



Australian Government

Department of Infrastructure and Regional Development

Bureau of Infrastructure, Transport and Regional Economics



Infrastructure, Transport and Productivity

This Information Sheet explores what productivity is and how it is measured, why multi-factor productivity is important to the welfare of Australians, and major productivity trends in Australia—notably the industry-wide slowdown in multi-factor productivity since 2002–03.

It then examines sources of the decrease in multi-factor productivity for the Transport, Postal and Warehousing industry, the link between productivity growth and transport infrastructure, and evidence of how well-targeted reforms and investments in transport have improved productivity in Australia.

Key measures to improve future productivity benefits of transport and related infrastructure are discussed, including: transparent cost benefit analysis, heavy vehicle charges reform, variable tolling of major urban roads and further application of technological improvements.

At a glance

- Multi-factor productivity growth is an important source of future national wealth.
- Since 2000 the rate of multi-factor productivity growth has slowed in Australia and other developed countries. For Australia, recent changes in measurement have smoothed this lower trend in multi-factor productivity growth (Australian Bureau of Statistics 2012). Despite this, the overall picture is for lower multi-factor productivity growth than in previous cycles.
- Multi-factor productivity growth for Transport, Postal and Warehousing has slowed since 2002–03. The main reason for this slowing appears to be capital deepening that is associated with large, sustained increases in private gross capital formation. The decline has accelerated since 2007–08 associated with large increases in public road and rail investment.
- Increases in multi-factor productivity growth for Transport, Postal and Warehousing since 2008–09 are due to significant increases in labour productivity.
- Despite short term impacts on multi-factor productivity, there is Australian evidence that well targeted investments in transport infrastructure result in productivity increases that benefit many other industries.
- Key areas where action to improve transport productivity has been suggested include:
 - Better prioritising of public infrastructure investments by transparent cost benefit analysis that captures whole of life costs including future maintenance needs.
 - Implementing cost-reflective road and rail pricing where user charges are linked to damage and future needs, and there is a locational link between heavy vehicle charges and funding of improvements.
 - Implementing city-wide variable tolling systems for major urban roads that allow consistent time of day and volume related tolling.
 - Development of economic evaluation guidelines and modelling techniques to enable effective comparison of Intelligent Transport System technologies and traditional infrastructure investment opportunities, and encouragement of pilot deployments of new technologies.

What is productivity?

Productivity is the efficiency of transforming inputs (capital, labour) into outputs (goods and services). The two main measures are labour productivity and multi-factor productivity.

Labour productivity is a partial measure calculated as real gross domestic product (GDP) or gross value added per unit of labour (commonly proxied by hours worked). Multi-factor productivity is a more complete measure calculated as real GDP or gross value added per unit of combined labour and capital inputs.

In order to interpret productivity trends, it is important to distinguish these productivity concepts from the measured productivity indices. While productivity statistics aim to measure technical progress or the efficiency of production, in practice they measure the difference between the growth in the volume of output and the growth in the volume of inputs, which reflects more than just technical progress.¹

As measured in the growth accounting framework, growth in labour productivity can be decomposed into capital deepening (or capital intensity), labour quality, and multifactor productivity.² Growth in capital deepening is an important driver, alongside multifactor productivity, of labour productivity (Australian Bureau of Statistics 2013).

While it does not make sense to discuss trends in measured labour productivity in isolation from changes in the productivity of capital, capital productivity indices do not produce useful, interpretable measures of the efficient use of capital. For this reason, the focus is usually labour productivity for which there are clear theoretical interpretations.

The focus on measured inputs and outputs also has implications for interpreting productivity trends in the non-market sector. The market sector accounts for around three quarters to four fifths of the economy. The non-market sector—now around a quarter of employment and a fifth of output—is less well measured (Gruen 2012). In particular, outputs in the services sector and non-traded services provided by government are not well measured.

Interpreting and measuring productivity trends over time is therefore not straightforward, because:

- External factors such as resource depletion and weather can affect measured productivity.
- Changes in capacity utilisation can significantly affect short term measures.
- Large increases in the capital stock can significantly reduce short term measures of multi-factor productivity.
- Changes in the quality of labour are difficult to measure.³
- A range of other technical issues, such as the treatment of financial assets, can affect productivity measures.
- Changes in productivity methodology can result in significant revisions to historical series.

¹ Factors other than technical progress include economies of scale, reallocation of inputs, changes in human capital, variations in capacity utilisation, climatic events, and measurement error (Australian Bureau of Statistics 2013, p.422).

² Increased capital deepening refers to increases in the capital to labour ratio. This means that, on average, each unit of labour has more capital to work with to produce output, so is an indicator of ability to augment labour. Labour saving practices result in increased capital deepening, which is often associated with a decline in capital productivity (Australian Bureau of Statistics 2013).

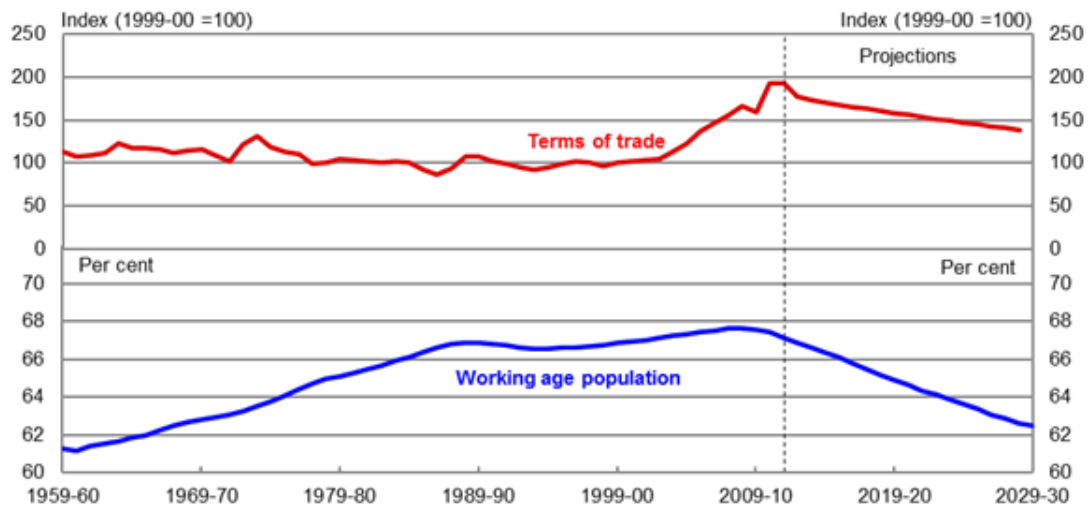
³ While desirable to reflect changes in measures of labour input such as the proportion of skilled to unskilled employees, data limitations mean the most common National Accounts labour measure is hours worked by total employed people (Australian Bureau of Statistics 2007).

Why is it important to increase future productivity?

Productivity, like production, matters not for its own sake, but because the growth it can generate results in the higher incomes and government revenues needed to raise living standards and rectify disadvantage (Banks 2012).

Productivity is a key determinant of the welfare of Australians because it has been an important source of income growth. Other sources of income growth include the terms of trade and utilisation of labour. An expected decline in Australia's terms of trade and ageing of the population are both likely to work against future growth in incomes (Figure 1).

Figure 1 Contributions to growth in average incomes



Source Gruen (2012)

While commodity prices are expected to remain elevated compared to history, they are expected to trend lower over time as global supply expands (Gruen 2012).

The ageing of the Australian population is also anticipated to detract from labour force participation, and growth in output and incomes per person, as the baby boomer generation moves into retirement. If this is the case, Australia will need to rely on productivity improvement to again become the dominant contributor to growth in incomes (Gruen 2012).

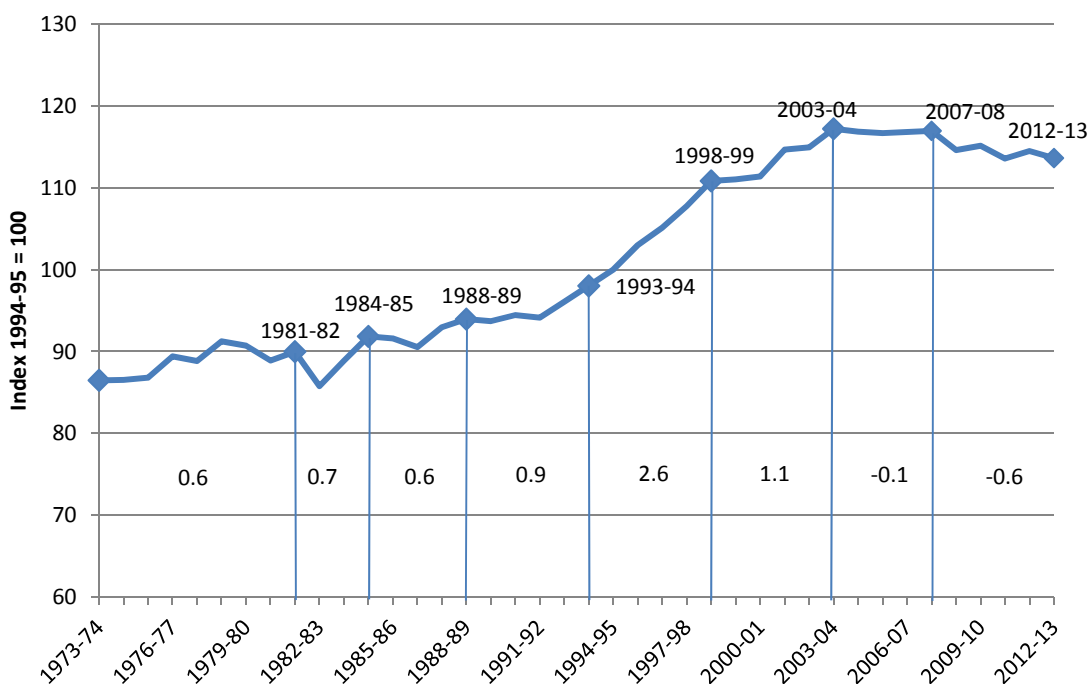
What are the key productivity trends in Australia?

Multi-factor productivity growth in market sectors grew rapidly in the 1990s up until 2003–04, when growth slowed. Since 2007–08, aggregate multi-factor productivity has declined (Figure 2).

The 2000s in Australia was an unusual period when labour productivity growth contributed around half the growth in average incomes, compared to an average of around 90 per cent over the four previous decades. The Australian community experienced strong growth in incomes in the 2000s only because of the unprecedented contribution of rising terms of trade (Gruen 2012).

From March 2004, the mining boom boosted Australia's terms of trade by almost 50 per cent up until the Global Financial Crisis (Figure 2). Following the Global Financial Crisis, the terms of trade rebounded and reached a new record high (Parkinson 2012).

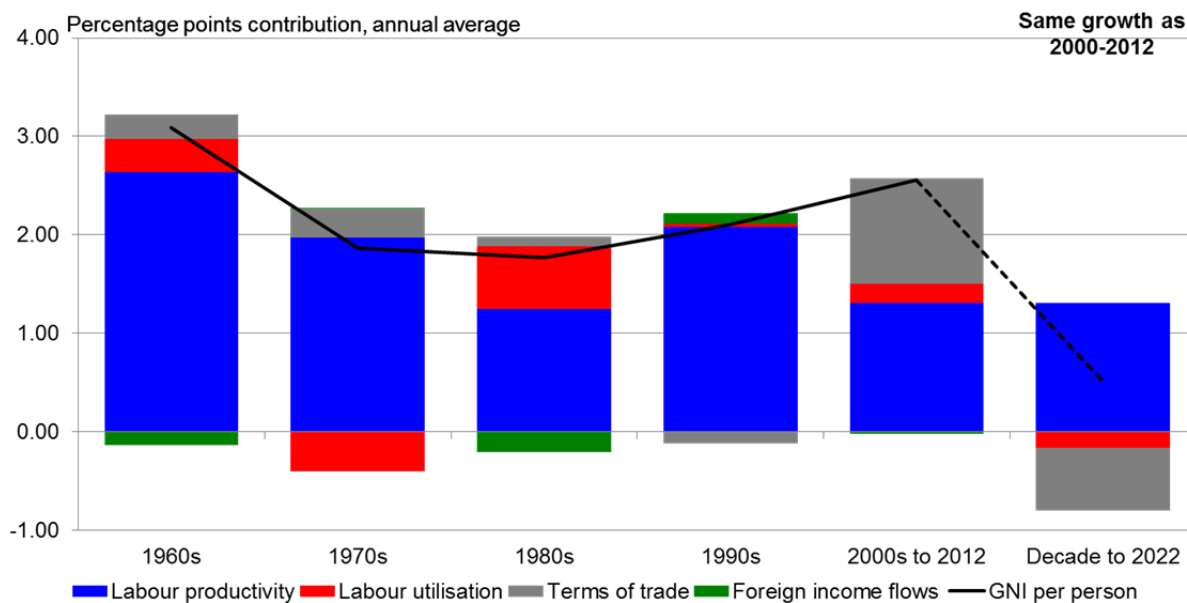
Figure 2 Market sector multi-factor productivity, 1973–74 to 2012–13



Source Zhao (2012, p.6); Australian Bureau of Statistics 5260.0

Figure 3 (Harris 2013) indicates how the combined effect of Australia’s ageing demographic and expected decline in the terms of trade might reduce average income growth in the decade to 2022, if ways were not found to generate a sustained improvement in multi-factor productivity.

Figure 3 Contributions to growth in average incomes



Source Harris (2013) based on Australian Bureau of Statistics 5204.0 and unpublished Australian Bureau of Statistics data, Productivity Commission calculations

Globally, labour productivity growth has fallen significantly since 2008 in most OECD countries where data are available, with the decline broadly spread across sectors. Labour input has fallen in many countries through reduced hours per person and job cuts. Multi-factor productivity also fell significantly, although the OECD considered it too early to say this was a long term trend (OECD 2012, p.11).

For Australia, there have been increases in measured multi-factor productivity series over the most recent cycle. The sources of this improvement are increases in labour productivity and changes to methodology (Australian Bureau of Statistics 2012):

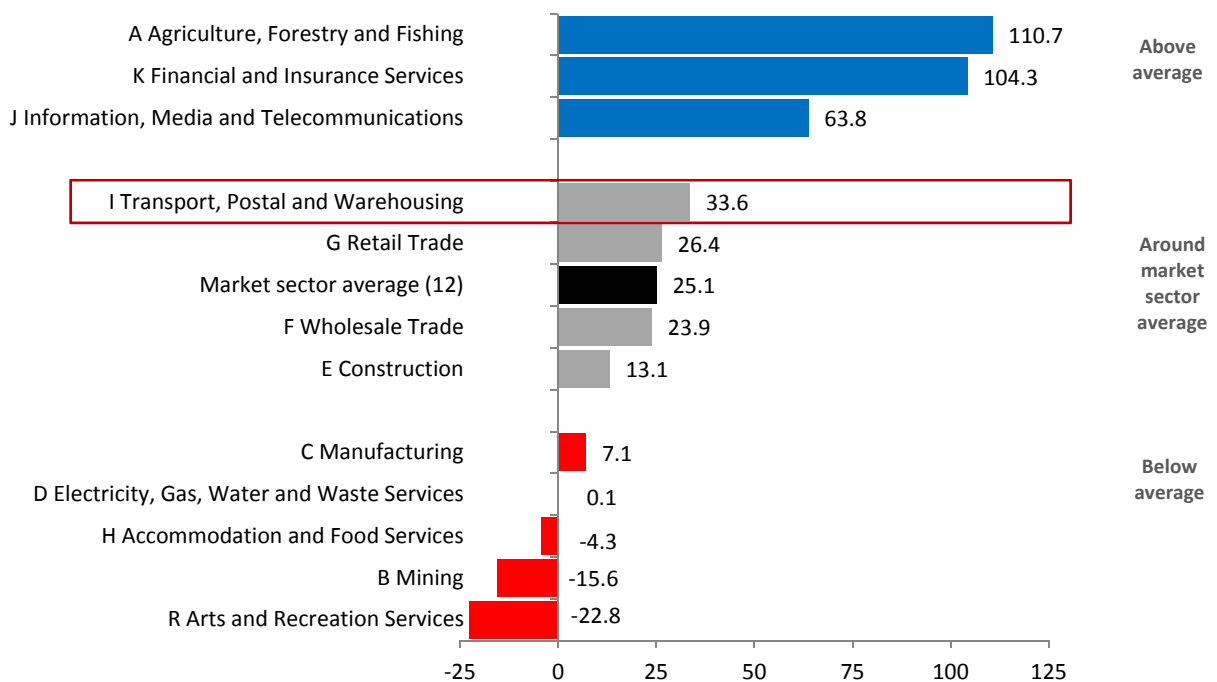
- Market sector labour productivity was up 2.9 per cent in the three quarters to December 2012, underpinning a 0.3 per cent improvement in multi-factor productivity in 2011–12
- Revisions to the statistical series reduced the volatility of productivity measures and moderated the recent decline in multi-factor productivity.

What are the key industry trends?

Multi-factor productivity growth rates have varied widely across industry groups.

While multi-factor productivity growth for Transport, Postal and Warehousing⁴ compares well to the long term average for the market sector (Figure 4), the rate of growth for this industry group has decreased in the last two decades (Figure 5).

Figure 4 Multi-factor productivity growth by industry group, 1985–86 to 2010–11

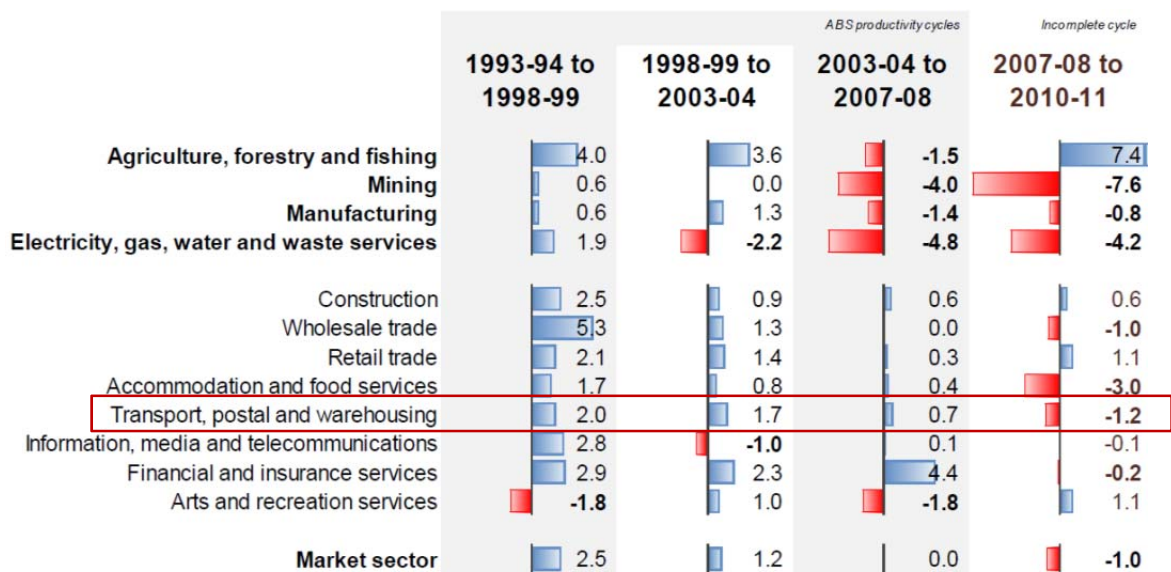


Source Zhao (2012), p.9

More significantly, multi-factor productivity growth has slowed since 1998–99 for the market sector as a whole, and this has occurred across many industry groups (Figure 5).

⁴ While the focus is transport productivity, transport is grouped with postal services and warehousing in the National Accounts (ANZIC Industry Division I) and the discussion here relates to the aggregate Transport, Postal and Warehousing industry group.

Figure 5 Industry multi-factor productivity growth rates



Source Zhao (2012, p.6)

In terms of the broader multi-factor productivity slowdown, analysis by Wei and Zhao (2012) showed that:

- The sharp decline in industry contribution during 2003–04 to 2009–10 could be traced to the mining, utility and manufacturing industries.
- IT capital deepening accounted for 9 per cent of the direct productivity decline in the 12 industries. The authors considered this “quite significant” as IT capital accounted for less than 5 per cent in aggregate value added.

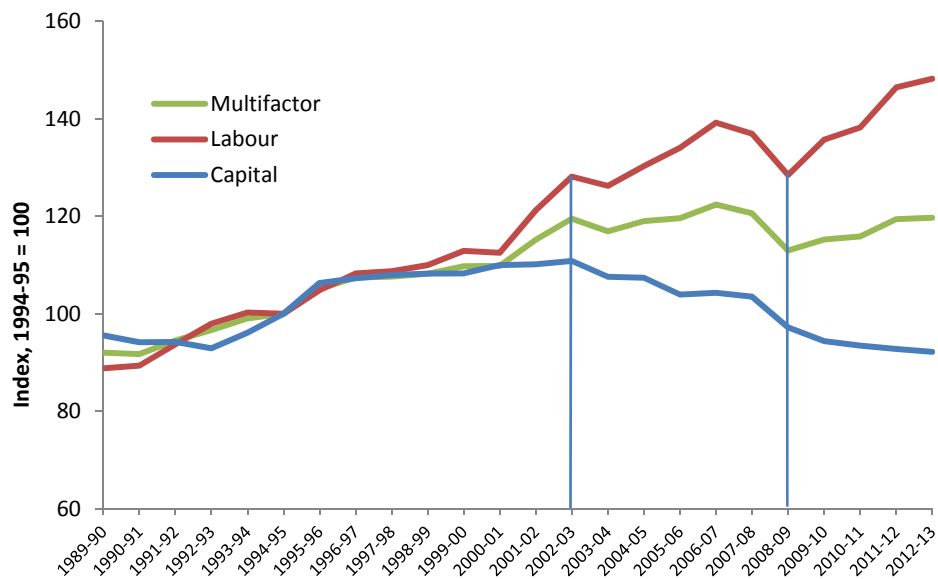
Specific multi-factor productivity trends included:

- a large rise for agriculture, forestry and fishing since 2007–08, attributed to the end of the drought;
- large reductions in mining attributed to production lags and resource depletion, however, measured productivity rises after adjustments for deposit quality and production lag; and
- a large reduction in utility industries, attributed to improvements in supply reliability for electricity and water (Zhao 2012).

Transport industry trends

For Transport, Postal and Warehousing, the reduction in multi-factor productivity growth rates since 2002–03 can be largely attributed to capital deepening (Figure 6), and the post-Global Financial Crisis increase in multi-factor productivity since 2008–09 can be attributed to significant increases in labour productivity.

Figure 6 Productivity indices for Transport, Postal and Warehousing, 1989–90 to 2012–13

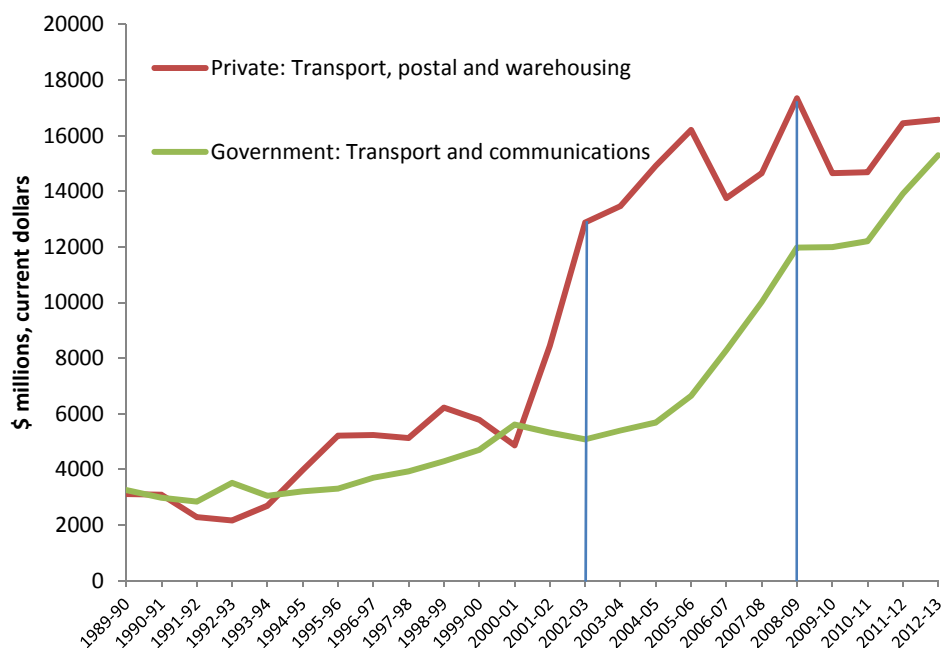


Source Australian Bureau of Statistics 5260.0.55.002

The decline in the capital productivity index in Figure 6 is correlated with large, sustained increases in private gross capital formation as shown in Figure 7. While the reasons for this increase in capital formation for Transport, Postal and Warehousing are not clear, it coincides with a sustained surge in capital formation in the mining industry.

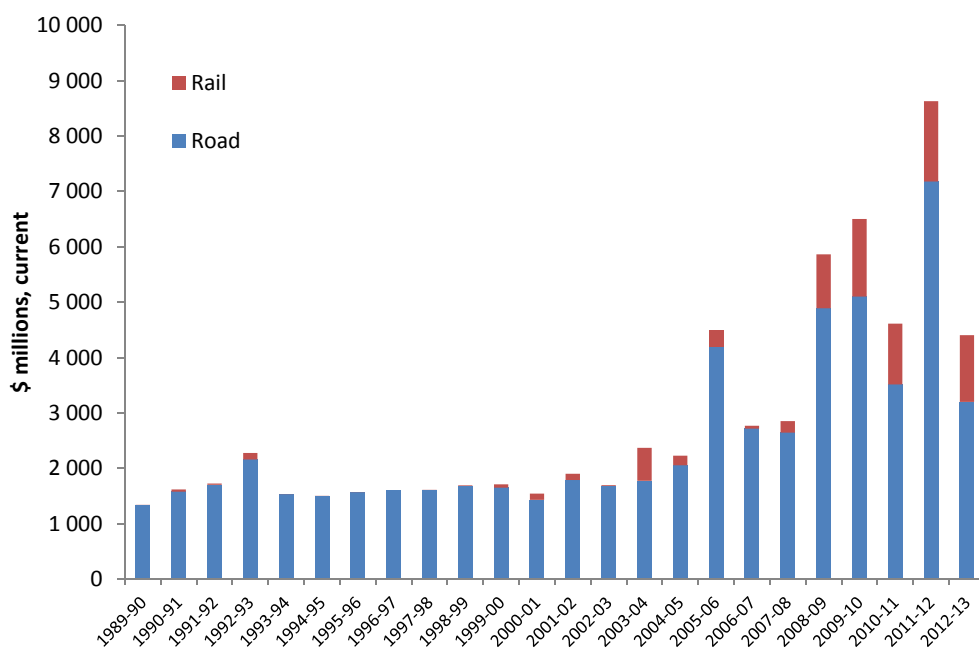
The decline in the capital productivity index for Transport, Postal and Warehousing has accelerated since the start of the global financial crisis, coinciding with large increases in public road and rail investments (Figure 8).

Figure 7 Gross fixed capital formation, transport related 1989-90 to 2012-13



Source Australian Bureau of Statistics 5204.0 (Table 52 and Table 53)

Figure 8 Australian Government investments in rail and road, 1988–89 to 2012–13



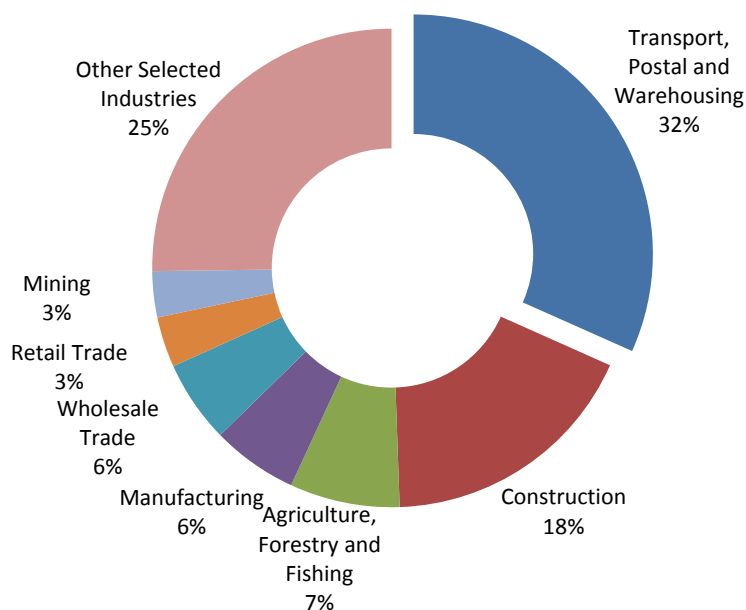
Source Department of Infrastructure and Regional Development

The measured decline in capital productivity indices in Figure 6 will be over-stated to the extent that services from the surge in public investment in road and rail are attributed solely to Transport, Postal and Warehousing (largely 'hire and reward' activity) as:

- Transport is frequently classified as an ancillary activity in enterprises and reported in other industry groups.⁵ For road transport, approximately a third of vehicle operating and capital expenditure is attributed to the Transport, Postal and Warehousing industry group (Figure 9).
- Private use of the public road network is treated as consumption and not captured as transport activity. For example, the future stream of services from consumer durable assets such as cars is conventionally treated as consumed as soon as the assets are bought by a household (Australian Bureau of Statistics 2013).

⁵ Under the national accounts, enterprises are allocated to industry groups according to primary value adding activity. A secondary activity is an activity with value added less than that of the principal activity. To be considered as either principal or secondary activities, the outputs from the activities must be goods or services that are capable of being delivered to other units even though they may be used for own consumption or for own capital formation. Enterprise transport activities incidental to the primary business activity are classified as ancillary activities, and reported within the industry group based on the primary activity. For national accounting purposes, output of an ancillary activity is not explicitly recognised or recorded, and all inputs to ancillary activities are treated as inputs to the principal or secondary activities they support (Australian Bureau of Statistics 2013).

Figure 9 Road transport running and road vehicle capital expenditure, 2010–11



Source Australian Bureau of Statistics 9296.0

Well targeted reforms and investments will improve productivity

Despite possible short term negative effects, transport investment can boost multi-factor productivity. The Productivity Commission's (2006) review of road and rail freight infrastructure pricing cited studies that found road infrastructure investment did induce productivity increases in the economy, although the nature of the link between public infrastructure spending and productivity growth had been debated.

There is ample Australian evidence that well-targeted transport investment results in significant, long term productivity benefits:

- The Australian freight task has quadrupled over the last four decades. This coincided with significant increases in freight sector productivity, especially in road freight where physical freight vehicle productivity has more than doubled over the same period (see Box 1).
- Australian Government funded infrastructure programs have resulted in significant benefits. BITRE meta-analysis of 128 road and rail project proposals indicates an average ratio of benefits to costs of about 2.7, and a present value of net benefits of \$62 billion (see Box 2). Cost savings are expected to be 1.3 per cent of total industry costs for the hire and reward road freight industry and 2.7 per cent of total industry costs for the rail freight industry.
- Waterfront multi-factor productivity compares well to market sector productivity since 1999-2000 following reforms in the 1990s (Box 3). As shown on the Brisbane waterfront, new technology can take time to implement and achieve productivity outcomes. While waterfront productivity measures have improved since the 1990s, in recent years the rate of improvement has slowed (see Box 3).

Box 1: Truck productivity: sources, trends and future prospects

Total domestic road freight has grown six-fold over the last four decades from around 27 billion tonne kilometres in 1971 to over 180 billion tonne kilometres in 2007. (A tonne kilometre is one tonne of freight moved one kilometre.) Over that period the average productivity of road freight vehicles—that is, the freight carried per registered freight vehicle including light commercial vehicles—has more than doubled. As a result, the 2007 road freight task required half as many vehicles as would have been required in the absence of productivity growth.

Productivity growth of heavy freight vehicles, that is, rigid and articulated trucks, has been even more pronounced; increasing almost six-fold since 1971. Articulated trucks alone have contributed over 90 per cent of the increase in total road freight vehicle productivity.

The principal factors contributing to increased heavy vehicle productivity include:

- the introduction of and expanded network access for larger heavy vehicle combinations, particularly B-double articulated trucks
- progressive increases in regulated heavy vehicle mass and dimension limits
- strong growth in long-distance freight
- cumulative long-term investment in major road infrastructure, particularly the realignment and duplication of parts of the intercapital national highway network.

Source BITRE Report 123 (BITRE 2011)

Box 2: Benefits of Australian Government infrastructure investment

The Australian Government spent \$36 billion, and the states and territories \$6 billion, on road and rail infrastructure between 2008–09 and 2013–14.

BITRE meta-analysis of 128 road and rail project proposals indicates an average ratio of benefits to costs of about 2.7, and a present value of net benefits of \$62 billion. By 2016:

- For the program as whole, 61 per cent of the total road cost savings and 41 per cent of total rail cost savings accrue to industry.
- This investment is expected to save the road freight industry \$1.1 billion per year, or 1.3 per cent of total road freight industry costs.
- Cost savings to the rail freight industry are expected to be \$300 million per year by 2016, or 2.7 per cent of total industry costs.

BITRE's estimates of the productivity benefits resulting from these road and rail construction projects include the expected direct savings in freight and business car travel costs.

Cost savings are expected to increase steeply over time as more projects come on-line until 2016 when implementation of projects is expected to be complete. After 2016, cost savings are assumed to only grow with traffic.

Benefits to private car users and rail passengers, while important, are excluded on the grounds that they do not directly improve productivity.

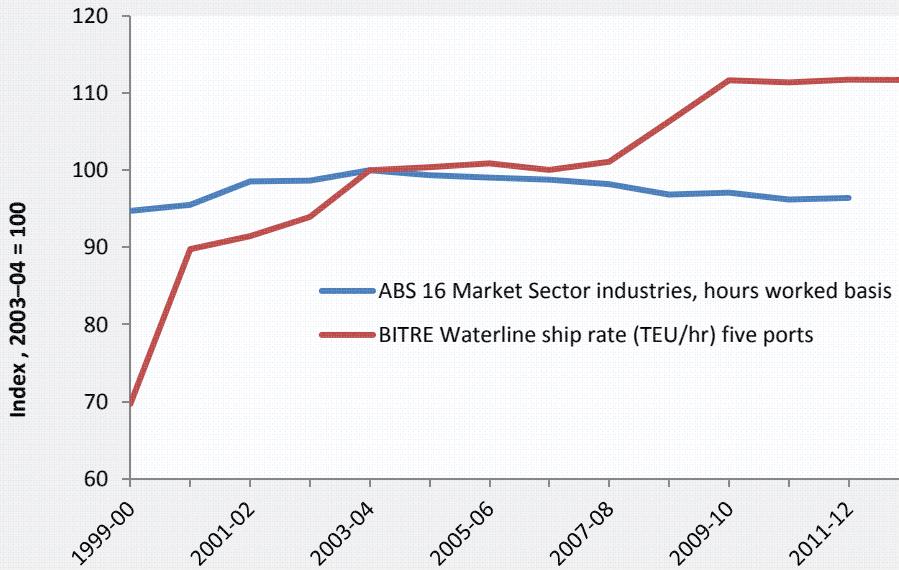
Source unpublished BITRE analysis

Box 3: Waterfront productivity: new technology challenge

Waterfront multi-factor productivity compares well to market sector multi-factor productivity since 1999-2000, with the latter declining since 2003-04. The five port ship rate (a proxy for productivity of labour and capital) improved significantly in the late 1990s through the early 2000s, when it reached a plateau. The ship rate increased again from 2007-08 then stabilised after 2010-11.

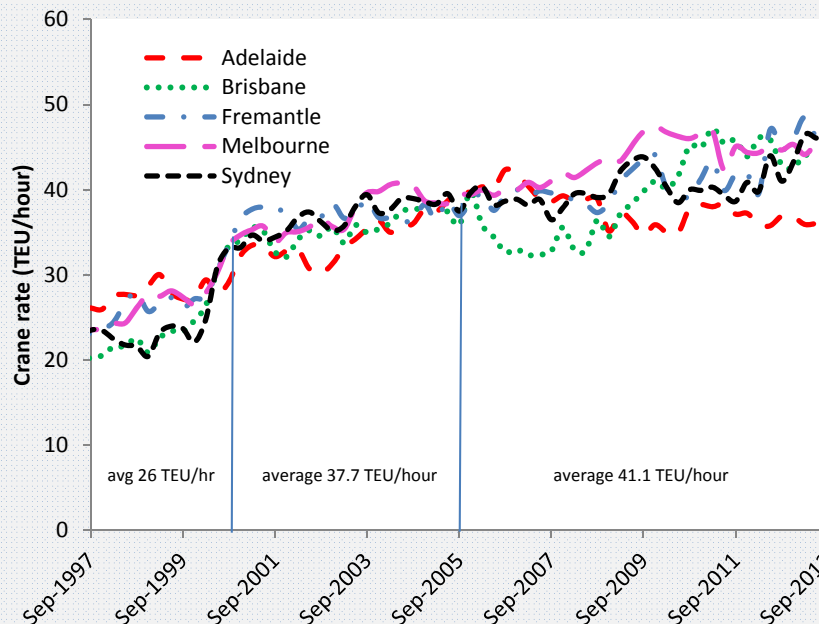
Crane rates (TEU per hour of crane operation) have improved throughout the past 15 years. The drop in productivity in Brisbane between 2006 and 2009 coincided with significant problems during and after the deployment of new automated container handling equipment which subsequently delivered productivity improvements.

Five port ship rates and market sector MFP



Sources BITRE Waterline series; Australian Bureau of Statistics 5260.0.55

Crane rates at Australian ports



Source unpublished BITRE analysis of data in Waterline series

Major infrastructure investments can increase capacity well beyond immediate demand, reducing measured productivity in the short to medium term. For example, major road and rail infrastructure is typically assumed to have a 30 year life. The productivity benefits of well-targeted investment may not be realised until all parts of the project have been completed and forecast increases in demand have eventuated.

Risks of over-capacity can be exacerbated by optimism bias⁶ in project assessment, as it results in inaccurate forecasts and inflated benefit-cost ratios. Bidding competition can further increase this risk for public-private partnerships (Lu, Louis and Harvey 2011).

While there has been significant investment in rail infrastructure, it may take service operators time to respond in terms of improved services. The challenge in improving rail productivity is illustrated by the Melbourne rail system (see Box 4). While the reports highlight issues for passenger services, these would also impact productivity on the 53 per cent of the network that is freight only or shared lines (BITRE 2013).

Box 4: Melbourne rail: the challenge of improving productivity

Recent reports highlight long term issues with signal reliability on the Melbourne train network:

- Signal failures occur five times a day on average on Melbourne's railways, creating chronic delays for commuters as trains are forced to slow down or stop completely to avoid a collision. There were more than 1900 signal failures in the 12 months to August 2013.
- A 1982 computer system, Metrol, controls signalling for all Metro and V/Line trains in inner city areas, approximately 55 per cent of the Melbourne rail network.

An \$88 million replacement control system, Train Control and Monitoring System (TCMS), will help deliver an increase in timetabled services, and dispatch train drivers more efficiently, improving reliability.

While TCMS will improve control of the signalling system (including inter-connections with the rest of the rail network), Metro has said that improving signal infrastructure in the field was a long-term, ongoing project and that "Some areas are worse than others and we are repairing equipment in order of priority." While new signalling has been installed at Dandenong and Camberwell since Metro began running the network, both stations continue to experience regular signal failures.

The Victorian Government is spending \$4.5 million on a high-capacity signalling trial on the Sandringham line. It has also applied for federal funding through Infrastructure Australia. If successful, high-capacity signalling could be installed on other lines as well.

Source Signalling faults hit rail 5 times a day (The Age, 24 October 2013); 20-year-old railway computers take a byte out of the past (The Age, 15 October 2013).

⁶ Optimism bias is a systematic tendency to under-estimate costs and over-estimate benefits (or traffic). The analyst's belief that a project will be successful affects study results, whether consciously or unconsciously. This differs from strategic mis-representation which is deliberate. Both have the same result: inaccurate forecasts and inflated benefit-cost ratios (Lu, Louis and Harvey 2011).

Regulatory changes can realise productivity benefits

Regulatory change can significantly improve the productivity of existing infrastructure. For example, changes to heavy vehicle regulation allowing longer and heavier vehicles on major freight roads have had major impacts on road freight productivity (see Box 5).

Box 5: Productivity impact of heavy vehicle regulatory reform

South Australia allowed higher mass limit (HML) vehicles access to South Australian highways from 1 January 2000, giving more general B-double access across the highway network.

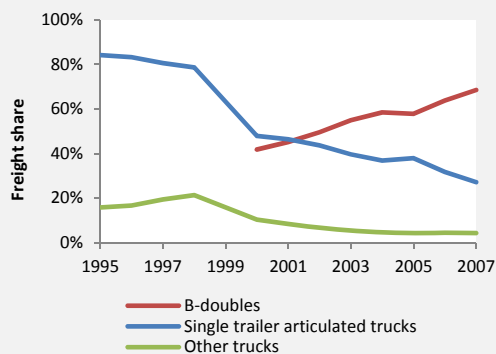
The impacts of this heavy vehicle regulatory reform are highlighted using vehicle count information collected by weigh-in-motion equipment. Figure A below shows the proportion of heavy vehicles by broad vehicle configuration between 1995 and 2008 at Truro on the Sturt Highway (approximately 90 kilometres northeast of Adelaide).

Following the regulatory change, new B-double category trucks achieved a freight share of over 40 per cent, and this share has continued to grow.

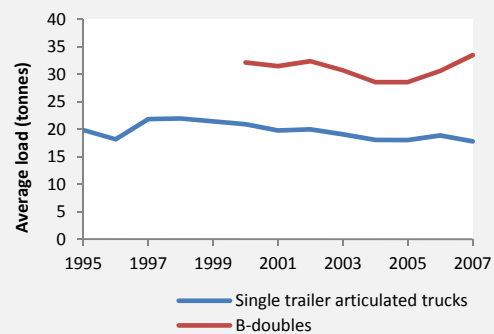
Much of the freight share captured by B-doubles was transferred from single trailer articulated trucks. Figure B shows that the average payload of B-double category vehicles measured at this site was around 30 tonnes per vehicle compared with around 20 tonnes for single trailer articulated trucks.

Heavy vehicle freight share and average loads, Truro (SA), Sturt Highway

A. Freight share



B. Average loads



Source BITRE unpublished data (data is missing between 1998 and 2000)

However, BITRE (2011) modelling suggests future road freight productivity growth is likely to be more muted in the absence of further heavy vehicle productivity enhancing regulatory reform:

- Fleet-wide heavy vehicle average loads are likely to increase by less than 5 per cent between 2010 and 2030, which contrasts sharply with the 40 per cent growth in average loads over the past two decades.
- Increased uptake of higher productivity vehicles available under Performance Based Standards, such as B-triples and AB-triples, is likely to have a relatively small impact on national heavy vehicle productivity since freight that can take advantage of these larger vehicles represents less than 20 per cent of total road freight.
- Nevertheless, these larger vehicle combinations offer important increases in heavy vehicle productivity and freight transport efficiency for transport operators, producers and consumers in rural and remote areas.
- If measures are not found to increase productivity in the transport sector, then significantly higher numbers of vehicles and drivers will be needed to meet projected future freight tasks.

Prices need to be right to maximise productivity

Key findings by the Productivity Commission (2006) were that:

- Current pricing and regulatory arrangements are hampering the efficient provision and productive use of road and rail infrastructure.
- The main efficiency losses with current road charging arrangements derive from the averaging of costs and charges, and disconnect between road revenue and spending decisions. These provide poor price signals and distort the incentives needed for efficient road use and provision.
- Developments in road pricing technology create the opportunity for more cost reflective pricing which, combined with institutional changes to link road supply and demand, offer the potential for substantial efficiency gains.

The issues involved in heavy vehicle charging and investment reforms are complex, including the need to consider changes to federal financial relations in order to implement charging reforms. Governments have agreed to commence work to implement initial heavy vehicle investment and access reform initiatives, while further consideration is given to next steps in the reform process.⁷

As transport demand grows, there is a need to make timely investments to add or upgrade capacity. While there are risks of over-investing or investing too soon, these risks can be mitigated by better, more transparent benefit-cost analysis. An important step towards this end is the current revision of the National Guidelines for Transport System Management (2006).⁸

In addition to improving means of funding investment and maintenance of road infrastructure, governments also need to consider reforms targeted at addressing issues associated with congestion. There are potentially large costs of doing nothing as congestion costs can increase disproportionately once a transport network or node approaches capacity.

BITRE (2007) estimates⁹ for road are that by 2020:

- The avoidable cost of road congestion in capital cities is expected to increase from \$14.2 billion in 2012 to \$20.4 billion.
- The cost of congestion in Sydney is expected to be \$7.8 billion.
- The cost of congestion in Melbourne is expected to be \$6.1 billion.

For road, congestion is an issue in capital cities during the morning and evening peaks. Commuting patterns are mostly about suburban travel: 15 per cent of employment is in the CBD, growing steadily in line with city population, but most jobs are further out and most people are working relatively close to where they live. While total road traffic is not increasing in Sydney and Melbourne, traffic volumes are increasing on freeways and traffic speed is slowing in the inner city. However, traffic volumes are much lower than expected for Brisbane toll roads (Daley 2012).

Time of use pricing of congested roads can mitigate productivity impacts by spreading demand peaks and maximising the productivity benefits of existing infrastructure by prioritising access to high value users (that is, freight over passengers, and business over leisure travel).

Daley (2012) estimates gains from congestion pricing in cities of \$2 billion per annum, assuming a reduction in congestion of 30 per cent due to congestion pricing.¹⁰ The impact of congestion pricing depends on local reaction; this remains untested in Australia.

While congestion has significant social impacts, costs are incurred by all road users including private users, and only part of total congestion cost can be attributed to reduced productivity. Without significant reform, BITRE estimates that business vehicle use will account for over 50 per cent of total delay costs in capital cities by 2020 (BITRE 2007).

⁷ See Transport and Infrastructure Council 23 May communique, available at http://www.transportinfrastructurecouncil.gov.au/communique/files/Council_1st_Communique_23_May_2014_VI.pdf

⁸ See <http://www.austrroads.com.au/planning-and-evaluation/ngtgm-revision>

⁹ In 2005 dollars. Updated BITRE estimates of future road congestion in capital cities are expected to be completed in early 2014.

¹⁰ Estimate cost of avoidable congestion in 2007 with a GDP deflator to 2022 and assuming no growth in road traffic. Future benefits of congestion pricing depend on traffic growth, which depends on 'unknowns' such as energy and petrol prices, public transport investment, public transport patronage, and reforms to other taxes such as fringe benefits tax.

Improving productivity in the transport sector

Parham (2012) identified four economy-wide sources of productivity growth:

- Creative destruction of firms
- Non-market sector
- Regulatory reforms
- More effective targeting of investments.

Of these identified sources, regulatory reforms and more effective targeting of investments were expected to be the key to future transport productivity growth.

Measures to improve productivity operate in three main ways:

- Better use of existing inputs using existing technology
- A shift in technological knowledge and capabilities can shift production abilities
- Changes in operating circumstances affect input or output use (Productivity Commission 2006).

Banks (2012) identified areas that remained crucial to future productivity growth for transport infrastructure:

- Undertake transparent cost-benefit analysis of all options prior to any major public infrastructure investment and when determining quality or environmental standards.
 - Public investments are otherwise prone to 'optimism bias' and a confusion between political and economic ends
 - Poor infrastructure decisions have a high opportunity cost and can be a long-term drag on the economy's productivity.
- Extend use of cost-reflective pricing, including to manage peak demand or supply disruptions.
 - Aversion to price rises, even where needed to balance supply and demand, can suppress or distort investment and may result in higher prices in the long term.
- Introduce institutional reforms for roads to connect revenue with spending decisions, while progressively moving to location-based road pricing, particularly for freight.

The Productivity Commission's (2014) draft report on Public Infrastructure states that the overriding message is the need for a comprehensive overhaul of processes in the assessment and development of public infrastructure projects:

- It is essential to reform governance and institutional arrangements for public infrastructure to promote better decision making in project selection, funding, financing and the delivery of infrastructure services.
- Well-designed user charges should be used to the fullest extent that can be justified. However, governments will have to at least partly fund some infrastructure projects and address equity issues.
- Significant road pricing and institutional arrangements are proposed to create more direct links to road users and to take advantage of advances in vehicle technology.

Priority measures to improve productivity

Better, more transparent cost benefit analysis.

The key to ensuring infrastructure delivers productivity benefits is getting the right investment decisions with the highest cost benefit ratios (Sims 2013).

Harris (2013) states that Australia can have a bias to large land transport projects over the more targeted, smaller ones with higher cost benefit ratios.

Maintenance tends to be underfunded relative to investment because of the smaller, less obvious nature of maintenance works relative to new infrastructure (Semmens 2006, Zeitlow 2006, cited in Harvey 2012). But deferring maintenance in the short term can be expensive in the long term (Harvey 2012).

The productivity of infrastructure investments can be improved by:

- Better, more transparent cost benefit analysis. The current revision of the National Guidelines for Transport System Management (2006) is an important step towards this end.¹¹
- Ensure whole of life costs are considered, including future maintenance need.

Cost-reflective heavy vehicle charges and investment that reflects future needs

For investment to be efficient, it needs to be made according to appropriate regulatory rules and standards (Sims 2013).

The Productivity Commission (2006) found there was no mechanism to approach users to suggest they pay for road usage in return for particular roads being built or upgraded, and that the National Transport Commission had no ability consider future investment needs either generally or in the case of specific roads.

Charges are still set by Transport Ministers following advice from the National Transport Commission, using principles that result in a focus on past expenditures, rather than future expenditure needs.

A key issue for operators is that freight transport link roads can have limits on use by heavy vehicles. This can reflect the fact that the trucks that use the road are not charged sufficiently to cover the damage they do to the road and, if they were, the funds raised would not go to those responsible for maintaining or upgrading the road (Sims 2013).

Important changes that would improve freight productivity include:

- Linking user charging directly with road planning, investment and maintenance.
- A locational link between heavy vehicle charges and the funding of road improvements to key freight transport link roads to increase heavy vehicle access.
- Heavy vehicle charging that has a means of allocating funds for future infrastructure needs.

¹¹ See <http://www.austroads.com.au/planning-and-evaluation/ngt-sm-revision>

Variable tolling of major urban roads

The right price signals and incentives are required to make the best use of existing and new infrastructure (Sims 2013).

Congestion costs that are not reflected in time of use or traffic volume related pricing will be indirectly reflected in increased end user demand.

Daley (2012) recommended time of day road pricing to reduce congestion, with a variable road pricing scheme that charges more at rush hour and other congested times. Good scheme design would be essential and must consider administrative costs, complementary investments (for example, public transport), equity concerns, and the right prices to achieve a significant reduction in congestion.

Systems that allow real time access (for example, HOT lanes) have already been implemented overseas.

Time of use pricing of congested roads can mitigate productivity impacts by spreading demand peaks and maximising the productivity benefits of existing infrastructure by prioritising access to high value users (that is, freight over passengers, and business over leisure travel).

The productivity of road networks could be improved by:

- Implementing city-wide variable tolling systems for major urban roads that allow consistent time of day and volume related tolling.

Further application of technological improvements

Intelligent transport systems (ITS) have the potential to deliver significant safety, environmental and efficiency benefits to the Australian transport system (SCOTI 2012).

Effective ITS projects can generate large benefits for small costs when compared to 'traditional' infrastructure investment. For example, the Monash Freeway coordinated ramp metering system increased the road's peak throughput by 30 per cent; a \$1 million pilot program had an economic payback period of just twelve days (Gaffney 2010).

Australia is an innovator in the global ITS market. The SCATS adaptive signal control system is extensively deployed in Australia and internationally (Stevanovic 2010); STREAMS integrated traffic management is widely used in Australia; and we are a world leader in interoperable electronic tolling (ITSA 2012).

However, more could be done to encourage the development and deployment of productivity-enhancing ITS solutions on Australian roads.

Measures that could improve productivity by facilitating technological improvements include:

- Development of economic evaluation guidelines and modelling techniques to enable effective comparison of ITS and traditional infrastructure investment opportunities.
- Encouragement of pilot deployments of new ITS technologies in Australia, including full economic appraisals and comparative analyses.

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