Does Measurement of Digital Activities Explain Productivity Slowdown? The Case for Australia

Derek Burnell and Amani Elnasri*

Abstract – The post 2004 slowdown in productivity growth in developed nations has led to speculation that mismeasurement of digital activities within the national accounts may be responsible. The Australian Bureau of Statistics' (ABS) modelling of potential missing output confirms the findings of Syverson (2017), Ahmad & Schreyer (2016) and Byrne, Fernald & Reinsdorf (2016) that unrecorded digital activities were of insufficient magnitude to explain the productivity slowdown. While there may be room for improvement in data sources and methods more broadly, conceptually digital activities are captured in the National Accounts framework.

JEL Classification: E23, O3, O4
Keywords: productivity slowdown, digital activities, missing output, output mismeasurement

** Australian Bureau of Statistics (derek.burnell@abs.gov.au)*

The authors would like to thank Paul Roberts and Katrina Richardson for helpful comments and Grace Kim for leading the quantitative study early on and members from the ABS National Accounts Branch who contributed by providing data needed to undertake the simulations.

Received on 29 June 2018, accepted after revisions on 23 May 2019.
Citation: Burnell, D. S. & Elnasri, A. (2020). Does Measurement of Digital Activities Explain Productivity Slowdown? The Case for Australia. *Economie et Statistique / Economics and Statistics*, 517-518-519, 123–137. https://doi.org/10.24187/ecostat.2020.517t.2022

The post 2004 slowdown in productivity growth in developed nations has led to speculation that mismeasurement of digital activities within the System of National Accounts (SNA) may be responsible.

Previous quantitative analysis examined whether the underlying concepts, sources and methods adequately captured emerging digital activities. Syverson (2017) estimated the counterfactual output required to offset labour productivity slowdown in the U.S. economy, and then tested whether estimation of new digital intensive activities could be of sufficient magnitude to account for the counterfactual output. Syverson concluded that the counterfactual argument that "true productivity growth has not slowed (or slowed considerably less than measured) since 2004 was not supported". The author's empirical results showed potential missing digital activity output was substantially lower. Rather, it was more likely that productivity measurement problems may exist for certain digital product classes on a smaller scale than hypothesised.

Other studies by the OECD and the IMF support these findings and evidence from Byrne *et al.* (2016), Nakamura & Soloveichik (2016), and Cardarelli & Lusinyan (2015) supports this view. For example, Byrne *et al.* (2016) note that mismeasurement of Information Technology (IT)-related goods and services was not confined to the post 2004 period. Rather, it was substantial prior to 2004 as well as more recently. Furthermore, rising import penetration for computers and communications equipment implies that U.S. domestic production, which matters for Gross Domestic Product (GDP) growth, has slowed. Using different approaches and data, and pointing to output saving technologies, Nakamura & Soloveichik (2016), and Cardarelli & Lusinyan (2015) argue that the slowdown more likely reflected a true reduction in the rate of technological growth rather than mismeasurement. Nonetheless, as digital activities increase, international collaboration between statistical agencies will become increasingly important. In particular, adopting good methods for price and volume estimation across similar digital technologies to facilitate like-for-like comparisons.

This paper extends Syverson's approach to the Australian economy. However, instead of labour productivity, the paper tests the counterfactual for Multifactor Productivity (MFP), which similarly slowed from 2003-04 as in the U.S. experience. The paper examines the case for potential missing digital output in the Retail industry, and digital peer-to-peer (P2P) activities in the Transport, Postal and Warehousing, Information, Media and Telecommunication and Finance and Insurance Services industries. In addition, the paper examines whether Australian results are sensitive to: *(i)* shorter mean asset lives accompanied by the One-hoss shay age-efficiency assumption for IT capital services; and *(ii)* backcasting quality adjusted internet prices to reflect the volume of data provided.

The rest of this paper proceeds by describing the Australian perspective on concepts, sources and methods. The missing output required by digital activities to explain the slowdown in Australia's MFP growth are estimated for specific industries. Other potential sources of the Australian productivity decline are discussed, followed by some concluding remarks.

1. The Australian Perspective

Conceptually, digital activities are included in the SNA framework whenever they give rise to measurable and recordable transactions. Ahmad & Schreyer (2016) and Byrne *et al.* (2016) clarified that while the SNA framework is robust in concept, digital activities enable some economic activity that was traditionally paid for to now be carried out as unpaid household work, and therefore no production is recorded. Similarly, the SNA was never intended to capture the willingness to pay (consumer surplus) for freely available goods and services. The Australian System of National Accounts (ASNA) framework is consistent with SNA so, by extension, is also robust in concept.

1.1. Sources and Methods

In practice, digital activities are recorded when the sources and methods are adequate. Most Australian businesses report to the Australian Taxation Office (ATO). The ABS uses this data in combination with data directly collected (such as the ABS annual Economic Activity Survey), to ensure that there are no significant undercoverage issues for the data reported for Australian resident businesses. Similarly, to minimise undercoverage in economic transactions between residents and non-residents, the ABS makes extensive use of administrative data (such as from the Australian Customs Office) and cross checks sources with the demand-side, like the Household Expenditure Survey.

Data from a variety of sources are confronted and contrasted within a Supply and Use Tables (SUTs) framework to estimate the current price estimates across the production, expenditure and income measures of GDP. The SUTs framework is a powerful tool to improve the coherence of the economic information system. SUTs reconcile how the supply of products within the economy within an accounting period are used for intermediate consumption, final consumption, capital formation or exports. The SUTs permit an analysis of markets and industries and allow productivity to be studied at this level of disaggregation. The ABS's SUTs are estimated for both current prices and volumes.

The chain volume estimates (and their associated deflators) in the ASNA are also confronted, particularly across the expenditure and production accounts. To facilitate improvement in the estimation of chain volume measures in services industries, over the last five years, the ABS has had an active program to ensure that more representative prices are available as services activities become more influential in the economy.

1.2. An Examination of Digital Data Sources

In this context, Ahmad & Schreyer (2016) noted that digital activities may open doors to new solutions to adequately capture source data. This has tended to be the experience in the ABS. For example, digitally sourced scanner data (transaction data) has been included in the ABS's consumer price index (CPI) dataset for a number of years. The approach has the advantage of increasing sample sizes (thereby lowering the sampling error) and helping to price heterogeneous products and services more accurately. The ABS is also acquiring consumer price data digitally via 'web-scraping' technologies.[1]

The coverage of services prices has also improved over time. For example, ride-sharing, shared accommodation and digital products and services (e.g. streaming services) were implemented recently into the CPI. However, accurately separating the price and volume components for services activities remains a challenging area for statistical agencies. Cross-country comparisons of the spread in the range of price growth for certain activities suggest that more effort is required in accounting for quality change for similar service in a more consistent manner. For example, the OECD's National Consumer Price Indexes for Telecommunications show wide-ranging growth patterns over the 13 years to 2015, falling around 40% for Italy to a rise of nearly 30% for Canada. The divergences between countries suggest that, at least for digital goods and services of similar characteristics irrespective of nation, more effort is required to separate the price and volume components to record quality changes more consistently.

Moreover, this paper recognises the importance to review more model-intensive areas of the national accounts, such as capital stock and productivity. This is because digital activities influence the way production is changing, impacting asset mix, asset lives and depreciation rates. One issue is that tablets and smartphones are now taking on the roles traditionally provided by computers, indicating higher replacement rates, especially in the more rapidly innovating industries. This implies higher depreciating assets requiring higher IT depreciation rates for user costs in productivity estimation. To improve visibility, this study separates the contribution of IT and non-IT capital in the productivity growth accounts.

2. Evaluating the Impact of Digital Activities on Australia's Productivity

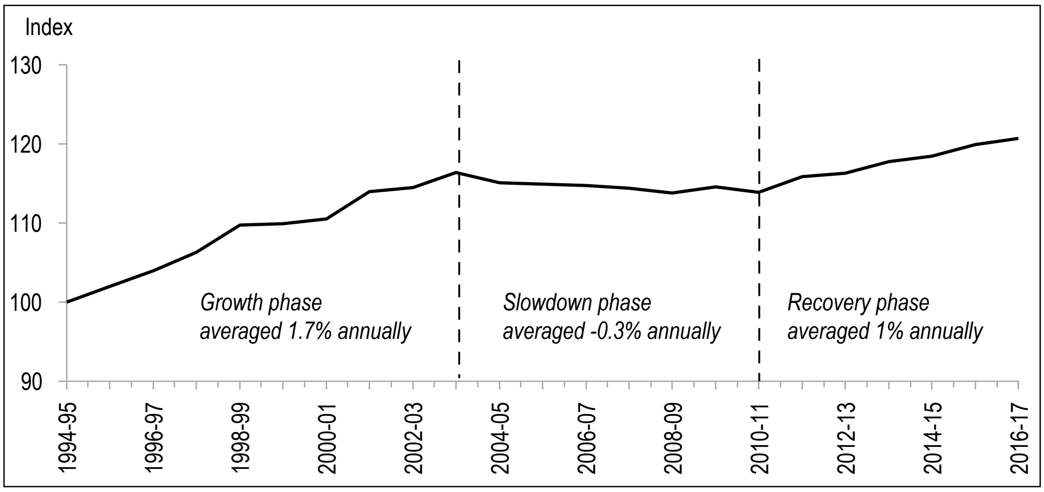
As mentioned earlier, this paper follows the Syverson's approach to estimate the counterfactual real output growth for Australia. Syverson defined counterfactual output as output required to sustain average labour productivity growth in the pre-2004 period. This paper, instead, defines counterfactual output based on various MFP growth targets achieved in the pre-slowdown period.[2]

Figure I shows the evolution of the Australian market sector's MFP over the period 1994-95 to 2016-17. The slowdown phase lasted from 2003-04 to 2010-11 (averaging -0.3% annually). Since 2011-12, MFP recovered, averaging 1% annually.

Using different average values of MFP growth over three different periods, the paper calculates the implied output growth required to explain each level of productivity growth. The following three scenarios are considered:

1. See ABS (2017) for more information on the recent ABS's methods and data sources in order to reflect the contemporary economy and consumer preferences in the Australian CPI.
2. While labour productivity measures output per hour of labour input, MFP measures output produced per unit of combined inputs of labour and capital.

Figure I – **Evolution of the 16 industry market sector MFP aggregate (1994-95 to 2016-17)**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002).

(i) the average annual long-term rate of MFP growth of the 12 selected industries aggregated over the period 1973-74 to 2003-04 (1%),[3]

(ii) the average annual rate of MFP growth of the 16 market sector industries aggregated over the period 1994-95 to 2003-04 (1.7%),[4] and

(iii) the average annual rate of MFP growth of the 16 market sector industries aggregated over the strongest growth cycle from 1993-94 to 1998-99 (2.6%).

Figure II highlights these three scenarios of MFP and the average annual output growth required to obtain each level of these MFP growth rates.

The analysis primarily focuses on potential mismeasurement in gross fixed capital formation (GFCF), household final consumption expenditure (HFCE), gross value added (GVA), and associated price deflators. Income measures, on the other hand, were found to be more robust. Although the ASNA adjust source data for under-statement of income (e.g. cash transactions in the construction industry), digital transactions are different as the relationship is typically three way via a facilitator. Transactions are more likely to be recorded in taxation data, since the facilitator has a registered Australian Business Number (ABN) to operate.[5] Accordingly, gross operating surplus or the income shares needed to aggregate capital services to the market sector, were not impacted by digital transactions. This assumes that any under-reporting of income would proportionally allocate to labour and capital income shares.

Detailed below are the empirical results for the digital activities identified as the most likely candidates for potential missing output: the sharing economy, telecommunication pricing, and IT enhancements.

2.1. Sharing Economy

Three general forms of intermediation of P2P services (sharing economy) are assessed in this paper: distribution services, ride-sharing services and financial intermediation services. For detailed discussion on these P2P services see Ahmad & Schreyer (2016).

2.1.1. P2P Retailing

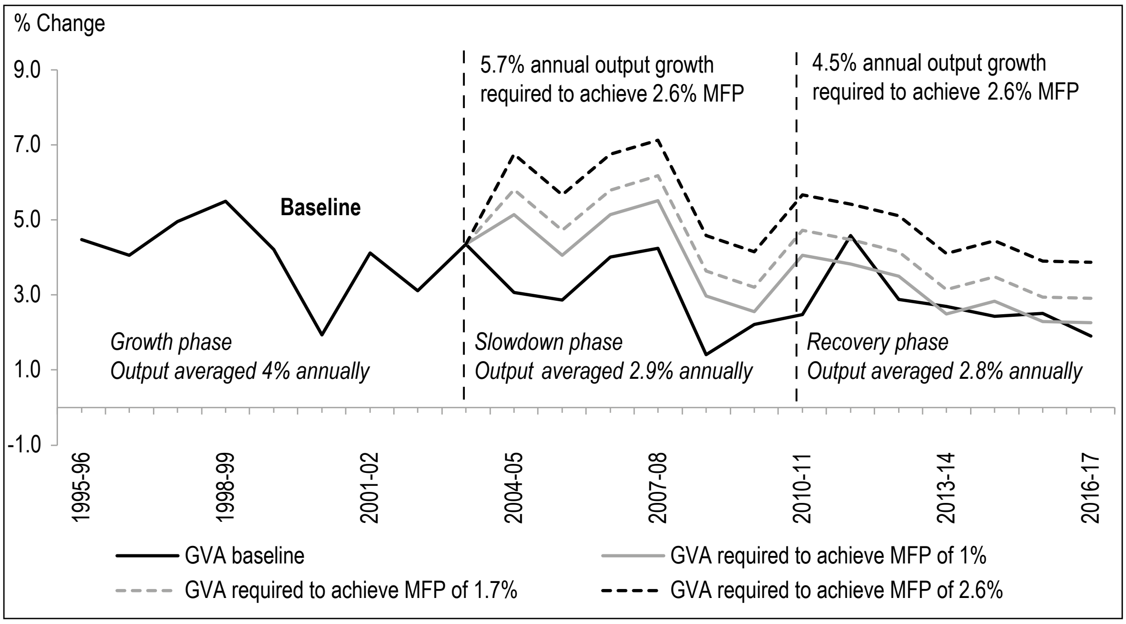
P2P or consumer-to-consumer retailing refers to transactions facilitated by a third party digital platform that brings buyers and sellers together. The underlying retail transactions are not new. Conceptually, all of these transactions and the

3. The 12 selected industries aggregate comprises the ANZSIC Divisions A to K and R, representing the ASNA definition of the market sector prior 2010-11. Estimates of MFP growth of this aggregate are published in the ABS cat. 5260.0.55.002.

4. The 16 market sector industries aggregate comprises the ANZSIC Divisions A to N, R and S (see Appendix). Estimates of MFP growth of this aggregate are published in the ABS cat. 5260.0.55.002.

5. In the digital activities, understatement of reported income is less likely to occur, as transactions between the facilitator and service provider are generally managed over a digital platform rather than cash. Moreover, they must have registered an ABN if their annual turnover exceeds AUD75,000.

Figure II – **The market sector output growth required post 2003-04 to achieve various MFP targets**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002) and authors' estimates.

GVA created are recorded in GDP. The main difference is that digital activities increase the scale of these transactions, since web-based intermediaries reduce entry barriers, and access to the internet facilitates consumer access (Ahmad & Schreyer, 2016). In Australia, many brick-and-mortar stores have extended their business to online retailer platforms via their own web portal or through a digital intermediary.

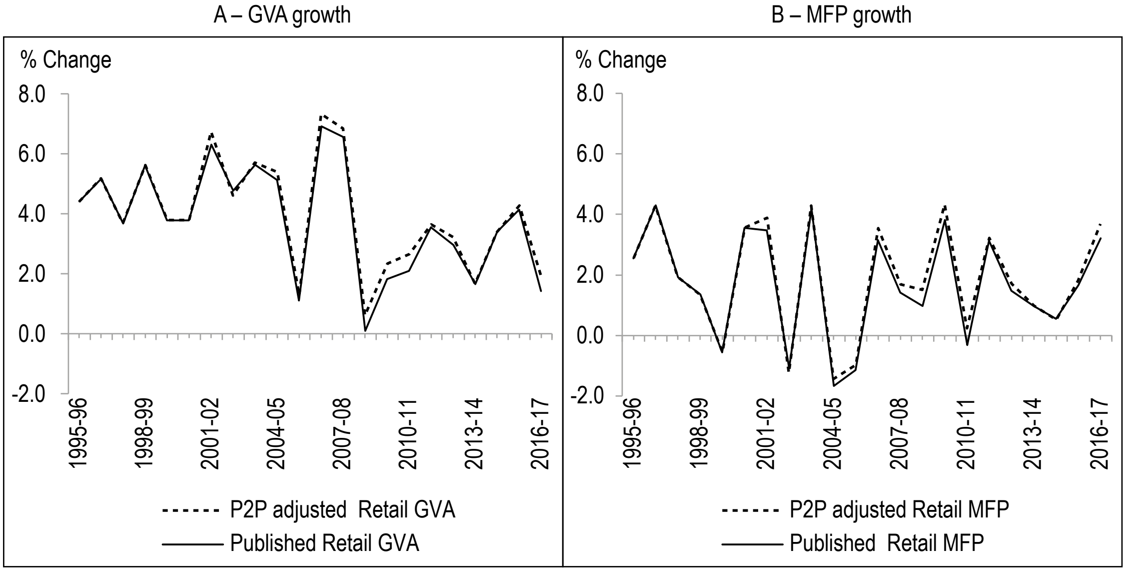
While investigations confirmed that products bought and sold through P2P retailing are captured through HFCE and imports, this study identified potential underestimation of Retail industry GVA caused by under-coverage of P2P intermediaries between 1999-2000 and 2013-14. This was mainly due to some online retailers not having the ABNs required for inclusion in the ABS surveys. To account for this, digital facilitator selling fees were modelled using an average fee per transaction method for the retailers without ABNs. The value of newly produced Australian goods (excluding second-hand goods and imports) that were sold by these online retailers was estimated to be approximately 4% of retail GVA chain volume measure in 2016-17. Figure III shows that the impact of the P2P adjustment on Retail industry GVA chain volume measures and MFP growth over the period 2001-02 to 2016-17 was immaterial.

2.2.2. Ride-Sharing Services

P2P ride-sharing refers to road transport services matching drivers and passengers digitally. These transactions are facilitated using tablets and smartphone applications. The taxi price index may not be a suitable deflator, because the price (depending on market forces of demand and supply) and ride quality are more dynamic. For example, cheaper rates are available relative to taxi fares when demand is subdued but when demand is strong, rates may exceed standard taxi fares. Accordingly, a separate price index for P2P ride sharing is applied in the ABS.

In Australia, ride-sharing services have grown substantially since 2014-15, with nearly 10 million rides facilitated since its inception. Potential missing output was identified before 2015-16, prior to a new tax law requiring ride sharers to register for an ABN. To quantify this, a 2% market share was assigned to ride sharing in 2012-13. From 2012-13, the market share progressively increased its share of transport services from 4% in 2013-14 to 6% in 2014-15, through to 10% since 2015-16. To reinforce potential missing volume growth, the analysis assumed prices were at the lower bound of 40% cheaper compared to taxis. Factoring into consideration the extent of ride-sharing discounting in the deflator not only reinforces the growth in real output through flexible

Figure III – **Retail trade, 1995-96 to 2016-17**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

pricing, real output growth is also reinforced by increased competition which has slowed the rate of price growth, or even resulted in some price decline over recent years. Moreover, since 2013-14, the modelled taxi and ride-sharing combined price deflator showed no significant price growth.

Modelling ride-sharing services is more complex than in the P2P retail scenario. Not only is pricing more dynamic, there is also the issue of reclassifying the HFCE component assigned to ride-sharing services as GFCF, which will impact upon capital services and hence productivity (Ahmad & Schreyer, 2016).[6] To account for this effect, a proportion of the stock of consumer durables attributable to ride-sharing was allocated to the capital services of road vehicles in the Transport, Postal and Warehousing (TPW) industry. Nonetheless, while significant in the context of transport consumption expenditure, this adjustment was small in the overall context of TPW industry GVA, at less than 0.1%. The impact of these adjustments on TPW real GVA and MFP growth, presented in Figure IV, are minimal.

2.2.3. Peer-to-Peer Lending

P2P lending facilitates the matching of borrowers and lenders via a digital platform, with intermediaries providing liquidity transformation services. Through a bidding process, these services potentially offer greater flexibility between interest rates and risk than traditional lending via financial institutions. P2P lending is an output of sub-division Finance in the Financial and Insurance Services (FIS) industry.

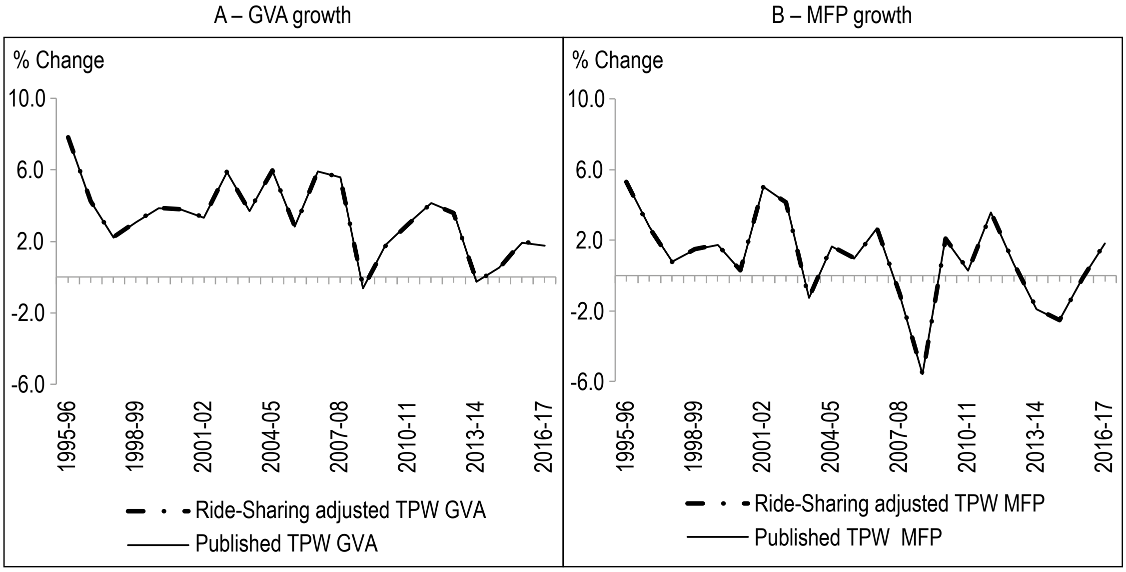
To capture emerging P2P lending impacts, FIS GVA was adjusted to capture missing loans. Industry analysis of the P2P lending market revealed that the potential missing FIS GVA for unrecorded loans from P2P lending, represented only 0.3% of total FIS GVA in chain volume terms in 2013-14, 0.6% in 2014-15, and 1% in 2015-16 and 2016-17. Therefore, the output adjustments had no material impact on FIS GVA and MFP growth (Figure V).

2.3. Quality-adjusted Internet Access Price

Quality change in digital products may also influence prices, and therefore volume estimates of GDP and productivity. One key area is the price of telecommunication services. Technological change has allowed internet service providers to offer customers progressively more generous download quotas at little or no additional cost, sometimes switching customers to an unlimited quota to maintain customer loyalty. In addition,

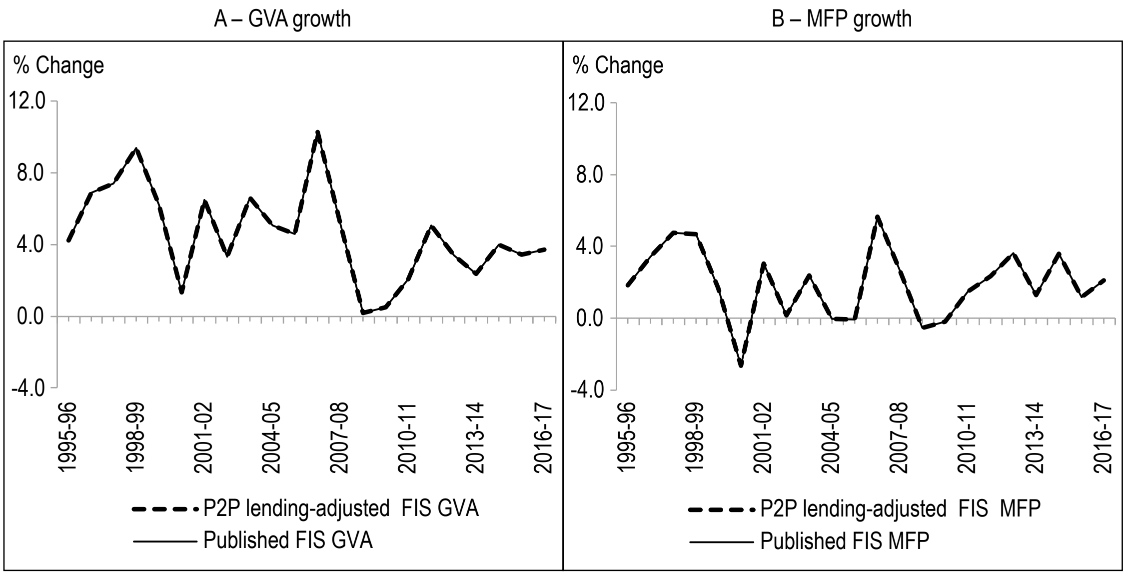
6. This reclassification has no impact on GDP growth so long as there is an equally offsetting adjustment to HFCE for the motor vehicles to be capitalised.

Figure IV – **Transport, postal and warehousing (TPW), 1995-96 to 2016-17**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

Figure V – **Financial and Insurance Services (FIS) (1995-96 to 2016-17)**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

with the emergence of tablets and smartphones, there has been a strong trend in the uptake of wireless internet services by customers. For example, the June 2018 issue of the Internet Activity ABS (2018b) reported that wireless data downloaded per customer tripled since 2010.

Commencing in 2013-14, the National Accounts quality-adjusted internet price index was based on the change in the Telecommunications equipment and services consumer price index (Telecommunications CPI). The Telecommunications CPI is quality-adjusted to reflect, for example, the progressively more generous download quotas, and fell around 20% since 2013-14.

From the March quarter 2014, the ABS significantly increased its use of transactions data to compile the Australian CPI, which included transactions for telecommunications services.[7] The transactions data enabled replacing point-in-time prices for certain products (previously collected by field collectors) with a unit value (from transactions data). The unit value approach is described in ABS (2018a) and ILO (2004).[8]

The Telecommunications CPI generally grew in the pre-2014-15 period (prior to the unit value approach), and then fell steadily from 2014-15 as quality-adjusted prices steadily fell (Figure VI). However, information is available to model the quality change for certain subgroups of telecommunication prior to 2014-15. In particular, the volume of wireless data downloaded and the number of subscribers reflect that download volumes grew steadily since 2010, ABS (2018b). Therefore, an adjustment was applied to capture understated real output growth for the period 2008-09 to 2013-14, which was prior to the introduction of the unit value method. This was modelled by extending back the post 2013-14 relationship between the Telecommunications CPI and wireless downloads per subscriber, since the understated growth in GVA was determined to be mainly in the wireless telecommunication component. Prior to 2008-09, specific information on downloads per subscriber was not available to model the extent of quantity change, so the Telecommunications CPI was used.

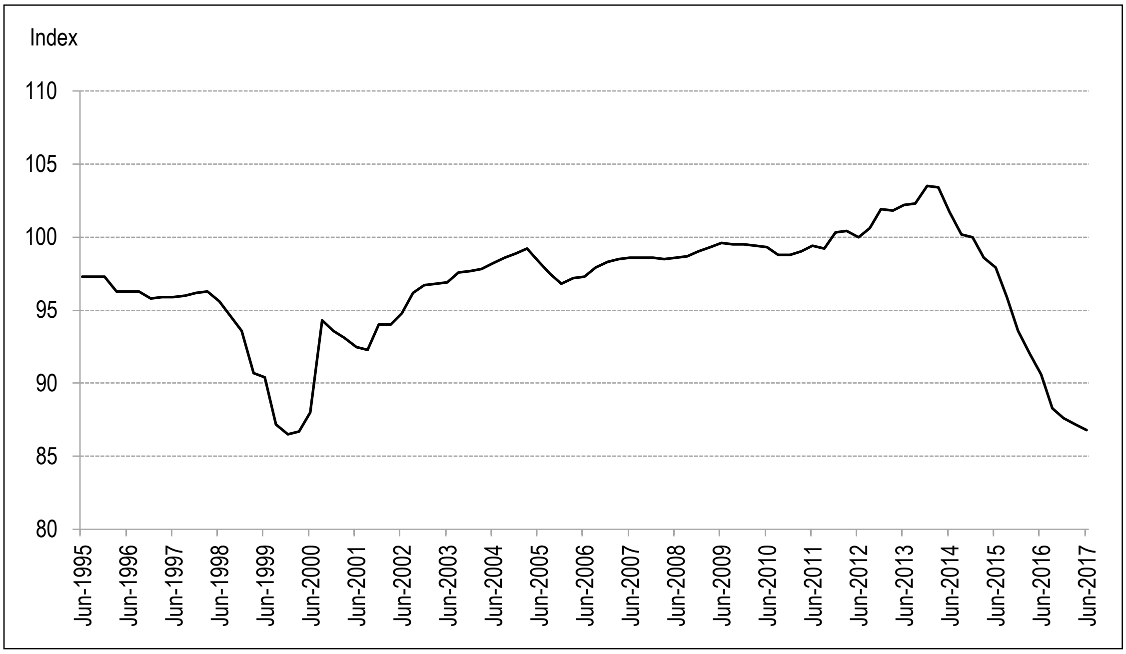
Using this approach highlights the impact of hidden quality change on Information, Media and Telecommunications (IMT) GVA and MFP between 2009-10 and 2013-14 (see Figure VII). Assuming the post 2013-14 relationship between wireless downloads per customer and Telecommunications CPI holds, the impact on GVA and MFP growth was positive, with adjusted GVA growth patterns aligning more closely with pre 2008-09 and post 2013-14 growth patterns.

2.4. Capital Services of Information Technology (IT)

Capital inputs are an important component for measuring MFP. This study evaluates the capital stock assumptions for computers and software, grouped as IT capital. Currently, the average asset lives (that is, average of the length of time they are used in production) for computers and software are fixed over time and across industries.[9] In addition, the same efficiency decay parameter, used to estimate the flow of capital

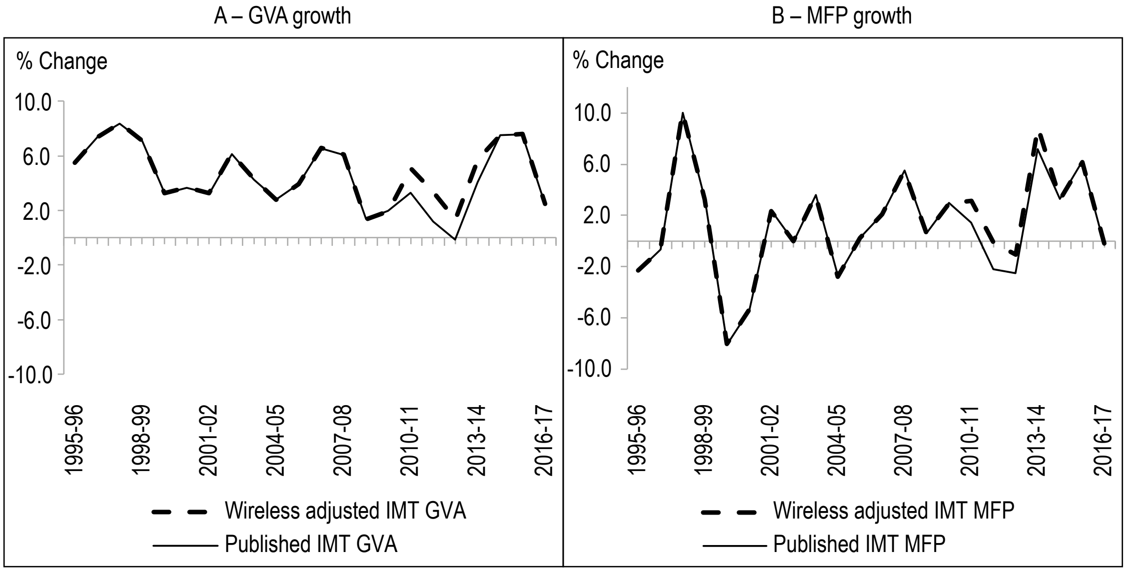
7. For more details, see the article "The Australian CPI: A Contemporary Measure of Household Inflation" in the September quarter 2017 issue of Consumer Price Index, Australia (Cat. 6401.0).
8. See sections 10.105 - 10.107 of (ILO, 2004).
9. SNA08 also recognises capitalisation of databases as intellectual property products, recommending the cost of production approach, or market price, if databases are sold. However, capitalised databases are not recorded in the ASNA due to lack of available data.

Figure VI – **Telecommunication equipment and services CPI**



Sources: ABS (Consumer Price Index, Australia, Jun 2017, Cat. no. 6401.0 and Internet Activity, Australia Cat. no. 8153.0) and authors' estimates.

Figure VII – **Information, Media and Telecommunications (IMT), 1995-96 to 2016-17**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

services, is applied to all types of machinery and equipment.[10]

The ABS currently applies the hyperbolic decay function with an efficiency reduction parameter of 0.5 for computers in all industries. Hyperbolic decay accelerates as computers age, due to the wear and tear effect.[11] However, Diewert & Wei (2017) argue that typically, the service flow that a computer generates over its useful life is roughly constant, implying a One-hoss shay age-efficiency function (a constant efficiency parameter of 1.0).[12]

The ABS's asset lives for computers and software currently are applied to all industries equally. However, the Bean review noted that efficiency and portability of IT capital may vary across industries (Bean, 2016). The ratio of IT GFCF to total GFCF indicates that certain industries (such as the FIS and Administrative and Support services) are more likely to intensively use computers as well as adopt new and improved computers more quickly. The faster replacement rates imply shorter IT asset lives in these industries (Bean, 2016).[13]

To account for these effects, a One-hoss shay age-efficiency function was applied to computers and software, and shorter asset lives for computers and software was applied for industries using IT capital more intensively. The existing and simulated new capital stock assumptions are presented in Tables 1 and 2 respectively. The adjustments to the efficiency reduction parameter and asset lives are made from 1999-2000 onwards.

Figure VIII-A shows that growth in capital services for the FIS industry slowed significantly due to the much shorter asset lives applied in the simulations. This is because shorter asset lives reduce the share of faster growing IT capital stock, relative to non-IT capital stock, in the industry. This more than offsets the increases in capital services growth due to applying the One-hoss shay age-efficiency function, resulting in MFP growth increasing in this industry. For most other industries, the One-hoss shay impact on capital services growth more than offset the reduction in capital services growth due to shortened assets lives, resulting in lower MFP growth in those industries. Figure VIII-B shows that the overall impact on the market sector is close to neutral.

10. The decline in the productive efficiency as an asset ages is described by an age-efficiency function. The age-efficiency function determines the loss in efficiency, mainly due to wear and tear as the asset ages.
11. The ABS uses a hyperbolic function in which the efficiency of the asset declines by small amounts at first and the rate of decline increases as the asset ages. See ABS (2015) for a discussion on capital stock measurement.
12. The One-hoss shay model assumes that the service flow of the asset is constant over the lifetime.
13. For example, the FIS industry embraces the use of digital technologies such as online banking services.

Table 1 – **Existing capital stock assumptions for IT assets**

Asset type	Age-efficiency slope (Beta)	Mean asset life		
		4 years	5 years	6 years
Computers	0.5		Divisions: All	
Computer software (purchased)	0.5	Divisions: All		
Computer software (in-house)	0.5			Divisions: All

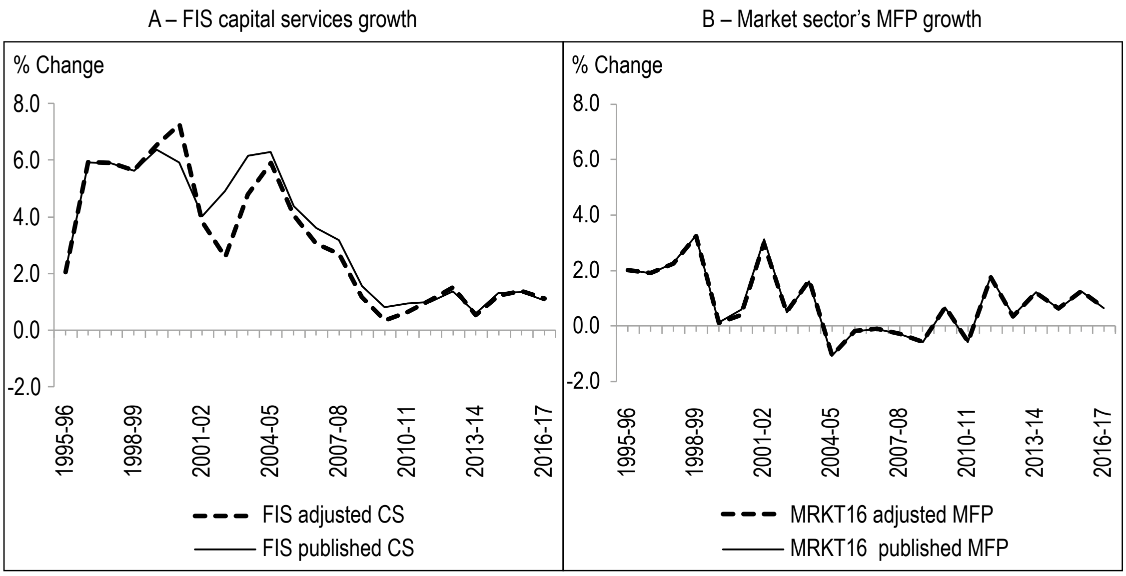
Note: A list of ANZSIC Divisions is provided in Appendix.

Table 2 – **Industry allocation of revised capital stock assumptions for IT capital services**

Asset type	Age-efficiency slope (Beta)	Mean asset life			
		2 years	3 years	4 years	5 years
Computers	1	Divisions K and N	Divisions G and M	Divisions A, B, C, D, E, F, H, I, J, L, R and S	
Computer software (purchased)	1	Divisions K and N	Divisions F, G, J, M and S	Divisions A, B, C, D, E, H, I, L and R	
Computer software (in-house)	1		Divisions K and N	Divisions F, G, J, M and S	Divisions A, B, C, D, E, H, I, L and R

Note: A list of ANZSIC Divisions is provided in Appendix.

Figure VIII – **The impact of ICT enhancement, 1995-96 to 2016-17**



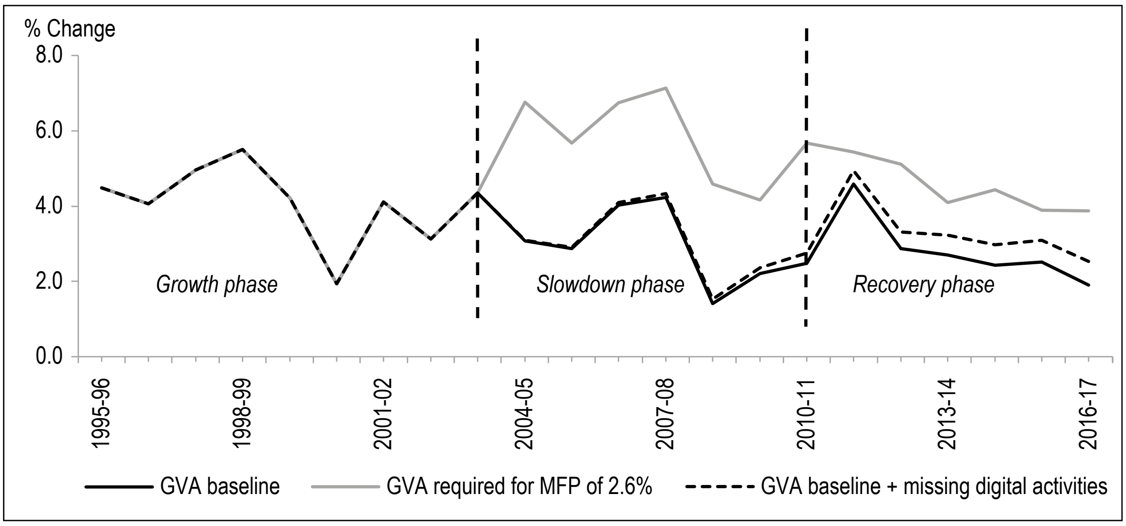
Sources: The authors' estimates based on data from ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002) and capital stock simulations under different age-efficiency assumptions.

2.5. The Overall Impact of Modelled Digital Activities

Each of the impacts discussed were combined into an overall impact of digital activities on Australia's market sector productivity. Figure IX presents the scenario of upper bound target output growth that corresponds to 2.6% MFP growth. The overall impact on the market sector GVA growth due to potential missing digital output is quite small during the productivity slowdown phase (2003-04 to 2010-11). Real GVA growth accelerates during the recovery phase (since 2011-12). By 2016-17, the GVA adjusted for digital output grew 0.6% per year stronger than the published baseline GVA.

The figure also shows that the upper bound target output was higher during the slowdown phase than the recovery phase. Going into the recovery

Figure IX – **The impact of digital activities on real GVA growth, 1995-96 to 2016-17**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

phase, the upper bound target output and GVA growth, including the potential missing digital output, start to converge. By 2016-17, the adjusted GVA is sitting almost midway between the baseline and upper bound output growth in 2016-17.

To put the counterfactual output into context, in 2016-17 market sector real GVA of AUD34,768 per capita would need to increase by an additional AUD12,278 per capita to maintain post-2004 market sector's MFP growth at 2.6%. However, potential missing digital output only accounted for AUD1,361 per capita, with the vast majority of AUD10,918 per capita of the counterfactual output gap unexplained. Similarly, Syverson estimated that to maintain labour productivity growth in the U.S. at the annual average growth recorded in the pre-slowdown period of 1994-95 to 2003-04 (of 2.8% per annum), would require a post 2004 counterfactual real output level around 17% higher in 2015, representing about USD9,300 per capita. The consumer surplus (outside of scope of production) from the new digital activities in 2015 was estimated to be approximately USD3,900 per capita, well short of the counterfactual per capita required to maintain labour productivity growth at 2.8%.[14] By comparison, the counterfactual output gap that can be explained by missing digital output in Australia is proportionally lower.

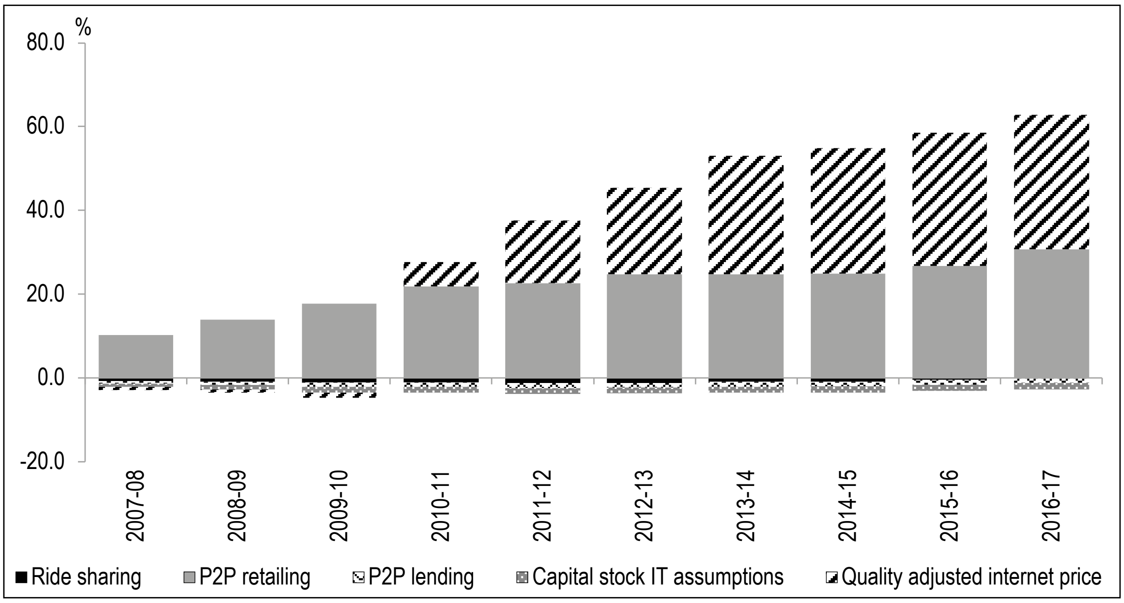
Figure X represents the breakdown of the contribution of digital activities to MFP growth by different digital platforms. The chart shows that P2P retailing and quality-adjusted internet price, were the main contributors to the potential digital mismeasurement. By comparison, ride-sharing, P2P lending and ICT enhancement impacts were negligible.

Another way to present the potential missing output lost due to digital activities, is to compare it to the remaining potential missing output required to achieve counterfactual output. Figure X plots this comparison for the upper bound MFP scenario. The figure highlights that during the productivity slowdown phase, the contribution of potential missing digital output to the counterfactual output required is small – although the share increases during the recovery phase. For example, in 2016-17 the potential missing output due to digital activities represented around 30% of counterfactual output. In part, this increased share can be attributable to the lower counterfactual output required during the recovery phase.

Figure XI suggests that, while the counterfactual output attributable to digital activities is small, its impact accumulates over time. This finding suggests that the ABS, and perhaps other statistical agencies, need to remain proactive to ensure data collection and pricing methods are adequately capturing the growing influence of digitally facilitated output. Figure XI also indicates non-digital, unattributed output,

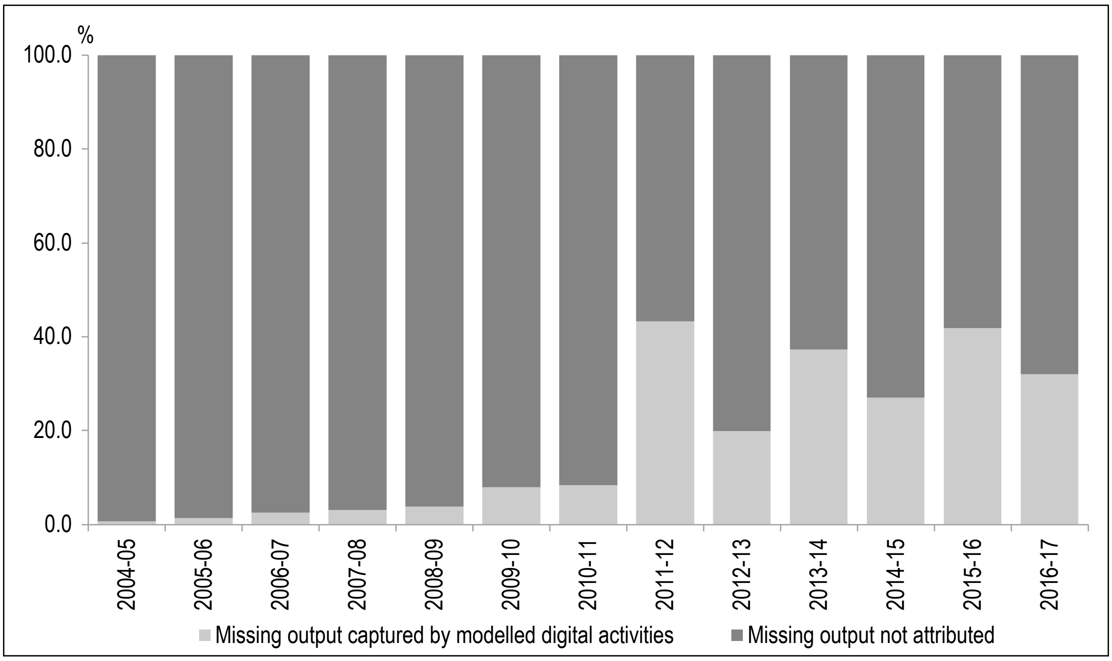
14. Estimates of consumer surplus can be wide ranging, depending on the model and approach. For example, Brynjolfsson & Oh (2012) estimated that the welfare gain from free digital goods and services averaged over USD100 billion per year during 2007-2011.

Figure X – **Contribution to MFP impact from different digital platforms, 2007-08 to 2016-17**



Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

Figure XI – **Overall impact of potential digital mismeasurement, 2004-05 to 2016-17**



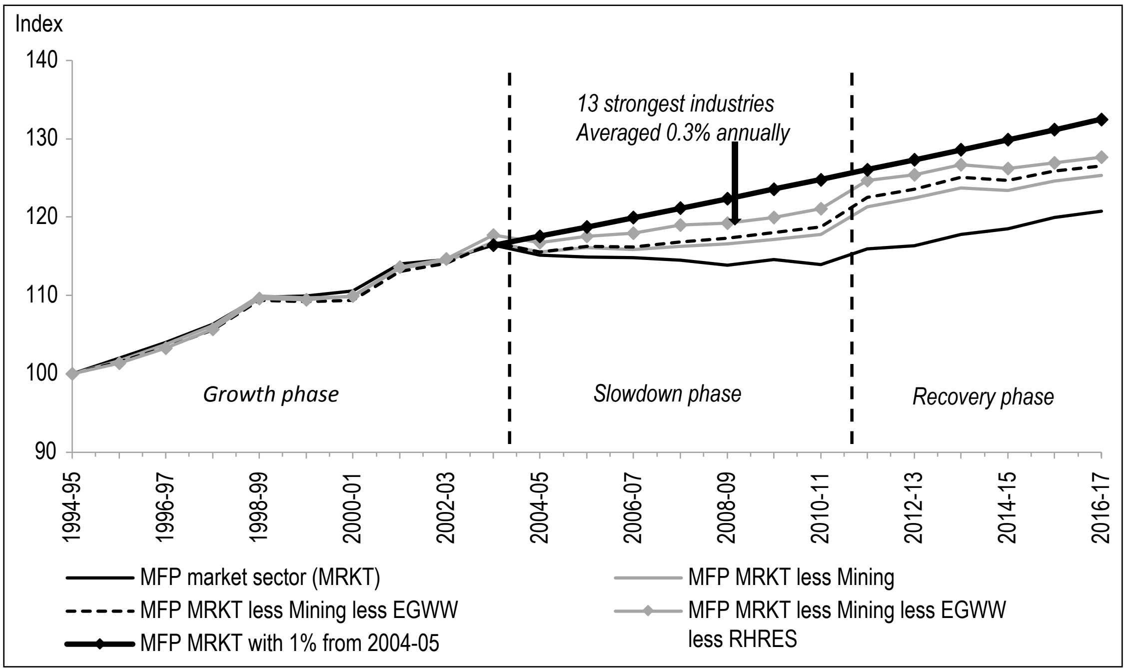
Sources: ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002 and Australian System of National Accounts, 2016-17, Cat. no. 5204.0) and authors' estimates.

represents the vast majority of counterfactual output, especially during the slowdown phase.

3. Industry Sources of Australia's MFP Slowdown

Since the earlier discussion established that digital mismeasurement is too small to play any significant role in Australia's post 2004 productivity slowdown, a crucial question then arises as to what are the sources of the productivity slowdown? One attempt to answer this question is to focus on the industries that have had the sharpest decline in productivity growth over this time. One key industry is Mining as it has generated a substantial proportion of the market

Figure XII – **Industry source of the market sector (MRKT) MFP slowdown, 1994-95 to 2016-17**



Sources: Authors' estimates based on data from ABS (Estimates of Industry Multifactor Productivity, 2016-17, Cat. no. 5260.0.55.002).

sector's output between 2000-01 and 2006-07 due to a resources boom. Nevertheless, it experienced a significant decline in its MFP growth, contributing substantially to the slowdown of the market sector's MFP growth. Besides Mining, the post 2004 slowdown in Australia's productivity was concentrated in a small number of industries, including Electricity, Gas, Water and Waste Services (EGWW) and Rental, Hiring and Real Estate Services (RHRES).

For the mining and EGWW industries, the digital intensity is too small to explain the slowdown. Rather, the slowdown in these industries can be attributed to other factors. For example, the Productivity Commission, noted timing lags between investment and output as well as using natural resources more intensively (e.g. mineral and energy resources in Mining, see Topp *et al.*, 2008) and water resources in EGWW (Topp & Kulys, 2012) in the production process. Official productivity measures do not capture natural resources in capital services because producers do not exercise ownership over them. However, there have been several recent studies modelling the impact of mineral and energy resources in Mining. For example, the ABS (2013) found that Mining capital services growth slows when mineral and energy resource inputs are included, thus reducing the decline in measured MFP.

To understand the sources of Australia's productivity slowdown, it is useful to investigate the influence of each of these industries on the market sector's MFP. Figure XII shows that when Mining, EGWW and RHRES MFP are excluded from the estimation of the market sector's MFP, the remaining 13 industries showed positive growth averaging 0.3% per year during the slowdown phase.[15] This reinforces the results found above about the minimal role of digital activities in explaining the productivity slowdown.

* *
*

The empirical analysis of this paper found that mismeasurement of the digital activities is too small to account for the majority of the productivity slowdown. This finding confirms similar results by Syverson (2017) and Byrne *et al.* (2016) whom found that digital mismeasurement would need to have increased by several orders of magnitude to offset the U.S. productivity slowdown. Moreover, the slowdown in productivity appears to be largely unrelated to the penetration of information technologies across industries and countries. ☐

15. *The ABS used data from Table 23 of Cat. 5260.0.55.002 to facilitate the estimation of several sub-aggregates, such as the non-mining market sector.*

BIBLIOGRAPHY

ABS (2018a). Consumer Price Index: Concepts, Sources and Methods (Cat. no. 6461.0). Australian Bureau of Statistics. https://www.abs.gov.au/ausstats/abs@.nsf/mf/6461.0

ABS (2018b). Internet Activity, Australia (Cat. no. 8153.0). Australian Bureau of Statistics. https://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/6342EA2E47A514E0CA25825F0014B06A?opendocument

ABS (2017). The Australian CPI: A Contemporary Measure of Household Inflation (Cat. no. 6401.0). Australian Bureau of Statistics. https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/6401.0Feature+Article2Sep+2017

ABS (2015). The Australian System of National Accounts: Concepts, Sources and Methods (Cat. no. 5216.0). Australian Bureau of Statistics. https://www.abs.gov.au/ausstats/abs@.nsf/mf/5216.0

ABS (2013). Introduction of Mining Natural Resources into Australia's Productivity Measures (Cat. no. 5204.0.55.010). Australian Bureau of Statistics. https://www.abs.gov.au/ausstats/abs@.nsf/7d12b0f6763c78caca257061001cc588/db52709664089c9eca257d0a00118204!OpenDocument

Ahmad, N. & Schreyer, P. (2016). Measuring GDP in a digitalised economy. OECD Statistics *Working Papers* 2016/07. Paris: OECD Publishing. https://www.oecd-ilibrary.org/economics/measuring-gdp-in-a-digitalised-economy_5jlwqd81d09r-en

Bean, S. C. (2016). *Independent Review of UK Economic Statistics.* Available at: https://www.gov.uk/government/publications/independent-review-of-uk-economic-statistics-final-report

Brynjolfsson, E. & Oh, J. (2012). *The Attention Economy: Measuring the Value of Free Digital Services on the Internet.* Proceedings of the Thirty Third International Conference on Information Systems, Orlando 2012. https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1045&context=icis2012

Byrne, D., Fernald, J. & Reinsdorf, M. (2016). Does the United States have a productivity slowdown or a measurement problem? *Brookings Papers on Economic Activity*, 47(1), 109–182. https://www.brookings.edu/wp-content/uploads/2016/03/byrnetextspring16bpea.pdf

Cardarelli , R. & Lusinyan, L. (2015). U.S. Total Factor Productivity Slowdown: Evidence from the U.S. States. IMF, *Working Paper WP/15/116*. https://www.imf.org/external/pubs/ft/wp/2015/wp15116.pdf

Diewert, E. & Wei, H. (2017). Getting rental prices right for computers: reconciling different perspectives on depreciation. *Review of Income and Wealth,* 63(1), 149–68. https://onlinelibrary.wiley.com/doi/full/10.1111/roiw.12249

ILO (2004). *Consumer price index manual: Theory and practice.* International Labour Office, Geneva. https://www.ilo.org/public/english/bureau/stat/download/cpi/order.pdf

Nakamura, L. & Soloveichik, R. (2015). Capturing the Productivity Impact of the 'Free'Apps and Other Online Media. Federal Reserve Bank of Philadelphia *Working Paper,* N° 15-25. https://conference.nber.org/conf_papers/f84255.pdf

OECD (2017). Measuring GDP in a digital economy. *Global Conference on the G-20 Data Gaps Initiative.* Washington DC, June 14-15, 2017. https://www.imf.org/en/Publications/SPROLLs/G20-Data-Gaps-Initiative#sort=%40imfdate%20descending

Topp, V. & Kulys, T. (2012). Productivity in Electricity, Gas and Water: Measurement and Interpretation. Productivity Commission Staff *Working Paper*, Canberra. https://www.pc.gov.au/research/supporting/electricity-gas-water/electricity-gas-water.pdf

Topp, V., Soames, L., Parham, D. & Bloch, H. (2008). Productivity in the Mining Industry: Measurement and Interpretation, Productivity Commission Staff *Working Paper*, December. https://www.pc.gov.au/research/supporting/mining-productivity

Syverson, C. (2017). Challenges to Mismeasurement Explanations for the U.S. Productivity Slowdown. *Journal of Economic Perspectives,* 31(22), 165–186. https://ideas.repec.org/a/aea/jecper/v31y2017i2p165-86.html. An earlier draft of this paper is also available at https://www.nber.org/papers/w21974.pdf

APPENDIX

The 16 market sector industries for capital simulations

A	Agriculture, Forestry and Fishing	I	Transport, Postal and Warehousing Services
B	Mining	J	Information, Media and Telecommunication Services
C	Manufacturing	K	Financial and Insurance Services
D	Electricity, Gas, Water and Waste Services	L	Rental, Hiring and Real Estate Services
E	Construction	M	Professional, Scientific and Technical Services
F	Wholesale Trade	N	Administrative and Support Services
G	Retail Trade	R	Arts and Recreation Services
H	Accommodation and Food Services	S	Other Services