses that buy grains, for example, have been seeking access to imported product for decades, but it can still take upwards of six months for import permits to be granted.
- Review domestic laws, regulations and practices that can restrict trade in services. For example, burdensome licensing requirements in sectors such as architectural and engineering services can increase administrative costs on foreign companies or prevent them from practicing in Australia.
- Reform Australia's anti-dumping system. The Commission has previously identified specific ways to improve the system (for example, *de minimis* margins), which has been used to protect certain firms at the expense of the broader community, but also suggested that consideration be given to whether the system should be retained at all.

Sources: Crook and Gordon (2017); Centre for International Economics and Sydney Centre for International Economics (1997); PC (2010, p. x, 2016, p. 2, 2019, p. 51); Sullivan (2018, 2019).

Regulations should not unnecessarily impede risk management and response

All levels of government have a role to ensure regulations achieve their outcomes, without unnecessarily impeding risk management and response by firms. Particularly pertinent to regulatory impacts on supply chains, better regulation should ensure that it is:

- outcomes focused, that is, not unduly prescriptive. This allows firms to have flexibility in finding the best way to comply with regulatory outcomes and adapt their operations, if required, during a disruption. For example, if a regulation prescribes a particular risk management approach, the firm does not have flexibility to assess what approach is most effective for their operations
- integrated and consistent with other laws, agreements and international obligations. This is particularly important, for example, to ensure domestic regulations do not impede international trade that could support a more diversified supply chain
- enforceable and embody the minimum incentives needed for effective compliance. This requires regulators to be resourced and empowered to enforce regulation in a manner that allows them to be responsive to changing circumstances, while ensuring that regulatory outcomes are achieved.

Regulation should be reviewed regularly to ensure it is fit for purpose, and while good regulatory systems should be set up to deal with changing conditions, temporary, ad hoc changes, such as those mentioned above about competition regulation, may be required to respond to unexpected disruptions. Such responses can be a good opportunity to review

regulatory systems, in line with a 'stewardship' approach to regulation. For example, the *Corporations (Coronavirus Economic Response) Determination (No. 1) 2020* (Cwlth) temporarily allowed companies to execute documents electronically. This option had long been sought by stakeholders, and was already permitted in comparable jurisdictions including New Zealand, the United Kingdom and the United States (Department of the Treasury 2020, p. 20). The Australian Government has since released an Exposure Draft Bill that would permanently allow the use of electronic signatures (the Corporations Amendment (Virtual Meetings and Electronic Communications) Bill 2020).

A framework for government action

With hindsight, it is easy to identify actions that governments might have taken to better support firms' preparation for the global supply chain disruptions wrought by the COVID-19 pandemic. And lessons have been learnt. But when looking forward, governments should bring a disruption-agnostic and principles-based approach to deciding how they support preparation for, and response to, disruptions to global supply chains that might threaten access to essential goods and services, in line with good policy process principles outlined in box 5.9.

Box 5.9 Good policy process principles where government intervention is appropriate

- Transparency: Governments should inform taxpayers about where and how public funds are being used. Where assistance involves mutual obligation, this should be clear and measurable by all parties.
- Accountability: Governments and the recipients of public assistance should both be accountable to the public for their actions. In terms of government accountability, the conditions under which industry assistance measures are established should be clearly articulated upfront, and it should be demonstrated to taxpayers that the benefits to the community from government intervention are expected to exceed the costs.
- Long-term sustainability: Where industry-specific assistance can be justified — given the presence of a government or other impediment, and the costs and benefits of policy intervention — it should not be regarded as a permanent lifeline. Well-designed assistance measures should seek to provide a sound footing for industries to achieve commercial viability, free of specific government funding or other advantage.

Source: PC (2014a, pp. 83–84).

Moreover, drawing on the principles of supply chain risk management outlined in this chapter, figure 5.1 outlines a framework that governments could use to decide whether and how to intervene in managing supply chain risks. Table 5.2 poses questions that are designed to clarify each step in the framework. The questions are directed at ensuring the continuity of supply for those goods and services that are essential to Australians' wellbeing.

It begins with understanding the problem. Governments need to identify the good or service that they care about, including whether it is vulnerable, essential and critical (based on the

framework outlined in chapter 3); how well firms manage the risk; and what strategies firms use to manage the risk.

Second, governments needs to establish their role, and identify all potential options for intervention. This includes understanding whether firms face any impediments to managing risks and whether government is best placed to address those impediments. It is important to clearly identify and articulate the objectives of any intervention here (that is, what barrier is being addressed) and canvas widely for options that might achieve that objective.

Third, governments need to assess the costs and benefits of intervention against no government action. In this step it is important to consider the market response during a disruption and whether government intervention will crowd out firm investment in risk management. Governments could decide to intervene if the benefits of intervention outweigh the costs. And finally, monitor and evaluate the effectiveness of its decision.

The Commission considers the number of goods and services likely to be identified by the proposed analytical framework in this study (chapter 3) is likely to be small and change over time. This means that it is important to regularly review the list of goods and services that are vulnerable to disruptions and essential and critical for the wellbeing of Australians, and whether government interventions are effectively addressing supply chain risks. The framework developed in chapter 3 provides a means to repeat such reviews relatively easily.

FINDING 5.3

There are conditions where government intervention in private sector risk management may be justified — specifically, if society's tolerance for a residual risk is lower than the residual risk that results from the market. Another situation is where government or other impediments prevent firms from effectively managing their risks.

That said, government intervention could crowd out private investment in risk management. The net benefit of any intervention would have to outweigh the possible costs.

The Australian Government also has responsibility for maintaining and promoting a respected and rules-based international trading system which promotes low-cost trading and firms' ability to insure themselves and respond to disruption. And all levels of government have responsibility for ensuring regulations are fit for purpose, including making temporary changes that let firms adjust to temporary disruptions.

Figure 5.1 **A framework for government intervention**

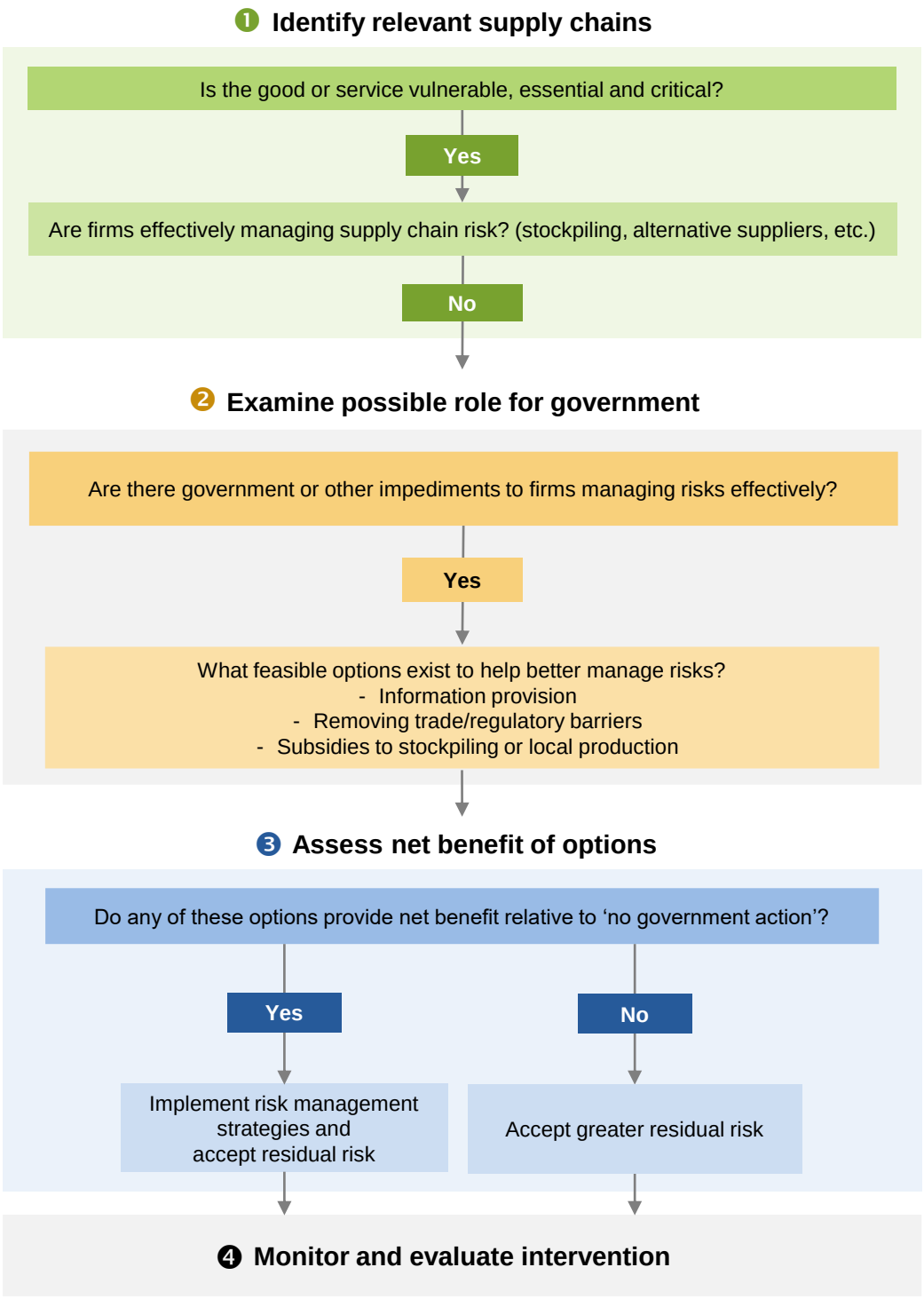


Table 5.2 **Questions to ask when considering government intervention**

Identify relevant supply chains

- What is the essential good or service of interest? What makes it essential? Are there any critical inputs? (Critical inputs cannot be replaced or designed out.)
- What makes the supply chain vulnerable?
- What disruptions could impact supply of the critical input in question? What are their characteristics, and the characteristics of the goods in question? Different treatments are suited to different goods/supply chains/risks (box 5.1).
- Have firms in the supply chain identified and taken ownership of the risk? How is the risk managed?

Examine possible role for government

- Are there impediments to firms managing risks? These may include:
  - inadequate information on risks
  - contagion effects resulting in firms choosing risky behaviour
  - externalities in consumption, resulting in individuals wanting less of the goods and services in question than would be preferred from the perspective of the community
  - inability to price risk (before or after disruption). Could be due to regulation or consumers buying from cheaper non-resilient supply chains in normal times
  - regulatory or trade barriers
- What is the negative outcome that government seeks to avoid? What level of risk can society bear?
- Does government have an advantage filling information gaps that would help firms better manage their supply chain risks? For example, information on geopolitical risk or meteorological information on natural disaster risks. Alternatively should government require firms to disclose information (for example, on stocks or suppliers) to increase supply chain transparency?
- Can government address trade/regulatory barriers to firms' ability to manage risks? For example, do tariff and non-tariff barriers prevent firms implementing diversification strategies?
- Would subsidies for stockpiling or local production improve supply chain resilience? For example, is the good perishable? Would local production be able to respond to expected disruptions? Would a local producer need to import raw materials? Do the raw material supply chains have similar vulnerabilities?

Assess whether the costs of interventions are justified

Do nothing

- What is the cost of government doing nothing?
- Can firms and consumers adapt their behaviour to use less of the essential good or service, or the critical input to their production? Would standard market processes lead to the critical input being reallocated from non-essential uses to essential uses?

Information provision

- How much would it cost to collect and disseminate information required to facilitate risk management? What burdens would be placed on firms and the community in collecting it?
- Would this crowd out private investment in information?

Remove trade or regulatory barriers

- What is the purpose of the policy? What are the costs (or risks) of changing it?
- How is this barrier preventing firms from effectively investing in supply chain risk? Are there alternative regulations that achieve the same outcome and better allow for supply chain risk management?
- Faced with major disruptions, regulations that were previously sensible may be overly restrictive. Could certain regulations be suspended or amended to make adjusting to the disruption less costly?

Subsidies to stockpiling or local production

- What are the costs of stockpiling? How much would prices rise if firms were required to invest in stockpiles? How much would firms need to be subsidised to optimally invest in stockpiles? Would subsidies crowd out private action?
- What is the local cost premium stopping firms investing in local production, unassisted by government? What would the cost of subsidising local production be?

A Consultation

Consultation to inform the preparation of the interim report comprised three workshops and bilateral meetings with representatives from Australian Government agencies. The workshops were held on 17 November 2020, 17 December 2020 and 2 February 2021. Table A.1 lists the agencies that were involved. Given the timelines of the study, the Commission has been constrained in its ability to consult more widely.

Table A.1 **Agencies that attended workshops or bilateral meetings**

Austrade
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Department of Agriculture, Water and the Environment
Department of Defence
Department of Foreign Affairs and Trade
Department of Health
Department of Home Affairs
Department of Industry, Science, Energy and Resources
Department of Infrastructure, Transport, Regional Development and Communications
Department of the Prime Minister and Cabinet
Department of the Treasury
National COVID-19 Commission

B Case studies in vulnerability

This appendix presents three case studies of essential goods to describe some of their properties and possible reasons for their vulnerabilities. The goods are: rare earths, water treatment chemicals and long-term fire retardant.

B.1 Estimating global supply concentrations

The first part of the framework developed for this study is to identify vulnerable goods. In chapter 4 three filters are applied to identify potentially vulnerable imports.

- The first ascertains whether the sources for each Australian import are highly concentrated. An import is deemed to be concentrated when more than 80 per cent originates from a single origin.
- The second filter ascertains whether the products are sourced from a concentrated global market. Global markets are considered highly concentrated when the main supplying country accounted for over 50 per cent of global exports or when the Herfindahl-Hirschman Index (HHI) is greater than 3100 points.
- The third filter determines whether Australia sourced its concentrated imports from the main global supplier in a globally concentrated market.

These filters are used to examine the supply chains of goods and inputs for rare earths, water purification and fire retardant.

B.2 Case studies

Rare earths

Rare earths (HS code 280530) are a group of 17 elements composed of scandium, yttrium, and lanthanides, which feature unique catalytic, metallurgical, nuclear, electrical, magnetic, or luminescent properties. Rare earth compounds are critical inputs in the manufacture of a number of essential technologies and industries such as electronics, renewable energy, medical and defence (Dushyantha et al. 2020). Rare earth elements are relatively abundant in the Earth's crust but rarely cluster in exploitable ore bodies (Haxel, Hendrick and Orris 2002).

Australian imports of rare earths in 2018 were virtually nil[19], reflecting the small size of the Australian manufacturing sector that uses these materials. Using the framework (chapters 3 and 4), imports of rare earths are not deemed to be vulnerable since the main supplying economy accounts for less than 80 per cent of imports. However, global trade data do not identify the 17 individual elements separately, and determining Australia's vulnerability in each would require more detailed data.

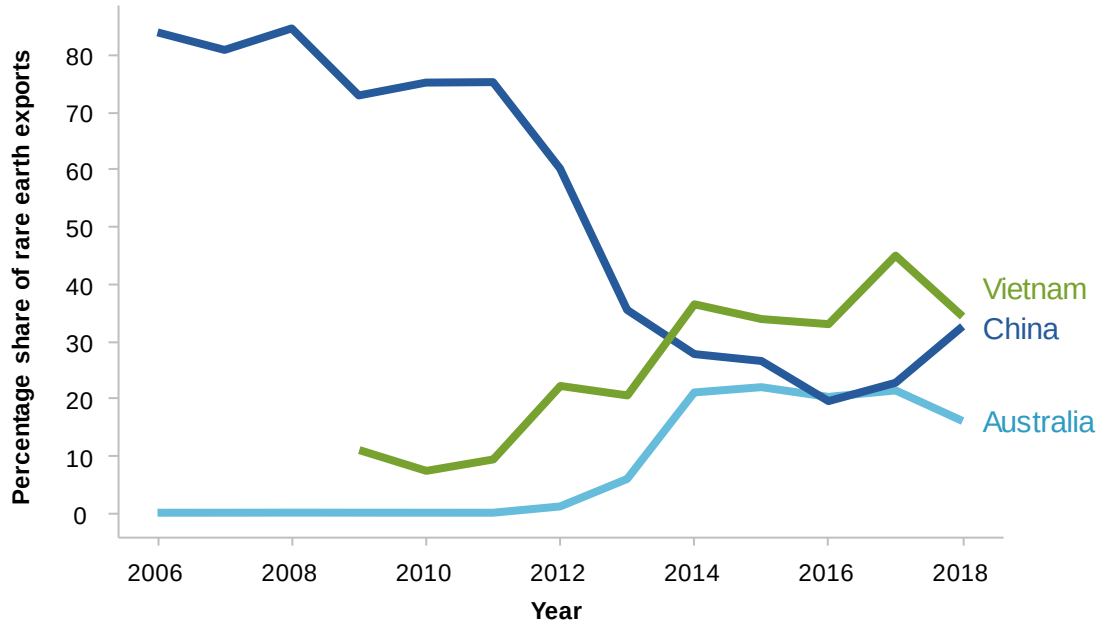
As of 2018, the global market for rare earths was not highly concentrated: as a group, rare earths had a HHI of 2555. Globally, the largest exporter was Vietnam (34.9 per cent), followed by China (31.6 per cent), and then Australia (16.3 per cent).

However China's role in rare earths is more important than the export data suggests. As the world's dominant supplier, it produces about 90 per cent of all output (Dushyantha et al. 2020). Before 2010 this was reflected in the trade data (figure B.1) but the period since has seen China's market share drop away as export quotas were tightened to 'ensure sustainability and curb environmental damage' (Branigan 2010).

Australian imports may be small, but rare earths are critical components of machinery, and electronic and medical equipment, some of which is likely to be essential. Disruption in the supply of rare earth would affect Australia as an end user of such equipment. Some of these goods have been identified in chapter 4 as being vulnerable, including laptops.

19 Significant differences exist between global trade data sources for rare earths, particularly in Australia's contribution to the world market. Analysis presented here is drawn from the BACI database provided by Centre d'Etudes Prospectives et d'Informations Internationales (CEPII).

Figure B.1 **Market concentration has declined following China's export restrictions**



Data source: Observatory of Economic Complexity (2018).

Water treatment chemicals

A continuous, stable and reliable supply of drinking water is essential. While water itself is sourced locally, making it drinkable is a multi-step process that involves a number of chemical inputs whose supply might be vulnerable.

In Australia, drinking water quality is governed by state authorities following national guidelines that outline a number of chemicals that can be used in the treatment process.

Water treatment chemicals are distributed across several HS codes and most chemicals appear to are not vulnerable when the first two filters are applied. In most cases where import concentrations of products have been greater than 80 per cent, the HHI for those products have shown the global market to be competitive (table B.1).

One exception, however, is disodium carbonate, where 93 per cent of Australia's imports are sourced from a dominant world supplier which possesses a market share in excess of 50 per cent. Although the world market appears relatively competitive (HHI 2314), Australia's concentrated buying patterns mean the supply chain for disodium carbonate is vulnerable.

That said, disodium carbonate is not critical as its role in pH correction appears to be substitutable. In the pH correction process, lime can be used instead of disodium carbonate and is applied by adding either slaked lime or quicklime; both are not vulnerable (table B.1).

Likewise, sodium hydroxide can also be used as a substitute for disodium carbonate and is traded in a large, competitive market with imports to Australia also being relatively unconcentrated.

Table B.1 **Water treatment chemicals are not vulnerable**

Product	*HS code*	*Use*	*Concentration of Australian imports (%)*	*HHI by value*[a]	*Export share of main global supplier*[a]
Aluminium sulphate	283322	Coagulation	**91.9**	780.5	18.9
Water filtering or purifying machinery or apparatus	842121	Filtration	25.4		
Calcium hypochlorite[b]	282810	Disinfection	73.0		
Potassium permanganate	284161	Disinfection	38.7		
Ammonium sulphate[c]	310221	Disinfection	66.4		
Copper sulphate	283325	Disinfection	40.5		
Parts for lamps (including UV)	853990	Disinfection	35.1		
Includes UV lamps	853949	Disinfection	34.6		
Chlorine	280110	Disinfection	**83.7**	1251.3	27.0
Hydrogen peroxide	284700	Disinfection	**100.0**	1243.2	23.9
UV or IR apparatus	901820	Disinfection	30.9		
Granulated activated carbon	380210	Disinfection	22.1		
Hydrochloric acid	280610	Disinfection	36.0		
Anhydrous ammonia	281410	Disinfection	69.8		
Disodium carbonate	283620	pH Correction	**90.9**	2885.8	**50.7**
Phosphoric acid[d]	280920	pH Correction	**96.3**	1703.5	35.3
Sodium tripolyphosphate	283531	pH Correction	65.7		
Sodium hydroxide	281511	pH Correction	47.9		
Sodium bicarbonate	283630	pH Correction	54.6		
Sulphuric acid	280700	pH Correction	54.7		
Quicklime	252210	pH Correction	36.7		
Slaked lime	252220	pH Correction	41.7		

[a] Calculated for products with import concentration in excess of 80 per cent. [b] Generally used in small systems only. [c] Used in the manufacture of chloramine. [d] For making sodium hexametaphosphate.

Sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished), *UN Comtrade* data, Melbourne Water (2020), NHMRC (2011).

Long-term fire retardant

There are two types of fire retardants. Short-term fire retardants are added to water and applied directly to a fire, enhancing the extinguishing ability of water itself. These typically take the form of liquids or foams. Long-term fire retardant is usually delivered from the air, mostly by fixed-wing aircraft to create fire breaks. It can be applied to slow or stop the progress of a fire, or as a preventative measure to protect property or strategic infrastructure

(DHHS (Vic) 2017). Long-term fire retardant was used extensively during Australia's 2019-20 bushfire season with large air tankers applying over 24 million tonnes across Australia (Royal Commission into National Natural Disaster Arrangements 2020a, p. 210).

Australia is reliant on a single supplier of retardant and only acquires enough in advance to cover a 'standard' bushfire season (Royal Commission into National Natural Disaster Arrangements 2020a, p. 233). The report suggested procurement plans should match 'anticipated requirements' and if that proved impossible, consideration should be given to domestic production.

The long-term fire retardant referred to in the Royal Commission report is the PHOS-CHeK range, manufactured by Perimeter Solutions in the United States. Perimeter Solutions supplies PHOS-CHeK to both Australian and North American fire and forestry services. Perimeter Solutions appears to be the only supplier of long-term fire retardant.

Trade in these products is not recorded under a standalone HTISC category. Given this lack of detail it is difficult to use trade data to assess its vulnerability. That said, sourcing this product from a single firm and plant makes it vulnerable to disruption.

C Technical application of the analytical framework

This appendix provides details on the application of the analytical framework developed in chapter 3 to Australian imports data presented in chapter 4.

- Section C.1 describes how the vulnerability of Australian imports data to supply risks arising from limited sources of supply was assessed.
- Section C.2 describes how Australian production data were used to assess the role that vulnerable imports played in the domestic production of essential goods and services.

The annexes to this appendix provide supporting information about the data sources and the product classifications used.

C.1 Assessing import vulnerability

The mechanical sorting undertaken in chapter 4 identified Australian imports that were sourced from the main global suppliers in concentrated markets (step 1 of the framework outlined in chapter 3).

This approach considered vulnerability arising from two perspectives:

1. from reliance on existing suppliers and trade flows to provide an indication of *actual* supply risks
2. from *possible* sources of supply to provide an indication of *potential* supply risk.

To illustrate the difference, while Australia may source all its imports of a particular product from a single country, other countries may be able to supply the product in the event of a disruption to supply.

The mechanical sorting involved progressively applying three filters to ascertain whether:

1. the main supplier of each product accounts for a large share of Australian imports
2. Australia sources its imports of each product from a concentrated global market
3. Australia sources it its imports from the main supplier in a concentrated global market.

The first filter relates to Australian imports, while the second and third filters relate to global markets. Given this, the analysis used two trade data sets — Australian imports data sourced

from the Australian Bureau of Statistics (ABS); and the United Nation's *Comtrade* database of global trade (annex A).[1]

The products that remain after applying all three filters are sourced from the main supplier in a highly concentrated global market with limited, if any, alternative sources of supply in the event of a disruption to existing suppliers. Such products are likely to be more susceptible to disruption than products sourced from more diversified markets.[2]

Approach used

Assessing import vulnerability involved linking Australian imports and global trade data at the same point in time. Linking trade data raised a series of questions:

1. As trade data come in different levels of product aggregation, what level of product disaggregation is appropriate for analysing supply chain risks?
2. Trade data relate to specific periods of time (such as monthly, and calendar and financial years), what time period is appropriate for the analysis?
3. As some trade is irregular and lumpy (such as imports of civilian aircraft and natural gas drilling platforms), should the analysis focus on a single year or span several years?

Level of analysis

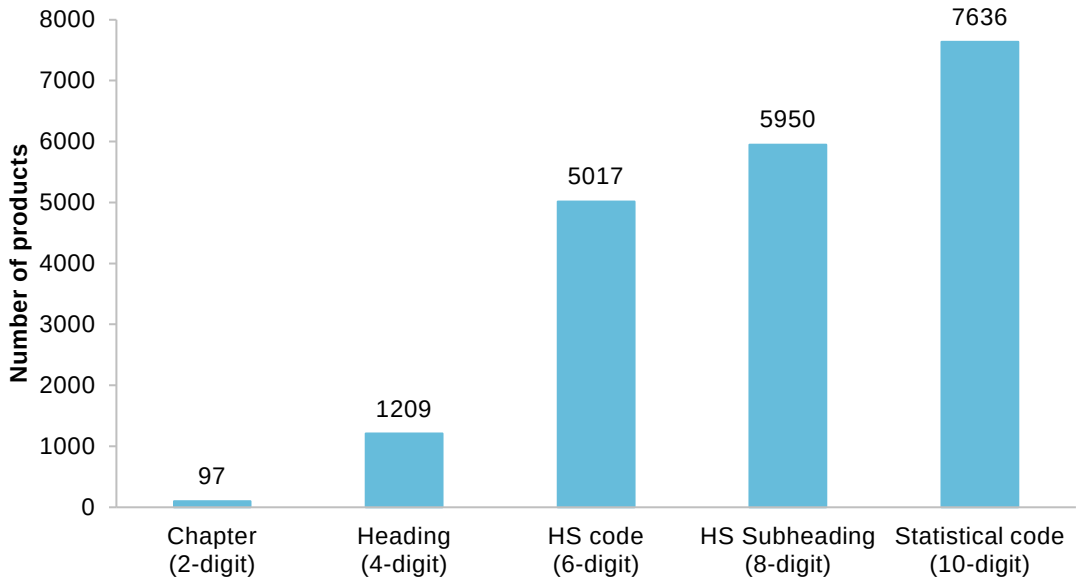
Trade and economic data are invariably aggregated to some extent (see annex B for details on product classifications). The trade data used in chapter 4 are classified according to the international Harmonized System (HS), or its Australian extension known as the Harmonized Tariff Item Statistical Code (HTISC). The HTISC has five levels of product aggregation, ranging from highly aggregated (known as the 2-digit Chapter) to highly disaggregated (Statistical codes, 10-digit). The number of products imported by Australia in 2016-17 differed by product classification (figure C.1).

Finer levels of product disaggregation enable a closer alignment with the specific products that may give rise to supply chain vulnerability, while higher levels of aggregation group products with broadly similar characteristics to reduce the volume of data. Some very fine levels of disaggregation add additional detail that is unnecessary for most purposes (such as differentiating the same product based on its thickness).

1 The use of global trade data to identify alternative potential suppliers may understate the number of concentrated products, as it implicitly assumes that all sources of potential supply are open to Australia, which may not actually be the case. Australian biosecurity restrictions, for example, prohibit the importation of certain agricultural products from potential suppliers *even if* supplies of these products were available on the world market.

2 The interest in potential suppliers means that the focus in the global trade analysis is on countries that *export* each product (even though the chapter focuses on Australian imports).

Figure C.1 **Number of products by HTISC classification**



Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

The level of import concentration varies depending on the fineness of the product classification used. Import concentrations will be higher for finer classifications (those with more digits) than for coarser ones (those with fewer digits), owing to the detailed nature of the product definitions. Finer product classifications are more homogeneous than coarser ones, but may not include products that are effective substitutes. The resulting higher import concentrations may give the impression that some products are vulnerable when substitute products are actually available. On the other hand, coarser classifications may give the false impression that supplies of imports are not concentrated, as concentrated products may be grouped with products that are not.

There is no right level of aggregation; judgment is needed to balance these two opposing potential sources of bias.

Time period covered

The data sources used contain data that span different time periods:

- the Australian imports data extend from January 2010 to July 2020.
- the global trade data extend from 2014 to 2017 (with preliminary data for 2018).

Using multiple years of data raises a set of trade-offs. In theory, it allows for the identification of products that are consistently assessed as vulnerable and might help avoid any bias that arises if a single year of data is not representative of others. However, using multiple years of data raises many practical issues. The main practical issue is changing

product classifications which render the data inconsistent over time and which complicate the linking of multiple years of data. The process becomes more challenging when linking across the different product classifications used in trade data and production data.

The time period selected should reflect the current (or most recent) state of affairs. For example, in the past 10 years, Australia's main supplier for a product may have changed, there may be new product technologies that replaced older ones, or the composition of the global trade market may have changed (such as, entries and exits of exporting countries or changes in the main exporter of a product). Using data that is not timely may result in out of date findings.

The Australian imports data span the beginning of the COVID-19 pandemic which may not reflect a typical year. The pandemic disrupted many trade flows, causing surges in imports of some products (such as personal protective equipment) and a drop in imports of others (such as manufactured products). Therefore, imports data for 2020 would not reflect a typical year or the usual functioning of the Australian economy.

The approach taken was to focus on trade flows in 2016-17, as it reflects the latest full year of the global trade data (2017) and the latest year of detailed production data. Given product classifications change over time, using a similar reference year facilitated the linking across multiple data sources (trade and production).

Thresholds used to assess concentration

Measures of concentration were used to ascertain the degree to which a product had a limited source of supply, and was, therefore, identified as vulnerable to disruption.

The trade data capture trade flows at the country level, not the firm level.[3] Thus, 'supplier' refers to a supplying country. This also means that measures of concentration may be overstated, as there may be many firms within a country who supply a product.

Australian import data

The concentration of imports was determined by assessing:

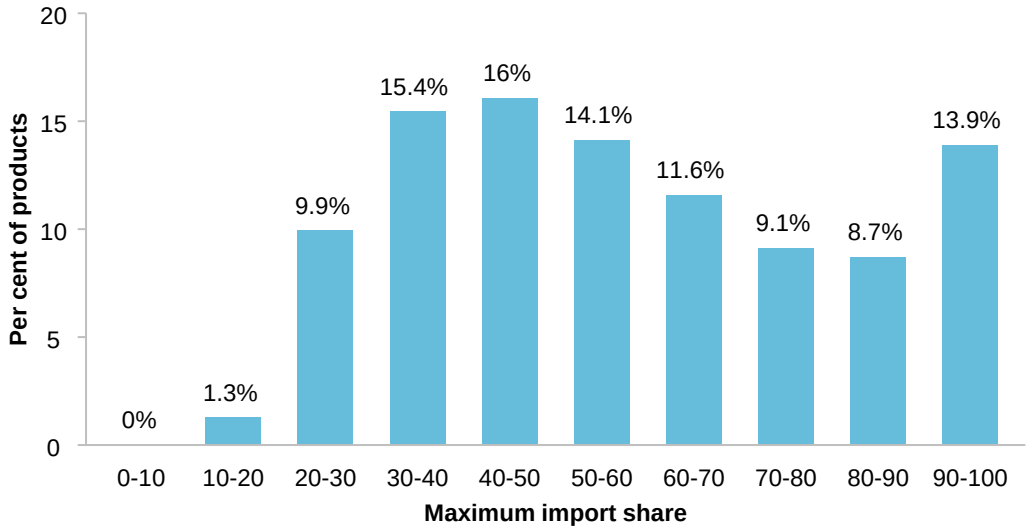
- the share of imports that each supplying country accounted for (referred to as 'import concentration')

[3] The geographic classifications used in the data is a mixture of sovereign countries (such as Papua New Guinea and Thailand) and geographic regions (such as Antarctica and the Channel Islands). Countries such as China, France, and the United Kingdom consist of multiple regions. For simplicity, the analysis talks in terms of 'countries' rather than 'economies'.

- the share of imports accounted for by the largest supplying country. Shares are based on the *value* of imports.[4]

The share of Australian imports accounted for by the largest supplying country varied markedly across products in 2016-17 (figure C2).

Figure C.2 **Distribution of the share of Australian imports accounted for by the largest supplying country, 2017[a]**



a Share of imports from the largest supplying country.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

Nevertheless, most imported products came from markets with high levels of concentration. Roughly, one-in-seven imported products in 2016-17 (13.9 per cent) came from markets where the main supplying country accounted for 90 to 100 per cent of all imports by value. An additional one-in-five products (17.8 per cent) came from markets where the main supplier accounted for 70 to 90 per cent of imports. Indeed, over half of all products came from markets where one country accounted for more than 50 per cent of imports of that product.

Judgement is required when choosing a threshold to classify an import as 'concentrated'. The number of concentrated imports identified is sensitive to the threshold selected (see sensitivity analysis below). A threshold of over 80 per cent was selected. As with any selected threshold, there might be products with high import concentrations (such as 79 per cent) that will be excluded but may potentially be an input into an essential industry that a policy maker might be concerned about. However, a threshold of 80 per cent provides a more

4 The free on board (FOB) value is used because the alternative (the commercial invoice value, insurance costs, and freight, CIF value) includes freight and insurance costs which may distort the measure of concentration.

conservative approach than a threshold of 90 per cent (which might appear to be the natural threshold choice given, in figure C.2, the distribution increases at the 90 per cent threshold).

Global trade data

Concentration in global market supply was assessed in terms of:

- the main exporter's share of global trade
- the Herfindahl-Hirschman Index (HHI).

Most empirical studies of market concentration calculate market shares based on financial values (such as the value of trade). However, market shares can also be calculated using the quantities traded. The two measures are generally highly correlated, but need not be. Diamonds are an example where a value share may differ materially from a quantity share, given the importance of quality (such as cut, colour, and clarity) in determining value. Differences can also occur for other reasons, such as differences in production concentration implying different unit prices.

The UN Comtrade database includes data on trade flows in both value and quantity terms, such that the market share could be calculated using either measure.[5]

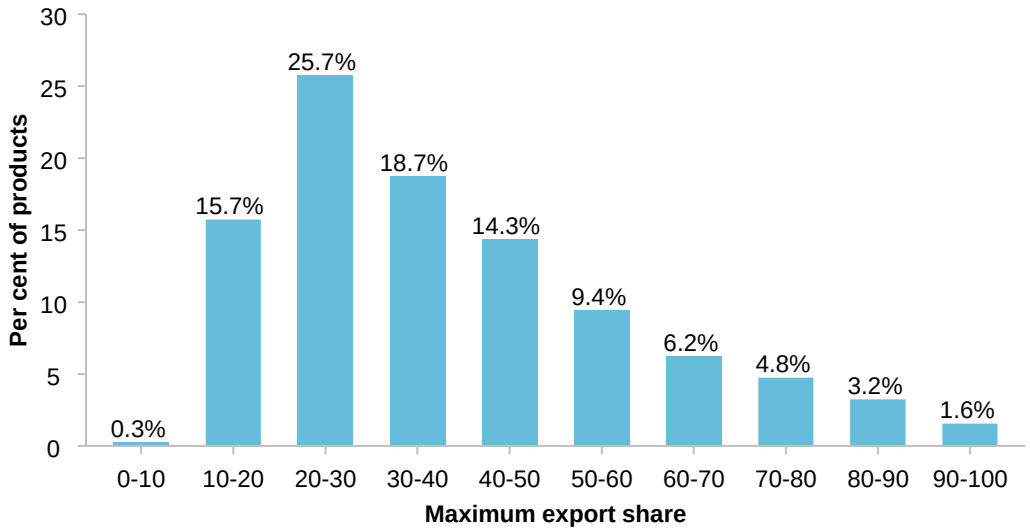
Choosing whether to calculate market shares based on quantity or value is not straightforward. If products within a product group are substitutes — even though their price and quality may differ — then quantity-based market shares indicate potential sources of supply are available from another supplier (regardless of the price or quality). However, quantity data is sometimes missing from the global trade data for some products and, therefore, need to be imputed.

The most comprehensive approach to identify all concentrated global markets is to calculate concentration measures using both a value-based market share and a quantity-based market share. The use of both measures errs on the side of caution by flagging the largest set of products for further investigation.

The share of global supply (exports) accounted for by the largest supplier of a product is presented in figure C.3. For only 1.6 per cent of products, the highest share was between 90 and 100 per cent. This means that, although there were other suppliers of the product, one country accounted for over 90 per cent of global exports. For a quarter of all products, the highest export share was greater than 50 per cent (that is, one supplier accounted for over half of a product's exports). The supply of these products may be vulnerable because of few potential suppliers and the potential for abuse of any market dominance (such as when China put quotas on exports of rare earth metals (Shen, Moomy and Eggert 2020, p. 127).

5 Quantity is reported in net weight in kilograms for most products and the value reported as the FOB value.

Figure C.3 **Distribution of the share of global exports accounted for by the largest global supplier, 2017**



Data source: UN *Comtrade*.

The HHI is the most used measure of market concentration. It is popular because it summarises information about both the number of exporters and their respective market shares. It is calculated as the sum of the square of the market shares of each exporter (limited to the largest 50 exporters). The HHI ranges from 0 to 10 000.

In antitrust law in the United States, a HHI between 1500 and 2500, when based on firm market shares, suggests a market is moderately concentrated and above 2500 indicates a market that is highly concentrated (US Department of Justice and Federal Trade Commission 2010). However, as the analysis in chapter 4 is on supplying *countries* rather than on individual *firms* on which the US antitrust law is based, a threshold above 2500 is more appropriate. This is because countries are an aggregation of the firms within them, and this aggregation makes the global market more concentrated.

Given this, a HHI of 3100 (the 75th percentile) was used to determine whether a global market is concentrated or not. The use of this threshold captures products where the main global supplier has a market share of less than 50 per cent, *but* where the market contains few suppliers (such that each country has relatively high market shares). These markets also pose risks for supply chains because there are few alternative suppliers. An example of such a market would be one in which the main supplier has a market share of 48 per cent and the remaining two suppliers each have a market share of 26 per cent. Such a market would not be considered concentrated based on the market share of the main supplier, but the resulting HHI of 3656 would indicate that the market is indeed highly concentrated.

Linking global trade data to Australian imports data

The Australian imports and global trade data were linked at the product level.

The World Customs Organization (WCO) revises the HS every five years, which makes linking by product classifications more challenging for the years in which the HS is revised. All of the global trade data use the 4th HS revision, which was implemented in 2012. As the Australian HTISC is based on the international HS classification, the Australian classifications also change, such that imports data between 2012 and 2016 use the 4th HS revision, but data after 2016 use the 5th revision that was implemented in 2017, which requires additional concordance work.

Sensitivity analysis

Sensitivity testing was undertaken to gauge the robustness of the import vulnerability analysis to:

- the level of product aggregation and concentration threshold selected
- the minimum value needed for a product to be considered potentially vulnerable
- whether imports of all products are likely to be essential.

Using a different concentration threshold and level of analysis

The number of imports identified is sensitive to the selection of product classification and the threshold for classifying imports as concentrated (table C.1). The use of coarser aggregated product classifications (those with fewer digits) results in fewer concentrated imports. Here, the concentration measures are typically lower because they reflect the average concentration for a large group of products — some of which may not be substitutes. For coarser product aggregations, a lower concentration threshold is appropriate. The use of highly disaggregated product classifications (those with more digits) results in many concentrated imports, especially if the threshold is set low. For finer product aggregations, a higher concentration threshold is appropriate.

Table C.1 **Number of imports identified as concentrated by threshold and product classification, 2016-17**
HTISC classification

	2-digit (97 products)	*4-digit (1209 products)*	*6-digit (5017 products)*	*8-digit (5950 products)*	*10-digit (7636 products)*
90 per cent	0	83	625	826	1 072
80 per cent	1	141	1 051	1 342	1 733
70 per cent	3	239	1 514	1 885	2 442
60 per cent	16	386	2 122	2 573	3 327
50 per cent	24	534	2 805	3 412	4 402

Source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

Using different value thresholds

The analysis in chapter 4 included all imports regardless of the values involved. This resulted in many small trade flows being assessed as vulnerable. However, small import values are generally unlikely to cause material consequences for the Australian economy if imports were to be disrupted, irrespective of whether they come from concentrated markets or not.

To test the sensitivity of the results to the absence of any minimum value threshold, the analysis was repeated using four alternative thresholds: A$400 000, A$1 million, A$10 million, and A$50 million (table C.2).

Using different sectoral coverage

The analysis in chapter 4 included imports from all sectors of the Australian economy. This resulted in many imports being identified as vulnerable, even though any disruption to their supply is unlikely to cause any significant impact on activities of national significance (such as wrist watches, Christmas decorations, and sparkling wine). These products are unlikely to be essential, even if they are identified as vulnerable.

To test the sensitivity of the results to the inclusion of imports from all sectors, the analysis was repeated excluding those 2-digit HTISC Chapters that are less likely to be critical to national activities (primarily imports of many agricultural items, some foods and many non-essential consumer-orientated manufacturing products).

Simultaneously imposing a minimum value threshold and restricting the sectoral coverage reduces the number of potentially susceptible imports (table C.2). The restricted sectoral coverage, coupled with a A$50 million value threshold, reduces the number of products to 35.

These sensitivity tests indicate that the approach taken to defining and assessing import vulnerability has a material impact on the number and type of products identified as vulnerable.

Table C.2 **Sensitivity testing of the number of most concentrated imports, 2017**

Minimum value threshold	*Restricted HTISC Chapters*[a]
0	550
$400 000	318
$1 million	252
$10 million	105
$50 million	35

[a] Excluding HTISC Chapters 1 to 24, 33, 39 to 71, 92, and 94 to 99.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

C.2 Assessing essential goods and services

The application of step 2 of the framework involved assessing whether any of the vulnerable imports identified in step 1 are:

- used as inputs in domestic production by essential industries, and whether the output of these industries are vital for meeting the basic needs of Australians (these imports are indirectly vital, as they form part of the local production of goods and services that meet the basic needs of Australians)
- vital for directly meeting the basic needs of Australians (these imports are directly consumed by Australian households).

Ascertaining the importance of vulnerable imports in the Australian economy — in terms of both their role in Australian production and their use in meeting the basic needs of Australians — required the linking of Australian imports data with Australian data on the production and consumption of different products.

The I–O tables

The analysis used Australian production data from the ABS *Input-Output* (I–O) tables for 2016-17 (ABS Cat. no. 5209.0.55.001). A summary of this data is outlined in annex A.

The I–O tables, which are contained in a series of excel spreadsheets, contain the most detailed production and consumption data available for the Australian economy that shows the interlinkages between products and industries in a given reference year (in this case, the financial year 2016-17). The tables cover:

- 114 products classified according to the 'Input-Output Product Groups', or IOPGs, which are generally listed in the rows
- 114 industries classified according to the 'Input-Output Industry Groups', IOIGs, which are generally listed in the columns.

Some additional product information is supplied, with a lag, in the supporting ABS *Input-Output Product Details* according to the more detailed Input-Output Product Classification (ABS Cat. no 5215.0.55.001). Even in its most disaggregated form, the products in the I–O tables are far more aggregated than those in the imports data used.

The key I–O tables that are relevant to the application of the analytical framework reported in chapter 4 are:

- the 'use table', which details the use of each product by each industry and category of final demand (I–O table 2)
- the 'imports table', which details the use of each imported product by each industry and category of final demand (I–O table 3).

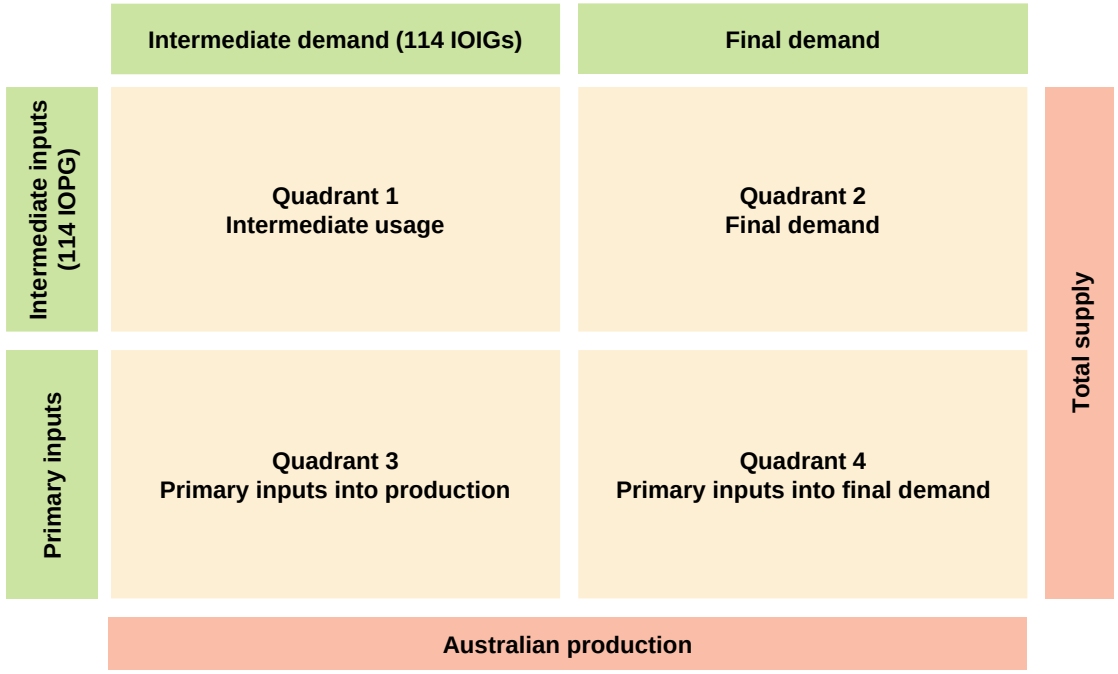
The use of *domestic* products by industries and category of final demand was derived by subtracting the use of imports from total use (that is, quadrants 1 and 2 in the use table *less* quadrants 1 and 2 from the imports table).

The basic structure of each of the key I–O tables is depicted in figure C.4.

- Quadrants 1 and 2 together show the total *use* of products. This includes the use of products as intermediate inputs into production by industries (quadrant 1) and final demand of households, government, gross fixed capital formation, changes in inventories, and exports (quadrant 2).
- Quadrants 1 and 3 together show the use or primary factors (labour and capital) and taxes used in *production* of each industry and by each category of final demand.

Quadrants 1 and 3 detail the cost structure of each industry (covering intermediate inputs use, primary factors use, and taxes).

Figure C.4 **Structure of an I–O table spreadsheet**



Classifying IOIG/IOPGs as essential

The narrow definition of essential goods and services outlined in chapter 3 are those that 'meet the basic needs of Australians', and include: the provision of water, medicines, communications, energy, defence, health, logistics, transactional banking, and government services.

This conceptualisation of essential goods and services is mapped to the products and industries that produce them in the I–O tables (table C.3).

Essential industries relate to the Australian *production* of essential products by each of the relevant IOIG industries. Essential products relate to the *consumption* (use) of each corresponding IOPG by each industry and category of final demand.

The industry and product labels in the I–O tables are identical, thus giving the appearance that the tables are symmetric. However, the products and industries are conceptually different. Typically, an industry (IOIG) is the largest producer of their corresponding product (IOPG). However, many industries may also produce products that are the primary to another industry — this is known as secondary production (shown in the I–O 'supply table', table 1).

The approach used here implicitly defines an industry as essential which means that every product that an industry produces is considered essential. However, in practice there may be outputs of an industry that are more essential than others. For example, the 'Human Pharmaceuticals and Medicinal Product Manufacturing' (IOIG 1801) industry predominately

produces human pharmaceuticals and medicines (IOPG 1801) but they also produce some amount of basic chemical manufacturing (IOPG 1803), which may not be as essential in meeting the basic material needs of Australians.

Table C.3 **Mapping of essential goods and services to Australian production data**

Essential good or service	*Input-Output Product/Industry Group (IOIG/IOPG)*
Banking (1)	Finance (6201)
Health (4)	Human Pharmaceutical and Medicinal Product Manufacturing (1801) Veterinary Pharmaceutical and Medicinal Product Manufacturing (1802) Health Care Services (8401) Residential Care and Social Assistance Services (8601)
Water services (1)	Water Supply, Drainage and Drainage Services (2801)
Communications (3)	Broadcasting (exc Internet) (5601) Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing (5701) Telecommunication Services (5801)
Energy (7)	Coal Mining (0601) Oil and Gas Extraction (0701) Petroleum and Coal Product Manufacturing (1701) Electricity Generation (2601) Electricity Transition, Distribution, On Selling and Electricity Market Operation (2605) Gas Supply (2701)
Logistics (7)	Road Transport (4601) Rail Transport (4701) Water, Pipeline and Other Transport (4801) Air and Space Transport (4901) Transport Support Services and Storage (5201) Wholesale Trade (3301) Retail Trade (3901)
Government (3)	Public Administration and Regulatory Services (7501) Defence (7601) Public Order and Safety (7701)

Aligning the trade and production data

The ABS does not publish a concordance or mapping from the HTISC classifications used in the trade data to the classifications used in the I-O tables. The absence of such a concordance impedes the analysis of supply chain vulnerability.

To overcome this, the Commission constructed a concordance to link the HTISC to the I-O tables. This process is not straightforward, and hampered by widespread changes to the trade and production classifications over time (annex B).

Annex A: Data sources

Australian imports data

The Australian imports data were sourced directly from the ABS.

The Australian Customs and Border Protection Service (ACBPS) collects detailed information on the value of imports for customs purposes. Among other things, this information includes:

- a description of the product imported
- the quantity imported
- the value of the imports
- the economy of origin for the imports
- numerous statistical classifications.

The ABS uses the ACBPS data as the basis for its merchandise imports statistics. The ACBPS classifies all imported products according to the HTISC (annex B).

The Commission used existing concordances to link the ABS import data to industry classifications.

Data confidentiality

The ABS confidentialises imports of certain products to protect the confidentiality of the transactions involved. Confidentialisation also extends to suppressing the identity of some supplying economies. Confidentialisation prevents the products (and/or supplying economy) from being identified.

Data cleaning

The imports data were cleaned to make it suitable for use. First, the monthly data were aggregated to yearly data. Second, goods that were imported into Australia that were re-exported were removed (the ABS refers to these transactions as ‘re-exports’). Third, imports to Australia from Australia were removed. Finally, transactions that involved negative values (CIF, FOB, or customs value) were removed.

Global trade data

The global trade data were sourced from United Nation’s international trade UN *Comtrade* database (https://comtrade.un.org/data/).

UN *Comtrade* is the largest and most comprehensive depository of international trade data. Over 170 reporter economies provide their annual international trade statistics. At the international level, the most detailed product classification available is the 6-digit HS code (annex B). The data collected use the HS revision implemented in January 2012 (also known as the 4th revision), and capture each reporting economy's exports of a product to the world (rather than to trading partners). Among other things, this information includes:

- a description of the product
- the exporting economy
- the quantity of the exported product
- the value of the exported product.

Trade data are typically messy and incomplete. An alternative global trade dataset was investigated — BACI data[6] ('Base pour l'Analyse du Commerce International': Database for International Trade Analysis) which is built directly from UN *Comtrade* data and includes bilateral trade flows for more than 5000 products and 200 countries. The BACI data are intended to show trade flows between trade partners and so only retain trade observations in which both trading partners are specified (that is, the importer and exporter). Whereas the UN *Comtrade* data sourced here records a country's exports of products without specifying its trading partners. This results in some data discrepancies between the databases.

Input-Output tables

The Australian production data were sourced from the ABS for the year 2016-17.

The I–O tables form part of the Australian national accounts, complementing the quarterly and annual series of national income, expenditure and product aggregates. They provide detailed information about the supply and use of products in the Australian economy, and the structure of and inter-relationships between Australian industries. Among other things, this information includes:

- intermediate inputs into production
- final demand
- primary inputs into production
- primary inputs into final demand.

The I–O tables contain information for 114 industry and product groups, which are classified using the IOIG and IOPG (annex B).

6 Publicly available for download: http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=37.

Annex B: Classifications

Harmonized System and Harmonized Tariff Item Statistical Code

The HS is a 6-digit code that is maintained by the WCO. The code is reviewed every five years and updated to ensure it remains relevant given developments in technology and changes in patterns of international trade. There have been five revisions to the HS since the first edition was implemented in January 1988, with the latest revision being implemented by Australia on 1 January 2017. The previous revisions to the HS by the WCO were implemented in Australia in 1996, 2002, 2007, 2012, and 2017. There were minor amendments in 1992. The next revised edition is scheduled for implementation in January 2022. The ABS create non-HS chapters 98 and 99.

Under the HS, each product is assigned to a six-digit product group. The classifications are hierarchical and arranged on a logical basis under specific Chapters (indicated by the first two digits), Headings (indicated by the third and fourth digits) and Subheadings (indicated by the fifth and sixth digits) (table C.4). The HS generally groups commodities according to their degree of manufacture, the material of which they are composed, and by similar generic descriptions. For example, live animals are classified within Chapter 1, animal hides and skins within Chapter 41 and leather footwear within Chapter 64.

Table C.4 **An example of the hierarchical structure of the HTISC**

Level	*Code*	*Description*
Chapter	61	Articles of apparel and clothing accessories, knitted or crocheted
Heading	61.10	Jerseys, pullovers, cardigans, waistcoats and similar articles, knitted or crocheted
HS code	61.10.30	Jerseys, pullovers, cardigans, waistcoats and similar articles, of man-made fibres, knitted or crocheted
HS subheading	61.10.30.00	Jerseys, pullovers, cardigans, waistcoats & similar articles of man-made fibres, knitted or crocheted
Statistical code	61.10.30.00.53	Women's or girls' jerseys, pullovers, cardigans, waistcoats and similar articles (excl. sweat shirts or the like) of man-made fibres, knitted or crocheted

Australia uses an extended version of the HS known as the HTISC to classify its international merchandise trade. The HTISC adds an additional four digits to the international six-digit HS code to give a 10-digit code. Consequently, the first six digits of the HTISC are the same as the first six digits of HS. The Department of Home Affairs adds the seventh and eighth digits to allow the application of different rates of import duty (the inclusion of these two additional digits give subheadings). The ABS adds the ninth and tenth digits for statistical purposes (giving rise to the statistical code) (table C.4).

Broad Economic Classification

The BEC was introduced by the United Nations in the early 1970s. The BEC groups commodities according to their main end-use, which align, as far as practicable, with the System of National Accounts (SNA) framework.

The 3-digit BEC classification groups goods into nineteen basic economic categories. Sixteen of these basic categories make up the broad end-use categories: consumption goods, capital goods and intermediate goods. A fourth category (other goods) includes the three remaining basic economic categories, which are difficult to assign to a single main-end use category. These are motor spirit (321), passenger motor cars (51) and goods not elsewhere specified (7). For example, motor spirit and passenger motor cars are used by both industry (as intermediate consumption and capital goods respectively) and households (as consumption goods).

An example of the different levels of aggregation for the BEC codes is presented in table C.5. The 3-digit BEC codes can be linked to the 10-digit HTISC codes.

Table C.5 **An example of the hierarchical structure of the BEC**

Level	*Code*	*Description*	*SNA*
Category	1	Food and Beverages	
Sub-category	11	Primary	
Basic category	111	Mainly for industry	Intermediate goods
Basic category	112	Mainly for household consumption	Consumption goods

Australian Input-Output table classifications (IOPC/IOPG/IOIG)

Input-Output Product Classification (IOPC)

The IOPC is a product classification that has been specifically developed for the compilation and application of Australian I–O tables. Because the I–O system describes the production and subsequent use of all goods and services, an I–O product is defined in terms of the characteristic products of industry sectors that produce the product. The IOPC has over 900 individual product items, which are represented by an 8-digit code (these codes are unrelated to the 8-digit HTISC codes).

Additional product information support the release of each I–O table with a lag (Cat. no. 5215.0.55.001). The additional information enables the number of products to be expanded from 114 IOPG to 900-odd IOPC. There is no additional industry information.

The ABS periodically revises the IOPCs. There have been five versions of the IOPC since 2005. There are publicly available concordance files between these IOPC classifications.

The ABS confidentialises production and consumption information for a number of IOPC classifications on confidentiality grounds. Two of these confidentialised products that are particularly pertinent for the analysis of import supply chain vulnerability are air transport and water transport.

Input-Output Product Group (IOPG)

Input-Output Product Groups (IOPG) are groups of related IOPCs that are aggregated in the published I–O tables. There were 114 product groups (4-digit codes) in 2016-17.

Input-Output Industry Group (IOIG)

Industries in the I–O tables are classified according to Input-Output Industry Groups (IOIG), which are based on the Australian and New Zealand Standard Industrial Classification (ANZSIC). There were 114 industry categories (4-digit codes) in 2016-17.

The ABS has revised the IOIGs, with three versions since 2005.

D Import demand elasticities

The last step of the analytical framework proposed in chapter 3 is to identify goods that are critical to the functioning of the economy and to the wellbeing of Australians. A good is *critical* if it is required for the supply of an essential good or service and cannot be substituted easily. This appendix tests whether a data-driven approach can be used to determine the criticality of a good. It does this by estimating demand elasticities for chemicals that are assessed as vulnerable and essential in the import data.

D.1 What is elasticity of demand and why is it useful?

The price elasticity of demand measures how the quantity demanded of a good changes in response to a change in price (box D.1). For most goods, if the quantity demanded decreases significantly when its price increases, their demand is said to be elastic. A demand that is not responsive is inelastic.

The elasticity of demand can be interpreted as an indication that the corresponding good is critical, because it reflects both the necessity of the good and the availability of substitutes. An inelastic demand indicates that users of the product cannot easily substitute away from it and must absorb price increases. For example, if the price of a lifesaving medicine were to increase, most people would still purchase it, and the quantity demanded would not decline much in response to the price increase. However, if the medicine could be substituted, a price increase would likely push users to purchase the alternative, decreasing the quantity demanded for the product whose price has increased.

Timeframes affect elasticities. In the short term, a good such as petrol for vehicles might be inelastic as alternatives are not available. But in the long term, the purchase of electric vehicles may mean people can substitute away from petrol, making the good more elastic.

Estimating elasticities

The simplest estimate of an elasticity requires (at least) two points where the price and quantity have changed (and other factors affecting the market remain unchanged). Statistical methods, such as regression techniques, can be used to isolate the effect of price changes from the effects of other influences on price — that is, by controlling for observed variables. For example, the demand for peaches might increase with income and decrease with price; including data on income in a regression isolates the effect of price changes from the effect of changes in income.

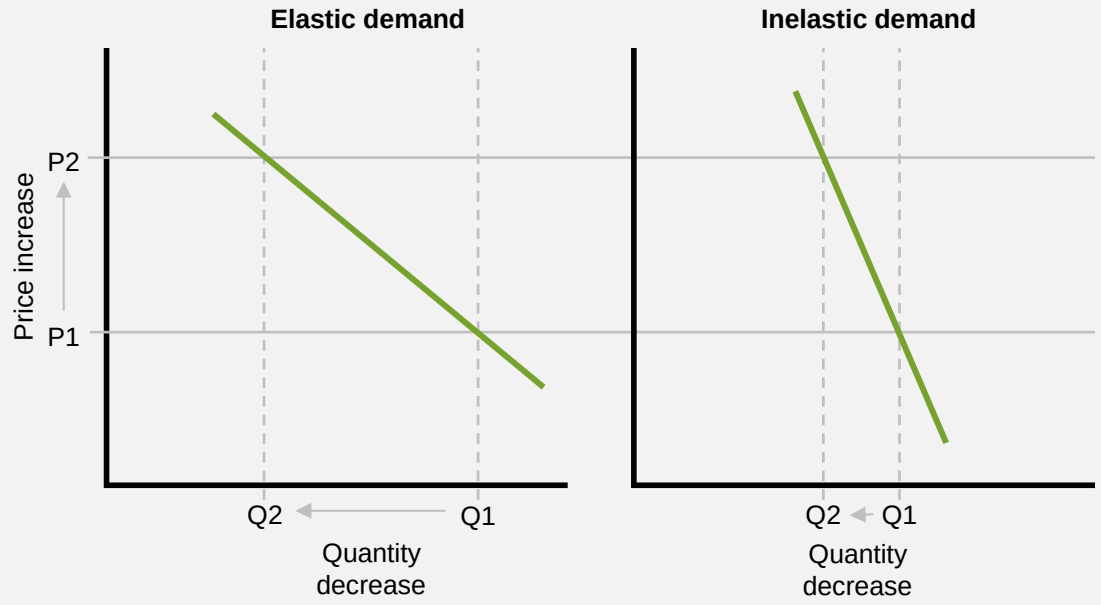
Box D.1 **Elasticities — a primer**

An elasticity is an estimate of the effect of a change in one variable from a change in another, related variable. The price elasticity of demand (E_p) is expressed as the percentage change in quantity demanded of a good ($\%\Delta Q$), divided by the percentage change in price ($\%\Delta P$) over the same period:

$$E_p = \frac{\%\Delta Q}{\%\Delta P}$$

Because quantity demanded declines when price increases, the price elasticity of demand is negative. Demand is considered inelastic if the price elasticity of demand is between zero and negative one — that is, the change in quantity demanded is less than the change in price. Demand is elastic if its elasticity is less than negative one.

As highlighted in the diagram below, an identical price increase can have different effects on the quantity demanded of a product depending on its elasticity — with smaller quantity changes resulting for the product with the more inelastic demand.



While statistical methods can control for some factors, unobservable factors can affect the accuracy of an estimate. For example, an increase to the price of iron ore is likely to increase its output, which would increase the quantity demanded of key inputs, such as bentonite (used as a binding agent in making iron ore pellets). An increase in the quantity of bentonite demanded due to the increase in the production of iron ore will likely drive higher prices of bentonite, but would not blunt demand, as these higher input prices would be offset by increasing iron ore prices. As a result, we might observe an increase in bentonite's price and quantity demanded and conclude that bentonite is *very* inelastic, failing to take into account the effect of the rising iron ore price on both price and quantity changes. Again, if there are data on the price or quantity of iron ore, either variable can be used as a control variable when estimating the demand for bentonite. But in many cases the data required will not be available, which will reduce the quality of estimates.

To estimate the demand elasticities of vulnerable and essential imports, the challenge is to find a price change that is independent of other factors that affect demand. One potential solution is to assume that Australia faces world prices and therefore price is independent of unobservable factors affecting Australian demand. The logic is that Australia is a small participant in the world market and so changes to Australian demand should not affect world prices. For example, if Japan normally imports little iodine, but for some unobserved reason increases its iodine imports, this would cause the price to increase. But this is unlikely to affect the iodine market in Australia. The Australian market's response to the price increase in iodine could then be used to estimate elasticity.

This will not always be true. For example, if Japan increased its imports of iodine due to a technological advancement that also affected Australia, then the Australian, Japanese and world demand will be affected. In this exercise, we assume that world prices are independent of Australian demand to estimate the elasticities of vulnerable and essential chemicals. The reasonableness of that assumption would need to be verified in each case.

D.2 Estimating elasticities for chemicals

Using ABS import data (chapter 4 and appendix C), we estimate elasticities for five chemicals — one of the main categories of essential and vulnerable goods identified in chapter 4. Chemicals are likely to be more homogenous within a category than many other types of vulnerable and essential goods, such as the various clothing categories that include personal protective equipment among many other items. This is important because differentiated goods each have a different price. If the goods are not homogenous, then the estimates will be affected by changes in the composition of what is imported, rather than changes in prices.

We aggregate the monthly ABS imports data into quarters to estimate elasticities at the 8-digit HTISC level. We derive unit values (prices) by dividing the good's value (including insurance and freight) by its quantity. We then construct a weighted average price using quantity as the weights to create a price variable that reflects the dominant price that the goods are purchased at. As a robustness check we estimated the elasticities using the median price and the results largely do not change.

To estimate the elasticity, we regress the log of the quantity on the log of the weighted average price, including dummy variables for the year and quarter to control for annual and seasonal effects. We do this for five chemicals[1], including disodium carbonate and citric acid.

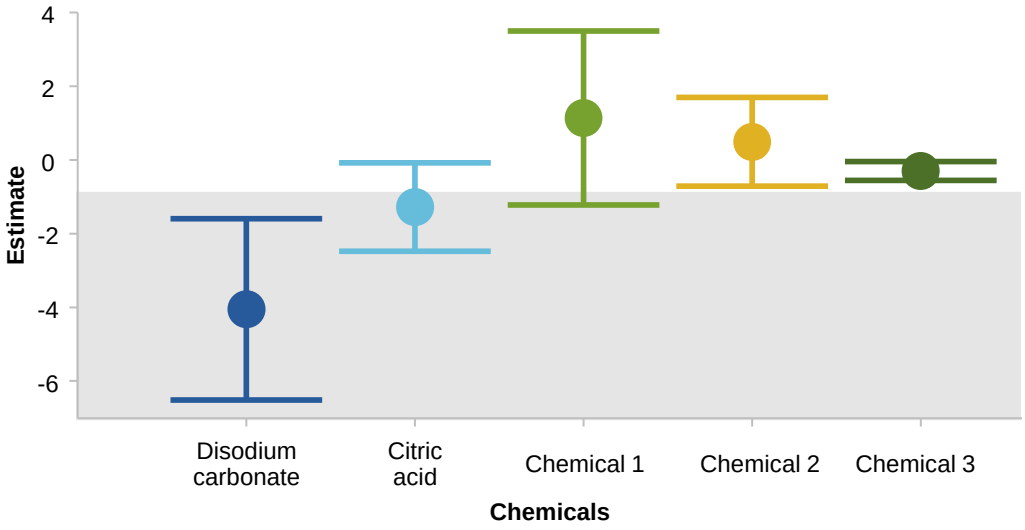
The results are presented in figure D.1. These results indicate that:

- the demand for disodium carbonate is highly elastic
- results for citric acid are inconclusive
- demands for the other chemicals are inelastic.

[1] To avoid identifying specific products, three chemicals are identified as chemical 1, chemical 2 and chemical 3.

Figure D.1 **Demand for some chemicals is elastic and demand for others is inelastic**

Regression coefficients with 95 per cent confidence intervals[a,b]



[a] Dots indicate the value of the coefficient. Whiskers represent the 95 per cent confidence intervals. We tested whether the results were statistically significantly different from negative one. Results for disodium carbonate (are significantly less than negative one at the five per cent level); citric acid (not statistically significant); chemical 1 (significantly greater than negative one at the ten per cent level), chemical 2 (significantly greater than negative one at the five per cent level), and chemical 3 (significantly greater than negative one at the one per cent level) [b] Shaded area indicates region with estimates less than negative one (elastic demand).

Source: Commission estimates.

What can this tell us about criticality?

As noted earlier, the estimates of elasticity can provide an indication of a chemical's criticality. The results of our regression analysis show that the demand for some chemicals are inelastic, which suggests they might be critical inputs.

However, criticality is also determined by a chemical's potential uses (box D.2), and whether it is an input into essential production. As shown in figure D.2, the data used to construct the elasticities for the chosen chemicals could reflect their uses in a number of different industries, which are mainly not essential. It is therefore difficult to make firm conclusions on criticality based on these results. More precise demand data are needed on prices and quantities for the specific products used in the essential industry only.

The estimates from the regressions on disodium carbonate broadly accord with analysis in appendix B, which indicates that many alternative pH correctors can be used to treat water. But again, the regression results are limited by the fact that the water industry accounts for

less than two per cent of disodium carbonate's total use in the data. (This small share means that if the water industry runs out of disodium carbonate, it could be diverted from non-essential uses for at least some time). While the regression results are consistent with findings in appendix B, it cannot be discounted that these results are driven by non-essential uses of disodium carbonate.

While elasticity analysis is one tool to examine the criticality of goods in the production of essential goods and services, it cannot replace an expert approach. This analysis indicates that further investigation of how and where chemicals are used is required. More disaggregated data would improve the analysis, but expert advice would be essential to better understand whether substitutes are available and whether the chemical is a critical input into production. Engagement of experts would also help stress test whether the assumptions needed to accurately estimate elasticities hold, and whether the conclusions that are derived from the estimates are valid.

Box D.2 Uses of some vulnerable and essential chemicals[a]

Disodium Carbonate (Soda Ash)

Disodium carbonate is an easily-produced and versatile compound. It is commonly used in the manufacture of glass, detergent, soap, paper and as a food additive. It is also used in water treatment, as a pH corrector for the protection of water infrastructure. In 2018, global trade in disodium carbonate was worth US$3.5 billion, with major suppliers including the United States (41 per cent), Turkey (17 per cent) and China (10 per cent). Australian imports accounted for 1.9 per cent of world trade.

Citric Acid

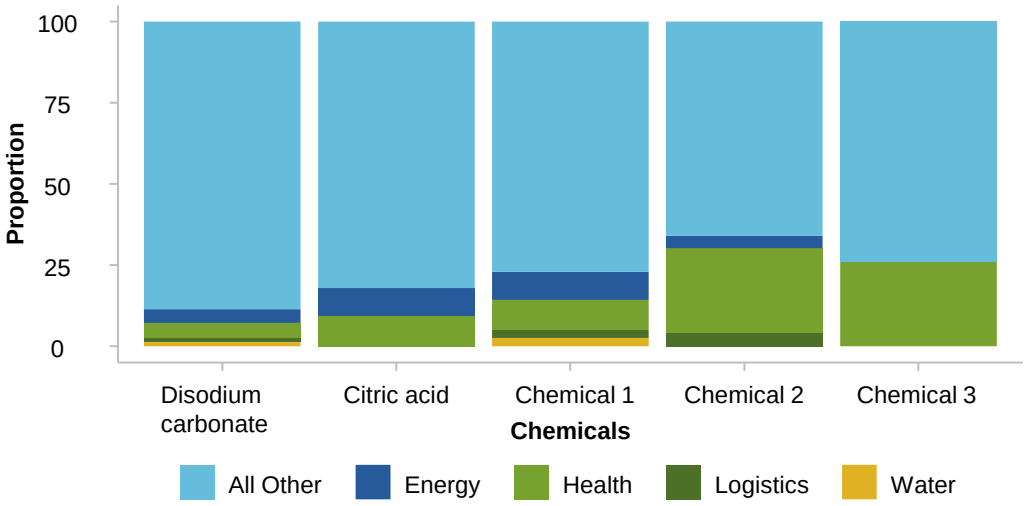
Citric acid has a number of properties that make it useful in manufacturing across a number of fields. It is commonly used to give a tart, sour or acidic flavour to manufactured foods and beverages. It is also used as an acidity regulator, a preservative and antimicrobial agent. In 2018, global trade in citric acid was worth US$1.1 billion, with major suppliers including China (59 per cent) and Belgium(11 per cent). Australian imports accounted for 0.7 per cent of world trade.

a Estimates of world market value and export shares have been taken from UN Comtrade data at the six digit level.

Sources: Observatory of Economic Complexity (2018); UN *Comtrade*.

Figure D.2 **The biggest users of chemicals are not essential industries**

Essential and non-essential industries[a] using chemicals, percentage by value[b]



[a] Banking, communications and government do not use these chemicals and are omitted from the chart. Non-essential industries are all other industries. [b] Value includes insurance and freight. Appendix C contains more detail on apportioning methodology.

Source: Commission estimates.

Other possible limitations

In addition to challenges in identifying the essential uses of these chemicals, the results should also be interpreted with caution due to other limitations.

The regression includes quarterly and yearly dummy variables to control for seasonal and annual effects. Results are sensitive to the inclusion of these dummy variables (table D.1). The adjusted R-squared is highest (in most cases) where the dummy variables are included, indicating that the dummy variables have some explanatory power and should be included in the regression. The data show seasonal and annual patterns, consistent with the explanatory power of the dummy variables (figure D.3). For example, imports of chemical 3 tend to dip in the second quarter, and the quantities of disodium carbonate and citric acid seem to grow year-on-year, especially after 2014.

Relevant variables that might be driving demand in Australia could be missing from the regressions. As outlined in the iron ore example above, an increase in the price of an output might raise the prices of inputs and simultaneously increase the quantity demanded of inputs (or dull a decrease in demand for them), resulting in an estimate that is more inelastic than the effect we are trying to measure. Quarterly and yearly dummy variables control for some of these unobserved factors (such as growth in demand relating to population and economic

growth), but there are many other possible influences on demand. For example, there could be technological changes that increase efficiency and could therefore decrease demand. Other technological changes could create new uses for a product, thus increasing demand for it. These effects could bias estimates.

Finally, estimates might reflect changes in the import mix, rather than a response to a price change. One way to assess this is by looking at prices of individual transactions. Variation in prices might indicate some heterogeneity in the products recorded. For example, a chemical could be sold in different concentrations, which would be reflected in their prices. While there is clustering around the weighted average price for some chemicals (figure D.4), there is still a lot of variation for what is assumed to be a homogenous group of products — or at least a group whose mix does not change markedly. Changes to the HTISC over time might also affect the import mix (for example, products might be reclassified into other HTISC codes or new codes might be created).

Summary

Given these limitations, the elasticities estimated in this appendix should be treated with caution. The results show that demand elasticities can give some indication about whether a product is critical to a production process, but data limitations make it difficult to apply the technique across a large number of products and be confident that the technique will accurately identify critical products. These limitations reinforce the need to stress-test both the approach and any conclusions with experts as outlined in the framework (chapter 3).

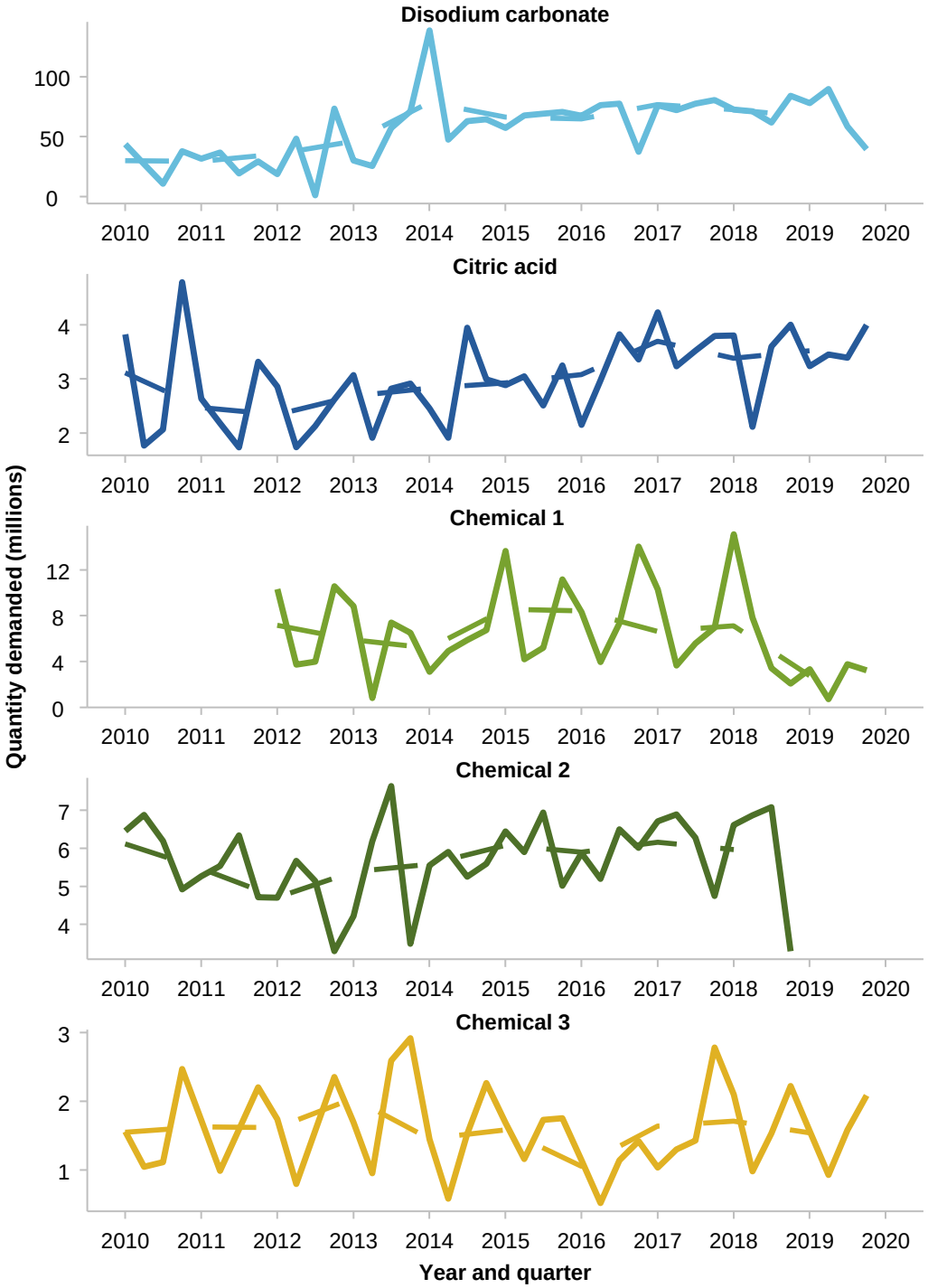
Table D.1 **Regression results**

	No dummies	*Year dummies*	*Quarter dummies*	*Year and quarter dummies*
Disodium carbonate				
Estimate	0.53	-4.40	0.80	-4.05
Standard error	0.81	1.14	0.82	1.25
Adjusted R-squared	-0.01	0.48	0.00	0.46
N	40	40	40	40
Citric acid				
Estimate	-0.47	-2.03	-0.10	-1.28
Standard error	0.44	0.60	0.42	0.61
Adjusted R-squared	0.00	0.32	0.18	0.44
N	40	40	40	40
Chemical 1				
Estimate	-0.64	1.68	-0.91	1.14
Standard error	0.79	1.33	0.70	1.20
Adjusted R-squared	-0.01	0.07	0.23	0.34
N	32	32	32	32
Chemical 2				
Estimate	0.56	0.29	0.63	0.49
Standard error	0.44	0.82	0.34	0.61
Adjusted R-squared	0.02	-0.10	0.43	0.43
N	36	36	36	36
Chemical 3				
Estimate	-0.51	-0.69	-0.15	-0.30
Standard error	0.16	0.18	0.14	0.13
Adjusted R-squared	0.18	0.26	0.65	0.79
N	40	40	40	40

Source: Commission Estimates.

Figure D.3 **Chemicals have annual and quarterly patterns**

Kilograms (in millions) imported to Australia, quarterly[a] for 2010 to 2019

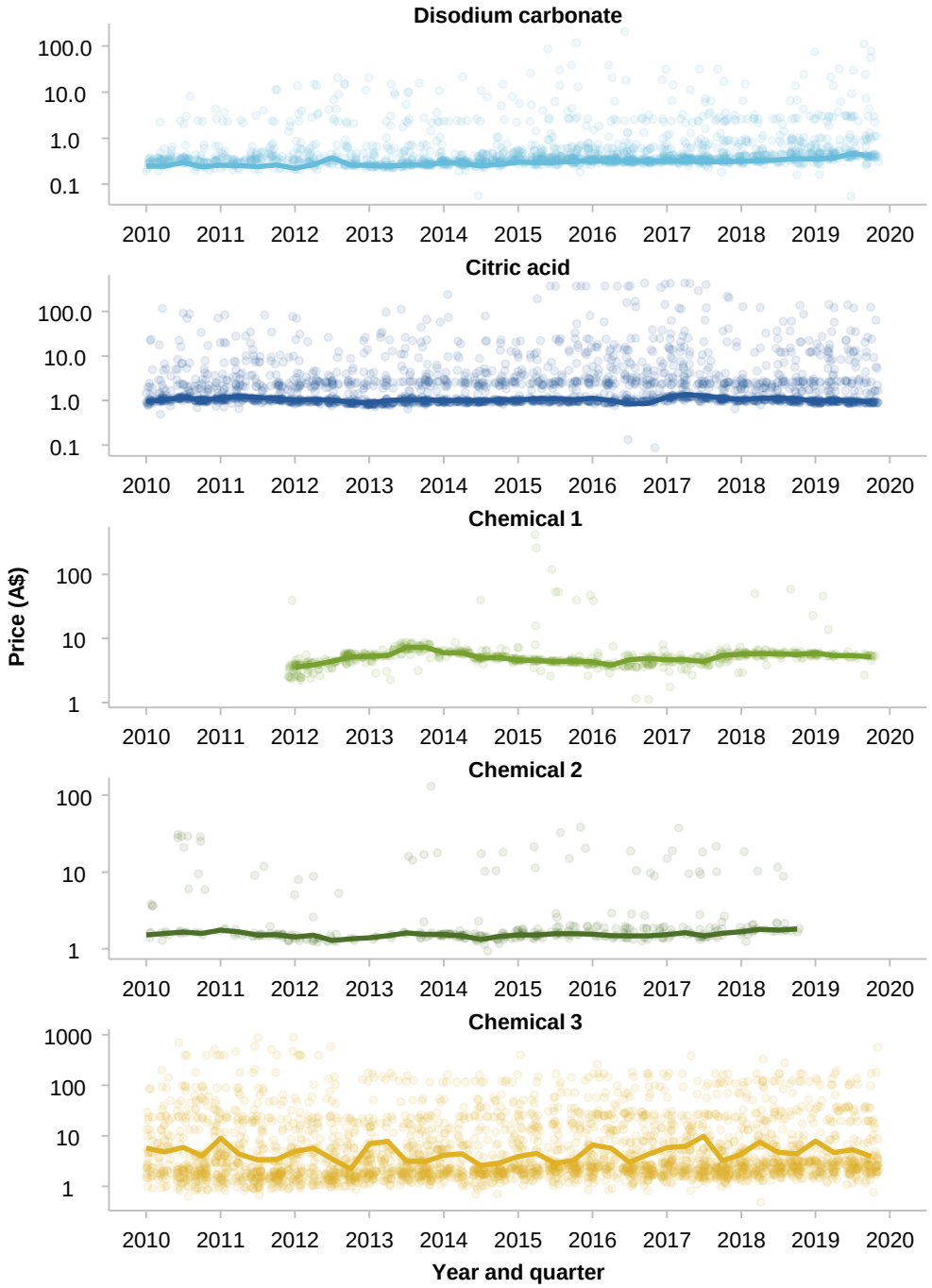


[a] The dashed line represents the average quarterly imports for the year.

Source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

Figure D.4 **Prices of chemicals vary**

Jitter plot[a] of prices[b,c] and weighted average price[d] ($AUD) from 2010 to 2019



[a] Jitter plots slightly perturb each point. [b] Prices are unit values, derived from values (cost including insurance and freight) divided by quantity. [c] Prices presented on a log scale and outliers over $AUD1000 have been removed for readability. [d] Weighted average price is denoted by the solid line.

Source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

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