NEW ZEALAND
PRODUCTIVITY COMMISSION
Te Kōmihana Whai Hua o Aotearoa

New Zealand's productivity growth: Component and industry decompositions

Research Note 2015/2

May 2015

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How to cite this paper: Laws, A., & Meehan, L. (2015). New Zealand's productivity growth: Component and industry decompositions, New Zealand Productivity Commission Research Note 2015/2. Wellington: Productivity Commission.

JEL classification: C43 Index Numbers and Aggregate. D24 Production; Cost; Capital; Total Factor and Multifactor Productivity; Capacity.

ISBN: 978-0-478-44016-4 (online only)

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Abstract

This note applies Diewert (2014a)'s productivity growth decomposition method to New Zealand data. This approach decomposes aggregate labour productivity growth into: industry labour productivity growth, changes in industry labour input shares and changes in industry real output prices. Similarly, aggregate MFP growth is decomposed into: industry MFP growth, changes in industry input shares, changes in industry real output prices and changes in industry reciprocal input prices. Consistent with Meehan (2014), industry labour productivity growth was a much larger component of aggregate labour productivity growth in New Zealand over the 1978-2011 period than changes in labour input shares.

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1 Introduction

This note applies the Diewert (2014a) productivity growth decomposition method to New Zealand productivity data. This approach decomposes aggregate labour productivity growth and multi-factor productivity (MFP) growth into within-industry productivity growth, changes in industry input shares and changes in industry real prices.

Denison (1962) was the first to observe that aggregate productivity growth cannot be calculated as a weighted sum of each industry's productivity growth and that resource reallocations across industries also play an important role. He therefore proposed a decomposition of aggregate labour productivity growth that accounts for not only weighted industry labour productivity growth, but also changes in industry labour input shares.

Tang and Wang (2004) provides an important extension to the Denison decomposition which takes account of changes in real output prices. However, their approach combines the effects of changes in real output prices with the effects of changes in input shares.

Diewert (2014a) reworks the Tang and Wang (2004) approach to decompose aggregate labour productivity growth into separate contributions from industry labour productivity growth, changes in industries' labour input shares and changes in industries' real output prices. He also generalises the approach to decompose MFP growth into: industry MFP growth, changes in industries' combined (labour and capital) input shares, changes in industries' real output prices, and changes in industries' real input prices.

Previous New Zealand Productivity Commission work decomposes New Zealand's aggregate labour productivity growth into within-industry productivity growth and labour movements between industries (Meehan, 2014). However, this previous analysis did not account for real output prices and focussed on labour productivity growth, while this note also looks at MFP growth.

The next section introduces the decomposition methodology. Section 3 presents overall component decompositions for aggregate labour productivity growth and MFP growth for MS-11 (eleven industries of the former measured sector) over the 1978 to 2011 period, and MS-16 (sixteen industries of the current measured sector) for 1996 to 2011. Section 4 then looks at the industry contributions behind the overall decomposition components. Section 5 concludes.

2 Methodology

This section outlines the method used to decompose New Zealand's aggregate labour productivity and MFP growth. This section draws heavily on Diewert (2014a).

2.1 Labour productivity growth

Table 1 summarises the variables used in the aggregate labour productivity growth decomposition and how each was calculated using Statistics New Zealand data. For more details of the source data, see Meehan (2014) and Statistics New Zealand (2014).

Table 1 Summary of terms and data sources for labour productivity growth decomposition

Variable	Definition	Description	Statistics New Zealand data
X_n^t Industry n labour productivity in period t.	$X_n^t \equiv \frac{Y_n^t}{L_n^t}$	Industry n real output divided by industry n labour input, for period t.	Y_n^t is chain-volume output data. L_n^t is industry hours paid from 2000 onwards, and backdated to 1978 using the labour input index.[1]
s_{Ln}^t Industry n share of total labour input in period t.	$s_{Ln}^t \equiv \frac{L_n^t}{L^t}$ where $L^t = \sum_{n=1}^{N} L_n^t$	Industry n labour input divided by total labour input, for period t.	As above, industry hours paid (L_n^t) and total hours paid L^t, backdated from 2000 using the labour input index.
p_n^t Industry n output price relative to aggregate output price in period t.	$p_n^t \equiv \frac{P_n^t}{P^t}$	Industry n value-added output price index divided by aggregate output price index, for period t.	Industry (P_n^t) and aggregate (P^t) implicit price indexes (nominal GDP divided by chain-volume GDP).
s_{Yn}^t Industry n share of total value-added output in period t.	$s_{Yn}^t \equiv \frac{P_n^t Y_n^t}{\sum_{n=1}^{N} P_n^t Y_n^t} = \frac{p_n^t Y_n^t}{\sum_{n=1}^{N} p_n^t Y_n^t}$	Industry nominal value-added output divided by aggregate nominal value-added. That is, industry n output price times industry n real output, divided by the sum of total output price times total real input	As above.

As detailed in Diewert (2014a) and using the terms in Table 1, the period t aggregate labour productivity, X_t, is defined as:

$$\begin{aligned} X^t &\equiv \frac{\sum_{n=1}^{N} P_n^t Y_n^t}{P^t L^t} \\ &= \frac{\sum_{n=1}^{N}\left(\frac{P_n^t}{P^t} Y_n^t\right)}{L^t} \\ &= \frac{\sum_{n=1}^{N} p_n^t Y_n^t}{L^t} \\ &= \sum_{n=1}^{N} p_n^t \left(\frac{Y_n^t}{L_n^t}\right)\left(\frac{L_n^t}{L^t}\right) \\ &= \sum_{n=1}^{N} p_n^t s_{Ln}^t X_n^t \end{aligned} \qquad (1)$$

[1] It would be preferable to use hours worked instead of hours paid to account for factors such as unpaid overtime and paid leave. However, Statistics NZ does not publish industry hours worked series as hours paid are considered more robust (Statistics New Zealand, 2014).

That is, aggregate labour productivity in period t is the weighted sum of the industry labour productivities, where the weight for industry n is the real output price for industry n (p_n^t) times industry n's share of labour (s_{Ln}^t).

Using the terms above, Diewert (2014a) derives the following expression for the aggregate labour growth factor (ie, one plus the growth rate) going from period t-1 to t, $\frac{X^t}{X^{t-1}}$:

$$\begin{aligned}\frac{X^t}{X^{t-1}} &= \frac{\sum_{n=1}^{N} p_n^t s_{Ln}^t X_n^t}{\sum_{n=1}^{N} p_n^{t-1} s_{Ln}^{t-1} X_n^{t-1}} \\ &= \frac{\sum_{n=1}^{N} \frac{p_n^t}{p_n^{t-1}} \frac{s_{Ln}^t}{s_{Ln}^{t-1}} \frac{X_n^t}{X_n^{t-1}} \frac{p_n^{t-1} Y_n^{t-1}}{L^{t-1}}}{\sum_{n=1}^{N} \frac{p_n^{t-1} Y_n^{t-1}}{L^{t-1}}} \\ &= \sum_{n=1}^{N} \frac{p_n^t}{p_n^{t-1}} \frac{s_{Ln}^t}{s_{Ln}^{t-1}} \frac{X_n^t}{X_n^{t-1}} s_{Yn}^{t-1} \qquad (2)\end{aligned}$$

That is, the aggregate labour productivity growth factor is the output-share-weighted average of the three growth factors associated with industry n:

- $\frac{X_n^t}{X_n^{t-1}}$, (one plus) labour productivity growth of industry n;
- $\frac{s_{Ln}^t}{s_{Ln}^{t-1}}$, (one plus) the growth rate in the share of labour used by industry n;
- $\frac{p_n^t}{p_n^{t-1}} = \frac{\frac{P_n^t}{P_n^{t-1}}}{\frac{P^t}{P^{t-1}}}$, (one plus) the growth rate of real output price of industry n.

Equation (2) can be re-expressed in growth rate terms (percentage change in variables) rather than growth factors (one plus the growth rates). Define aggregate labour productivity growth rate (Γ), industry labour productivity growth rates (γ_n), industry real output price growth rates, (ρ_n) and the industry labour input share growth rates (σ_n) between periods t-1 and t as:

$$\Gamma \equiv \frac{X^t}{X^{t-1}} - 1 \qquad (3)$$

$$\gamma_n \equiv \frac{X_n^t}{X_n^{t-1}} - 1 \qquad (4)$$

$$\rho_n \equiv \frac{p_n^t}{p_n^{t-1}} - 1 \qquad (5)$$

$$\sigma_n \equiv \frac{s_{Ln}^t}{s_{Ln}^{t-1}} - 1 \qquad (6)$$

Substituting definitions (3)-(6) into (2):

$$\begin{aligned}\Gamma &= \sum_{n=1}^{N} s_{Yn}^{t-1}\left[(1+\gamma_n)(1+\rho_n)(1+\sigma_n)-1\right] \\ &= \sum_{n=1}^{N} s_{Yn}^{t-1}\gamma_n + \sum_{n=1}^{N} s_{Yn}^{t-1}\rho_n + \sum_{n=1}^{N} s_{Yn}^{t-1}\sigma_n + \sum_{n=1}^{N} s_{Yn}^{t-1}\gamma_n\rho_n + \sum_{n=1}^{N} s_{Yn}^{t-1}\gamma_n\sigma_n + \sum_{n=1}^{N} s_{Yn}^{t-1}\rho_n\sigma_n + \sum_{n=1}^{N} s_{Yn}^{t-1}\gamma_n\rho_n\sigma_n\end{aligned} \tag{7}$$

That is, aggregate labour productivity growth, Γ, is a cubic function in the industry growth rates for labour productivity, γ_n, real output price growth rates, ρ_n, and industry labour input share growth rates, σ_n.

The total contribution to aggregate labour productivity growth, Γ, from industry n is the nth term of the first line of Equation (7), $s_{Yn}^{t-1}\left[(1+\gamma_n)(1+\rho_n)(1+\sigma_n)\right]$. If industry n's real output price and labour input share remained constant, then the contribution of industry n to aggregate labour productivity growth would simply be industry n's labour productivity growth times its initial share of aggregate value-add. If industry n's real output price growth and labour input share growth are non-zero, then its contribution to aggregate labour productivity growth is augmented by industry n's labour input share growth factor, $1+\sigma_n$, and industry n's relative real output price growth factor, $1+\rho_n$. Augmenting by $1+\sigma_n$ is intuitive – if industry n's share of labour input increases, the importance of industry n in aggregate labour productivity increases. Augmenting by $1+\rho_n$ is less intuitive, but it also reflects the relative importance of industry n. An increase in the real price of industry n's output relative to aggregate output prices will increase the importance of this industry in aggregate output growth and therefore aggregate labour productivity (Diewert, 2014a).

The second line of Equation (7) says that aggregate labour productivity growth, Γ, is equal to the sum of output-share-weighted averages of: industry labour productivity growth rates, industry real output price growth rates, industry labour input share growth rates, the quadratic terms in the industry growth rates, and the cubic term in the industry growth rates. Since growth rates tend to be small, the first three terms tend to dominate the quadratic and cubic terms.

For ease of interpretation, the seven terms in the last line of Equation (7) can be grouped into three sets of terms: 1. within-industry labour productivity growth, 2. labour input share growth and 3. real output price growth:

1. Industry n's contribution to aggregate labour productivity growth due to *within-industry labour productivity growth*, that is, the change in industry n labour productivity, ΔX_n:

$$\Delta X_n \equiv s_{Yn}^{t-1}\gamma_n\left(1+\frac{1}{2}\rho_n+\frac{1}{2}\sigma_n+\frac{1}{3}\rho_n\sigma_n\right) \tag{8}$$

2. Industry n's contribution to aggregate labour productivity growth due to the *change in industry n labour input share,* Δs_{Ln} :

$$\Delta s_{Ln} \equiv s_{Yn}^{t-1}\sigma_n\left(1+\frac{1}{2}\gamma_n+\frac{1}{2}\rho_n+\frac{1}{3}\gamma_n\rho_n\right) \tag{9}$$

3. Industry n's contribution to aggregate labour productivity growth due to the *change in industry n real output prices*, Δp_n :

$$\Delta p_n \equiv s_{Yn}^{t-1}\rho_n\left(1+\frac{1}{2}\gamma_n+\frac{1}{2}\sigma_n+\frac{1}{3}\gamma_n\sigma_n\right) \tag{10}$$

The three component contribution can be summed up across industries to give aggregate labour productivity growth:

$$\Gamma = \sum_{n=1}^{N} \Delta X_n + \sum_{n=1}^{N} \Delta s_{Ln} + \sum_{n=1}^{N} \Delta p_n \qquad (11)$$

That is, Equation (7) is simplified by assigning the second and third order terms to corresponding first order terms in a symmetric, even-handed manner. As mentioned, the second, third and fourth terms of Equations (8)-(10) tend to be very small as long as growth rates are small, meaning the first term dominates.

2.2 MFP growth

The methodology for the decomposition of MFP growth is analogous to that of labour productivity growth with an additional factor, real input price, incorporated. Table 2 summarises the variables used.

Table 2 Summary of terms and data sources for MFP growth decomposition

Variable	Definition	Description	Statistics New Zealand data
X_n^t Industry n MFP in period t.	$X_n^t \equiv \frac{Y_n^t}{Z_n^t}$	Industry n real output divided by industry n combined inputs, for period t.	Y_n^t is chain-volume output data. The real volume of each input (capital and labour) is calculated by dividing the input's income by that input's price index. Input volumes are then combined using a Tornqvist index, following Statistics New Zealand (2014) to calculate Z_n^t.
w_n^t Industry n input price relative to aggregate price in period t.	$w_n^t \equiv \frac{W_n^t}{W^t}$	Industry n real input price divided by total input price index.	Each industry's capital and labour input price indexes are calculated by dividing nominal input income by the real input index. The aggregate price for each input is a (input volume) weighted average of all individual industries' prices. A Tornqvist index is used to combine the two input prices.
s_{Zn}^t Industry n share of total input in period t.	$s_{Zn}^t \equiv \frac{W_n^t Z_n^t}{\sum_{n=1}^{N} W_n^t Z_n^t} = \frac{w_n^t Z_n^t}{\sum_{n=1}^{N} w_n^t Z_n^t}$	Industry n input price times industry n real input, divided by the sum of total input price times total real input.	Each industry's real input price is multiplied by their share of total inputs. As above, real input volume is found by dividing capital and labour income by their respective price indexes.
p_n^t Industry n output price in period t.	$p_n^t \equiv \frac{P_n^t}{P^t}$	Industry n output price index divided by total output price index, for period t.	Nominal output divided by chain-volume output is used to create a price index for individual industries and the aggregate measured sector.
s_{Yn}^t Industry n share of total value added output in period t.	$s_{Yn}^t \equiv \frac{P_n^t Y_n^t}{\sum_{n=1}^{N} P_n^t Y_n^t} = \frac{p_n^t Y_n^t}{\sum_{n=1}^{N} p_n^t Y_n^t}$	Industry n output price times industry n real output, divided by the sum of total output price times total real input	As before, the price index is taken from nominal divided by chain-volume output. The real output price is used, defined previously as industry-specific price index over the total price index.

As detailed in Diewert (2014a) and using the terms in Table 2, the period t aggregate MFP, X_t, is defined as:

$$
\begin{aligned}
X^t &\equiv \frac{\sum_{n=1}^{N} p_n^t Y_n^t}{\sum_{n=1}^{N} w_n^t Z_n^t} \\
&= \frac{\sum_{n=1}^{N} \frac{p_n^t}{w_n^t} \frac{Y_n^t}{Z_n^t} w_n^t Z_n^t}{\sum_{n=1}^{N} w_n^t Z_n^t} \\
&= \sum_{n=1}^{N} \frac{p_n^t}{w_n^t} X_n^t s_{Zn}^t
\end{aligned} \tag{12}
$$

It follows from (12), aggregate MFP growth between period t-1 and t is:

$$
\begin{aligned}
\frac{X^t}{X^{t-1}} &= \frac{\sum_{n=1}^{N} \frac{p_n^t}{w_n^t} X_n^t s_{Zn}^t}{\sum_{n=1}^{N} \frac{p_n^{t-1}}{w_n^{t-1}} X_n^{t-1} s_{Zn}^{t-1}} \\
&= \frac{\sum_{n=1}^{N} \frac{p_n^t}{p_n^{t-1}} \frac{w_n^{t-1}}{w_n^t} \frac{X_n^t}{X_n^{t-1}} \frac{s_{Zn}^t}{s_{Zn}^{t-1}} \frac{p_n^{t-1}}{w_n^{t-1}} X_n^{t-1} s_{Zn}^{t-1}}{\sum_{n=1}^{N} \frac{p_n^{t-1}}{w_n^{t-1}} X_n^{t-1} s_{Zn}^{t-1}} \\
&= \sum_{n=1}^{N} \frac{p_n^t}{p_n^{t-1}} \frac{w_n^{t-1}}{w_n^t} \frac{X_n^t}{X_n^{t-1}} \frac{s_{Zn}^t}{s_{Zn}^{t-1}} s_{Yn}^{t-1}
\end{aligned} \tag{13}
$$

Note that this follows since:

$$
\begin{aligned}
\frac{p_n^{t-1}}{w_n^{t-1}} X_n^{t-1} s_{Zn}^{t-1} &= \frac{p_n^{t-1}}{w_n^{t-1}} \frac{Y_n^{t-1}}{Z_n^{t-1}} \frac{w_n^{t-1} Z_n^{t-1}}{\sum_{n=1}^{N} w_n^{t-1} Z_n^{t-1}} \\
&= \frac{p_n^{t-1} Y_n^{t-1}}{\sum_{n=1}^{N} w_n^{t-1} Z_n^{t-1}}
\end{aligned} \tag{14}
$$

and so:

$$
\frac{\frac{p_n^{t-1}}{w_n^{t-1}} X_n^{t-1} s_{Zn}^{t-1}}{\sum_{n=1}^{N} \frac{p_n^{t-1}}{w_n^{t-1}} X_n^{t-1} s_{Zn}^{t-1}} = \frac{p_n^{t-1} Y_n^{t-1}}{\sum_{n=1}^{N} p_n^{t-1} Y_n^{t-1}} = s_{Yn}^{t-1} \tag{15}
$$

In words, aggregate MFP growth (plus one) is an output-share-weighted average of industry MFP growth factors, times an augmentation factor, which is the product $\frac{p_n^t}{p_n^{t-1}} \frac{w_n^{t-1}}{w_n^t} \frac{s_{Zn}^t}{s_{Zn}^{t-1}}$. This decomposition is very similar to the labour productivity growth decomposition (Equation (2)) but with an extra contribution factor, the reciprocal of the real input price growth factor ($\frac{w_n^{t-1}}{w_n^t}$).

Define:

$$\sigma_n \equiv \frac{s_{Zn}^t}{s_{Zn}^{t-1}} - 1 \qquad (16)$$

$$\omega_n \equiv \frac{w_n^{t-1}}{w_n^t} - 1 \qquad (17)$$

Using definitions (4), (5), (16) and (17), the decomposition of aggregate MFP growth ($\Gamma \equiv \frac{X^t}{X^{t-1}} - 1$) into explanatory industry contribution terms is:

$$\Gamma = \sum_{n=1}^{N} s_{Yn}^{t-1}\left[(1+\gamma_n)(1+\rho_n)(1+\omega_n)(1+\sigma_n)\right] \qquad (18)$$

Thus the contribution of industry n depends on its MFP growth (γ_n), its output share (s_{Yn}), its real output price growth (ρ_n), its real reciprocal input price growth (ω_n), and its input cost growth (σ_n).

The industry n contribution term can be expanded into the sum of 15 separate contribution effects: four first-order terms, six second-order interaction terms, four third-order interaction terms and one fourth-order interaction term. For ease of interpretation, we adopt Diewert (2014a)'s grouping into four sets of terms: 1. within-industry MFP growth, 2. input share growth, 3. real output price growth and 4. *reciprocal* real input price growth:

1. Industry n's contribution to aggregate MFP growth due to *within-industry MFP growth*, that is, the change in industry n MFP, ΔX_n:

$$\Delta X_n \equiv s_{Yn}^{t-1}\gamma_n\left(1+\frac{1}{2}\rho_n+\frac{1}{2}\omega_n+\frac{1}{2}\sigma_n+\frac{1}{3}\rho_n\omega_n+\frac{1}{3}\rho_n\sigma_n+\frac{1}{3}\omega_n\sigma_n+\frac{1}{4}\rho_n\omega_n\sigma_n\right) \qquad (19)$$

2. Industry n's contribution to aggregate MFP growth due to the *change in industry n input share*, Δs_{Zn}:

$$\Delta s_{Zn} \equiv s_{Yn}^{t-1}\sigma_n\left(1+\frac{1}{2}\gamma_n+\frac{1}{2}\omega_n+\frac{1}{2}\rho_n+\frac{1}{3}\gamma_n\omega_n+\frac{1}{3}\gamma_n\rho_n+\frac{1}{3}\omega_n\rho_n+\frac{1}{4}\gamma_n\omega_n\rho_n\right) \qquad (20)$$

3. Industry n's contribution to aggregate MFP growth due to the *change in industry n real output prices*, Δp_n:

$$\Delta p_n \equiv s_{Yn}^{t-1}\rho_n\left(1+\frac{1}{2}\gamma_n+\frac{1}{2}\omega_n+\frac{1}{2}\sigma_n+\frac{1}{3}\gamma_n\omega_n+\frac{1}{3}\gamma_n\sigma_n+\frac{1}{3}\omega_n\sigma_n+\frac{1}{4}\gamma_n\omega_n\sigma_n\right) \qquad (21)$$

4. Industry n's contribution to aggregate MFP growth due to *changes in industry n reciprocal real input prices*, Δw_n:

$$\Delta w_n \equiv s_{Yn}^{t-1}\omega_n\left(1+\frac{1}{2}\gamma_n+\frac{1}{2}\rho_n+\frac{1}{2}\sigma_n+\frac{1}{3}\gamma_n\rho_n+\frac{1}{3}\gamma_n\sigma_n+\frac{1}{3}\rho_n\sigma_n+\frac{1}{4}\gamma_n\rho_n\sigma_n\right) \qquad (22)$$

These terms sum to the aggregate MFP growth rate, Γ:

$$\Gamma = \sum_{n=1}^{N} \Delta X_n + \sum_{n=1}^{N} \Delta s_{Zn} + \sum_{n=1}^{N} \Delta p_n + \sum_{n=1}^{N} \Delta w_n \qquad (23)$$

2.3 A note on interpretation

Applying the above method to Australian data, Diewert (2014a) finds that the real output price growth component makes virtually no contribution to *aggregate* labour productivity growth. That is, aggregate labour productivity growth is almost entirely explained by within-industry labour productivity growth and labour input share changes. In addition, aggregate MFP growth is almost entirely explained by the within-industry MFP growth contributions. The real output price growth, the changes in real output prices, real reciprocal input prices and input cost shares are approximately zero in aggregate.

On the face of it, this result seems to be a puzzle. However, Diewert (2014b) shows that it is due to the use of index numbers to calculate aggregate output and the corresponding implicit aggregate output price deflator.[2] Therefore, for labour productivity:

$$\frac{X^t}{X^{t-1}} \approx \sum_{n=1}^{N} s_{Yn}^{t-1} \frac{s_{Ln}^t}{s_{Ln}^t} \frac{X_n^t}{X_n^{t-1}} \qquad (24)$$

and for MFP:

$$\frac{X^t}{X^{t-1}} \approx \sum_{n=1}^{N} s_{Yn}^{t-1} \left(\frac{X_n^t}{X_n^{t-1}} \right) \qquad (25)$$

That is, the industry real output augmentation factors, $\frac{p_n^t}{p_n^{t-1}}$, in aggregate, contributes virtually nothing to overall labour productivity growth. For aggregate MFP growth, the input share changes also contribute virtually nothing. That is, in aggregate the augmentation factor $\frac{p_n^t}{p_n^{t-1}} \frac{w_n^{t-1}}{w_n^t} \frac{s_{Zn}^t}{s_{Zn}^{t-1}}$ is approximately zero.

Note that this only means that the real output price component of labour productivity growth will be approximately zero in *aggregate*. Likewise, the real output price change, reciprocal real input price change and input share change components are approximately zero in *aggregate*. It does not mean that the *industry* real output price component will each be zero – it just means that when aggregating over industries, the industries that make positive contributions will be approximately balanced by industries that make negative contributions.

Therefore, our discussion in Section 3.1 on the contribution of each component to aggregate labour productivity growth focuses on the contributions of the within-industry labour productivity growth and labour input share change components, not the real output price change component. However, this output price component is still an important part of the discussion in Section 4.1, which looks at the contribution of individual industries. Likewise, for aggregate MFP growth, the aggregate analysis focuses on the contributions of within-industry MFP growth, not on the real output price change, reciprocal real input price change and input share change components (Section 3.2). However, these additional three components are still an important part of the discussion on the contribution of individual industries (Section 4.2).

[2] In the case of New Zealand, Statistics New Zealand uses a chained Laspeyres volume index of the constant-price value added of the industries that comprise the measured sector (Statistics New Zealand, 2014).

In addition, as mentioned above, for the labour productivity growth decomposition, the second- and third order interaction terms of the within-industry labour productivity growth, change in labour input shares and change in real output price components (Equations (8)-(10)) tend to be small provided that the growth of the components is small. Similarly, for MFP growth, the second-, third- and fourth-order interaction terms of Equations (19)-(22) tend to be dominated by the first-order term. Therefore, our interpretation of industry contributions in Section 4 will focus on the first-order term. For example, we will generally describe the contribution of industry n to the within-industry labour productivity term (Equation (8)) as a simple function of the size and labour productivity growth of industry n, ignoring the second- and third-order terms. This simplification allows for a more intuitive interpretation and generally makes little difference in practice due to the small magnitude of the higher-order terms.

3 Aggregate analysis: MS-11 and MS-16

This section presents results on the decomposition of New Zealand's aggregate labour productivity growth and aggregate MFP growth. We examine the overall components of aggregate labour productivity growth for the MS-11 and MS-16 sectors (Section 3.1) and then look at aggregate MFP growth for MS-11 and MS-16 (Section 3.2).

3.1 Decomposition of aggregate labour productivity growth

Figure 1 displays the component contribution effects and overall aggregate labour productivity growth for 11 of the 12 industries of the former measured sector (MS-11) for the years 1978-2011.[3] Annual average growth is given over five complete productivity growth cycles, one incomplete cycle (2008-2011) and the whole 1978-2011 period.[4]

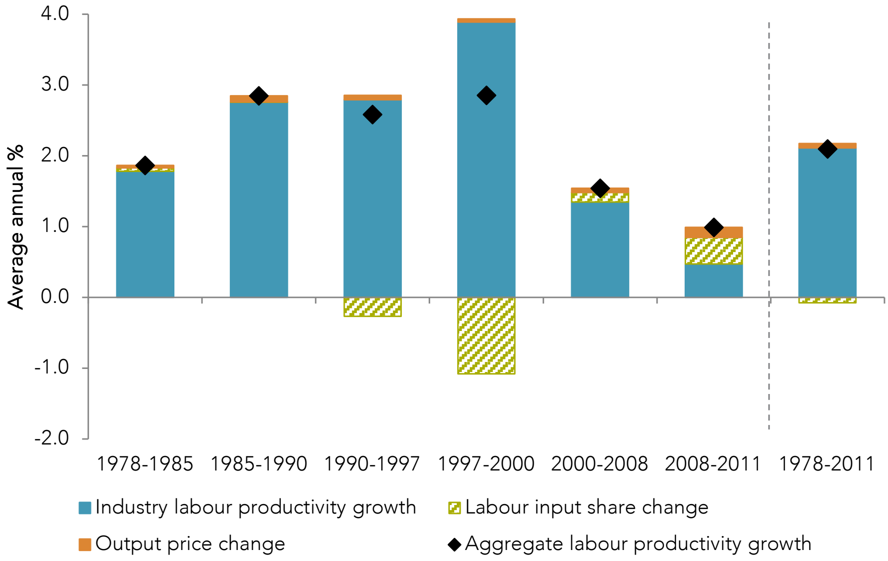
As discussed in Section 2.3, following the recommendation in Diewert (2014b), we focus on the within-industry labour productivity growth and labour input share change components. However, for completeness, we include the output price change component in the figures below, and as expected, it makes a very small contribution to aggregate labour productivity growth.[5]

[3] These 11 ANZSIC06 industries are: agriculture, forestry and fishing; mining; manufacturing; electricity, gas, water & waste services; construction; wholesale trade; retail trade; accommodation & food services; transport postal & warehousing; information, media & telecommunications; financial & insurance services. The 12th industry of the former measured sector, arts and recreation services, is not included as Statistics New Zealand does not publish this industry's series back to 1978 due to robustness issues. However, to maintain consistency with the Australian Bureau of Statistics series, Statistics New Zealand publishes aggregate data for MS-12.

[4] Comparison across productivity growth cycles is preferable to year-on-year comparisons as the former minimises the impact of factors that vary within cycles (such as capacity utilisation). See Statistics New Zealand (2007) for further details.

[5] The only productivity cycle where the output price change component makes a non-negligible contribution is the latest incomplete cycle, 2008-2011. Although we have not fully investigated why this is the case, it may be associated with the measurement inaccuracies with recent chain-volume output values which usually lead to revisions of the latest years of data in future releases.

Figure 1 Components of aggregate labour productivity growth, MS-11, 1978-2011



The overall patterns of aggregate labour productivity growth show that the highest growth occurred in the late 1980s and throughout the 1990s. Labour productivity growth fell away considerably in the 2000s (for a detailed discussion of these aggregate trends, see Conway & Meehan, 2013).

Consistent with Meehan (2014), within-industry labour productivity growth is a much larger component of aggregate labour productivity growth than changes in labour input shares. The main exception to this trend is 2008-2011; however caution should be taken in interpreting this result as the 2008-2011 productivity growth cycle is incomplete.

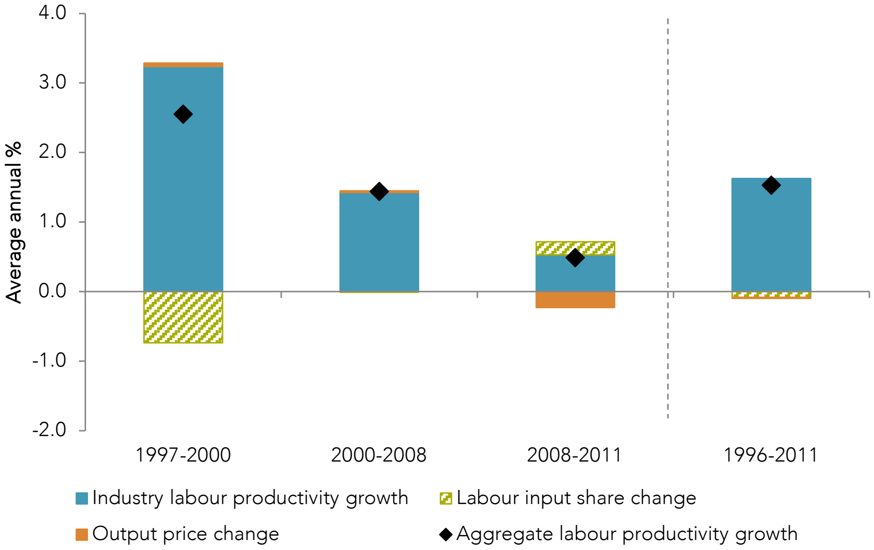
Over the entire 1978-2011 period, changes in the labour input shares reduced aggregate labour productivity growth slightly. Average annual aggregate labour productivity growth was 2.1%, with labour input share changes contributing just -0.1 percentage points. During the 1990s, changes in industry labour input shares reduced aggregate labour productivity growth. While this negative contribution was modest in the 1990-1997 cycle (-0.3 percentage point contribution to aggregate labour productivity growth of 2.6%), it was more sizable in the 1997-2000 cycle (-1.1 percentage point contribution to aggregate labour productivity growth of 2.9%). During the 2000-2008 period, the labour input share contribution was positive but small (0.1 percentage points of the 1.5% aggregate growth rate).

Figure 2 presents the same decomposition for the 16 industries of the current measured sector (MS-16).[6] These data are preferable to MS-11 data in theory given that they cover a larger proportion of the overall economy, but are only available from 1996. Furthermore, some of the additional industries may have measurement issues, particularly that of rental, hiring and real estate.[7] In comparison, the previously presented MS-11 analysis gives a longer term and more accurate, despite more restricted, picture of decomposition trends. Therefore analysis of MS-16 data supplements rather than replaces the MS-11 analysis.

[6] MS-16 includes the MS-11 industries plus: rental, hiring & real estate; professional, scientific & technical services; administrative & support services; arts & recreation and other services.

[7] The level of labour productivity in rental, hiring & real estate is very high. This may be because this industry includes the output of private rental dwellings, but there is no corresponding labour input for this output (see Mason, 2013). We are examining growth rates rather than levels, so this issue may be less problematic, but will still influence factors such as the weight this industry is given in the aggregate calculations.

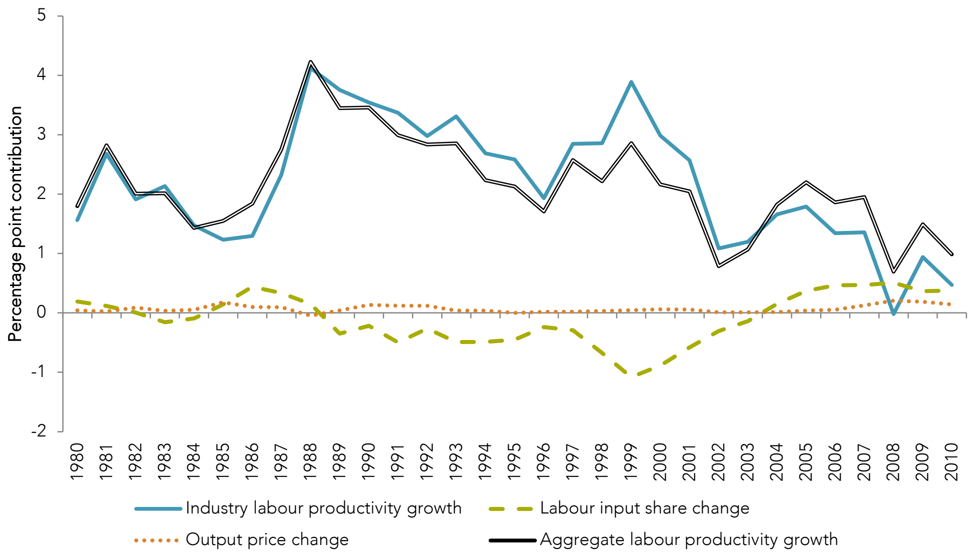
Figure 2 Components of aggregate labour productivity growth, MS-16, 1996-2011



The additional industries change the decomposition of aggregate labour productivity somewhat, but overall, the trends are similar for MS-11 and MS-16 (Figure 1 and Figure 2). The first difference is that aggregate labour productivity growth in MS-16 is lower in all three labour productivity cycles. For example, growth was 2.6% in MS-16 in the 1997-2000 cycle versus 2.9% in MS-11. For the 1997-2000 cycle, the negative contribution of labour input share changes was larger for MS-16 than MS-11. For the 2000-2008 cycle, while there was a small positive contribution of changes in the labour input share for MS-11, this almost entirely disappears for MS-16. The positive contribution of changes in the labour input share was also smaller for the 2008-2011 cycle for MS-16 compared with MS-11.

Figure 3 shows the contributions of the different components of aggregate labour productivity growth for individual years from 1980 to 2010 for MS-11 (using a three-year moving average) and allows us to look at the time trends in more detail. In the late 1980s and throughout the 1990s, relatively high aggregate labour productivity growth occurred despite the negative contributions from labour input share growth. These trends likely reflect the significant economic reforms and restructuring occurring during this period (for a discussion see Conway & Meehan, 2013; Meehan, 2014). During the 2000s, aggregate labour productivity growth was much lower despite positive contributions from labour input share growth in the second half of the first decade of the 2000s.

Figure 3 Annual component contributions to aggregate labour productivity (3-year-moving average, MS-11, 1980-2010)

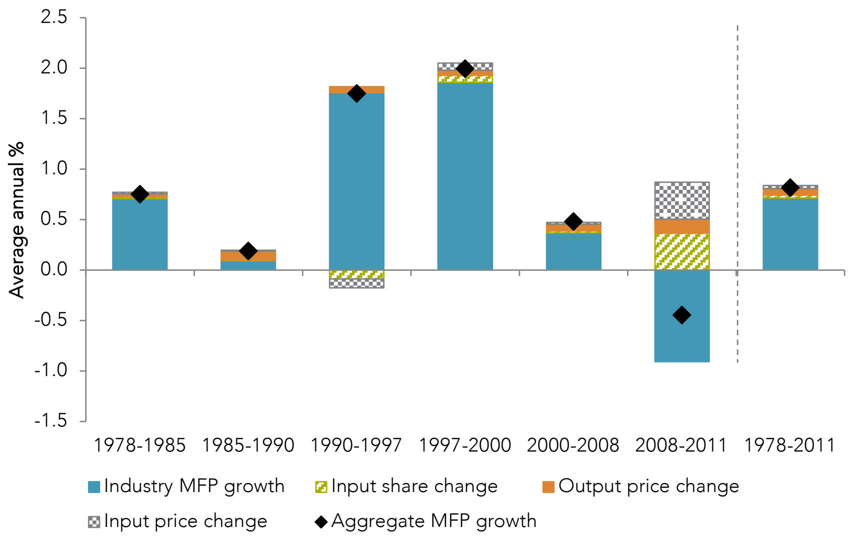


3.2 Decomposition of aggregate MFP growth

As discussed in Section 2.3, aggregate MFP growth is approximately equal to the output-share weighted sum of industry MFP growth, as the nature of the other three components means that they are small.[8] The small difference between the within-industry MFP growth component and aggregate MFP growth is equal to the sum of the other three components (input share changes, real output price changes and reciprocal real input prices changes). As such, although we present the other three components in the figures below for completeness, we focus on the within-industry MFP growth component.

Recall that aggregate labour productivity growth was highest in the 1985-1990, 1990-1997 and 1997-2000 productivity growth cycles (Figure 1). MFP growth was also high during the 1990s. However, MFP growth was very low in the 1985-1990 period, which means that the high labour productivity growth in this period came from capital deepening (as discussed in Conway & Meehan, 2013) (Figure 4). MFP growth was negative during the 2008-2011 period, however, this cycle is incomplete so measurement issues, particularly relating to capacity utilisation, means that this result should be interpreted with caution.

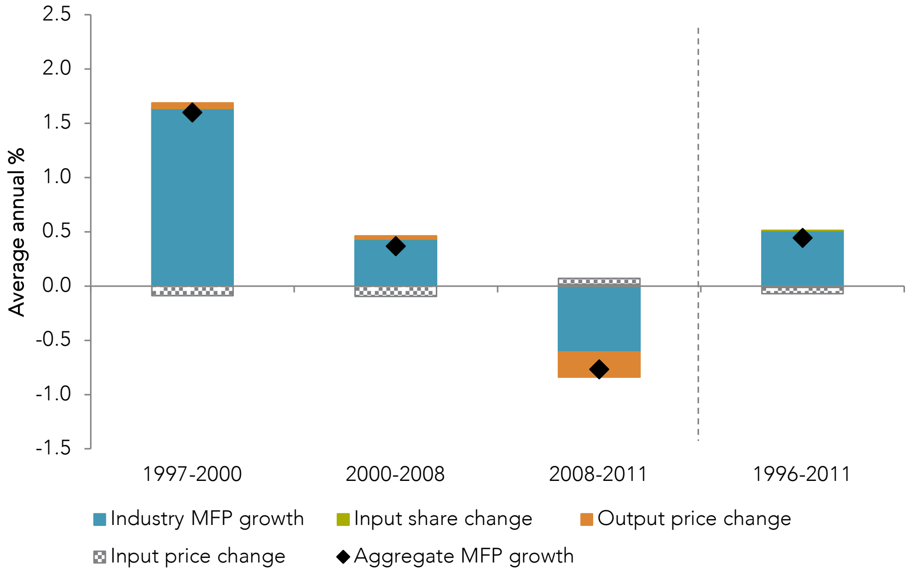
Figure 4 Component contributions to aggregate MFP growth, MS-11, 1978-2011



As with labour productivity growth, aggregate MFP growth is lower in MS-16 than MS-11 (Figure 5). The overall patterns of higher MFP growth in the 1997-2000 cycle followed by low growth in the 2000-2008 cycle and negative growth in the incomplete 2008-2011 cycle are similar.

[8] Once again, we find that this holds overall productivity cycles except the latest incomplete cycle, 2008-2011. See Footnote 5.

Figure 5 Component contributions to aggregate MFP growth, MS-16, 1996-2011



4 Industry contributions to growth components

We now decompose the components of aggregate labour productivity growth (industry labour productivity growth, labour input share changes and output price changes) and aggregate MFP growth (industry MFP growth, input share changes, output price changes and input price changes) into industry contributions. Industry-level patterns can provide insights into the aggregate trends – for example, which industries contributed to the negative labour input share component of aggregate labour productivity growth in the 1990s?

As discussed in Section 2.3, while some of these components mostly net out in total, these are still of interest at the industry level. In addition, each industry's contribution to a particular component is (largely) determined by the size of its output share and the magnitude of the increase or decrease of the relevant component for that industry.[9] For example, manufacturing's contribution to the aggregate within-industry labour productivity growth component is approximately equal to manufacturing's output share times its labour productivity growth. Likewise, manufacturing's contribution to the aggregate labour input share component is approximately equal to manufacturing's output share times the change in its labour input share.

Only results for MS-11 and selected productivity growth cycles are presented here. However, Appendix A includes MS-11 results for the remaining productivity growth cycles.

4.1 Labour productivity growth

We first look at the whole 1978-2011 period (Figure 6). Manufacturing made the largest contribution (about 0.5 percentage points of the aggregate within-industry labour productivity component of 2.1 percentage points). Manufacturing's large contribution was due to its large size (an average of about 30% of total output over this period) coupled with reasonable labour productivity growth (1.7% a year). Information media & telecommunications also made a large contribution despite its smaller size (about 7% of output) due to its very high labour productivity growth rate (5.8% a year). Agriculture, forestry &

[9] We add the qualifier "largely" as industry's contribution to each component is its output share multiplied by the relevant component, plus a set of higher-order interaction terms. As discussed in Section 2.3, since these higher-order terms tend to be small, so for purposes of interpretation, we mostly ignore them.

fishing also made a large contribution due to its high growth rate (3.4% a year) and reasonable share of output (about 11% of output).

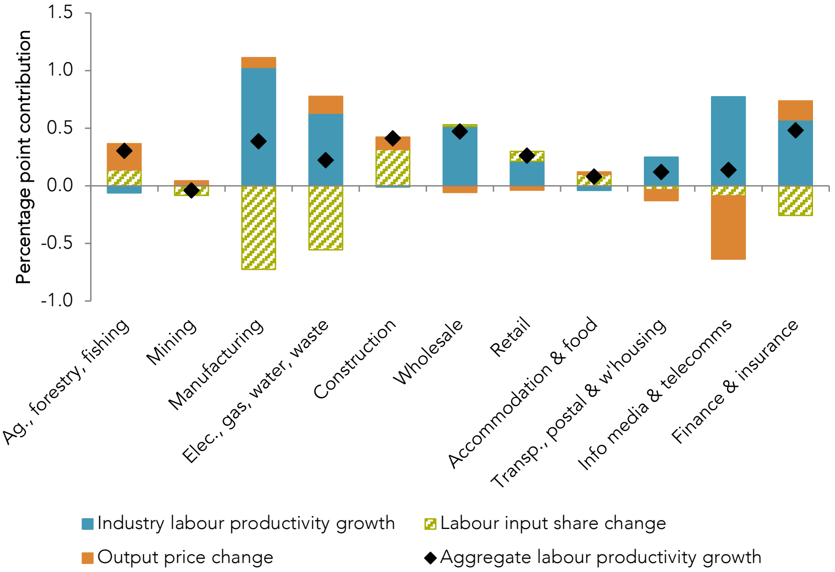
Four industries had a decreasing share of output in the 1978-2011 period and therefore made a negative contribution to the labour input share change component: agriculture, forestry & fishing; manufacturing; transport, postal & warehousing; and information media & telecommunications (Figure 6). Manufacturing made the largest negative contribution as this large industry's labour input share growth was about -0.8% a year. Agriculture, forestry & forestry's labour input share growth was the largest of any industry at about -0.9% a year, but its overall contribution is smaller than manufacturing's since it is a smaller industry. Looking at the seven industries that made a positive contribution to the labour input share change component, accommodation & food services had by far the largest growth in labour input share, at about 2.5% a year. But because this industry is small (about 3% of output) its contribution was about the same as the construction, wholesale trade, retail trade and finance & insurance industries.

The most noticeable industry contribution to the output price change component over the 1978-2011 period is information media & telecommunications (Figure 6). It made a large negative contribution as its output prices decreased not just relative to those of the prices of other industries, but also in absolute terms (-2.9% a year). The decrease in the price of this industry's output reflects the worldwide trend of falls in the price, and increases in the quality, of ICT products.

Figure 6 Industry contributions to aggregate labour productivity growth, 1978-2011

A period of particular interest is the short 1997-2000 cycle (Figure 7). Aggregate labour productivity growth was high during this period, but the labour input share change component was large and negative. Which industries accounted for this large negative component? Six out of the 11 industries had a decreasing share of labour input over this period and therefore made a negative contribution to this component. The largest contributor was manufacturing, followed by electricity, gas, water & waste and finance & insurance, with the remaining industries making a small negative contribution. Manufacturing's labour input share fall by about 2.5% a year during this period, coupled with the large size of this industry resulted in its large negative contribution. Electricity, gas, water & waste is a small industry, accounting for about 5% of MS-11 output, but its labour input share decreased by a massive 10.1% a year over this period. This fall likely reflects labour shedding in this industry due to reforms that were accompanied by very large improvements in labour productivity, which increased by about 13.2% a year during this period (for a discussion see Meehan, 2014). The finance & insurance industry accounts for about 7% of output and its labour input share fell by about 3.3% a year during this period.

Figure 7 Industry contributions to aggregate labour productivity growth, 1997-2000



4.2 MFP growth

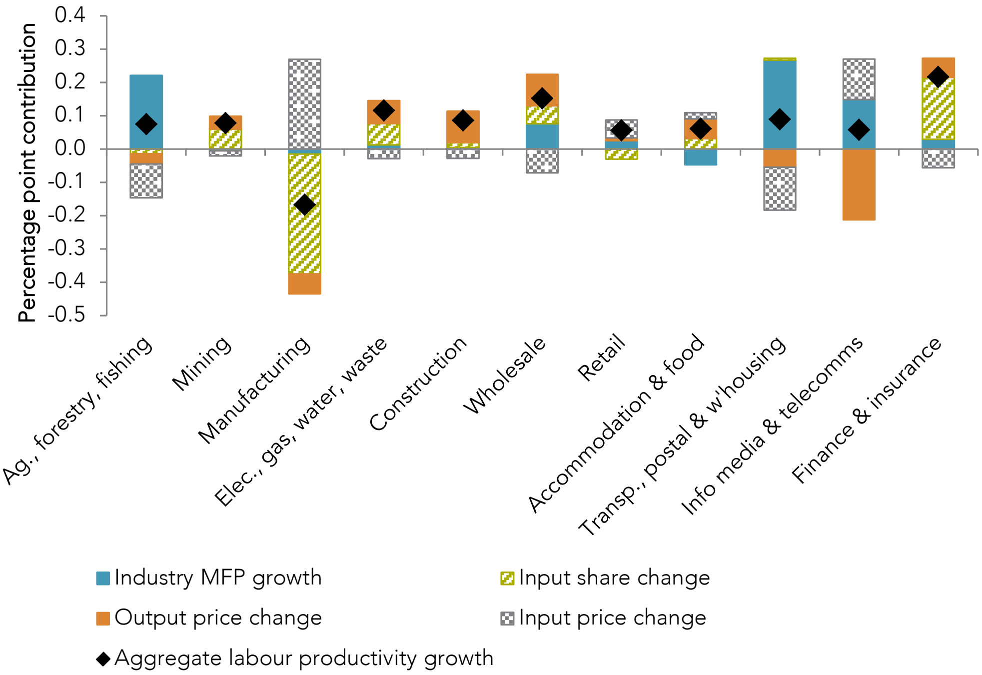
We now decompose the four components of aggregate MFP growth (industry MFP growth, input share changes, output price changes and input price changes) into industry contributions. Over the whole 1978-2011 period, three industries made noticeably larger contributors to industry MFP growth than the other eight industries: agriculture, forestry & fishing; accommodation & food services; and information media & telecommunications (Figure 8). All three of these industries are modestly-sized industries that had well above-average MFP growth rates. Agriculture, forestry & fishing had an average output-share size of about 11% over this period, and average MFP growth of 2.2% a year. Transport, postal & warehousing accounted for about 8% of output and had MFP growth of 3.3% a year. Information media & telecommunications accounted for 7% of output and had MFP growth of 2.3% a year. The biggest industry, manufacturing, made almost no contribution to the industry MFP growth component due to its very small MFP growth rate of 0.06% a year. Manufacturing's results are in contrast to the results for industry labour productivity growth, suggesting that manufacturing's large contribution to industry labour productivity growth was due to capital deepening.

Unlike in the case of the labour input share component of aggregate labour productivity growth, the combined (ie, labour and capital) input share growth component nets out of aggregate MFP growth overall. However, it is interesting to look at which industries made negative and positive contributions to the overall near-zero component. Just three of the 11 industries made negative contributions (agriculture, forestry & fishing, manufacturing and retail trade), with manufacturing the only industry making a sizable negative contribution. Manufacturing is not only a large industry, the change in its share of total inputs (capital and labour combined) was also sizable (-1.2% a year). Manufacturing was also the largest negative contributor to the labour input share component of labour productivity growth. However, the fall in its combined input share was even larger than its fall in labour input share, resulting in an even larger negative contribution to MFP growth than to labour productivity growth. Most of the remaining industries made small positive contributions, except for finance & insurance which made a sizable positive contribution. Finance & insurance is a reasonably small industry (accounting for about 7% of output) that increased its combined input share substantially (by about 2.9% a year). This combined input share growth was much larger than its increase in its labour input share (0.9%), resulting in a much larger positive contribution to the input share component of MFP growth compared with the labour input share component of labour productivity growth.

Manufacturing made a sizable positive contribution to the *reciprocal* input price growth component. This positive contribution was due to a combination of the large size of the industry and a reasonable increase in its reciprocal input price growth (ie, a decrease in its real input prices) of about 0.9% a year. Information media & telecommunications also made a positive contribution – it experienced the largest growth in its reciprocal real input prices of any industry (1.9% a year) but made a smaller overall contribution than manufacturing due to its smaller size. Agriculture, forestry & fishing and transport, postal and warehousing both made reasonable negative contributions to reciprocal input price growth, as reciprocal real input prices fell (ie, real input prices rose) in these two industries.

As discussed in the labour productivity growth results (Section 3.2), information media & telecommunications made a sizable negative contribution to output price growth as prices fell not just in relative terms, but also in absolute terms.

Figure 8 Industry contributions to aggregate MFP growth, 1978-2011



We now look at 1990-1997, 1997-2000 and 2000-2008 productivity growth cycles, with a focus on the industry MFP growth component. The 1990s period of high aggregate MFP growth was followed by low MFP growth in the 2000s. Which industries contributed to the good performance of the 1990s and which were responsible for the 2000s slowdown? The two productivity growth cycles of the 1990s were quite different. Agriculture, forestry & fishing and transport, postal & warehousing were the largest contributors to industry MFP growth in the 1990-1997 period (Figure 9), while manufacturing and wholesale trade industries were the largest contributors in the 1997-2000 period (Figure 10). Transport, postal and warehousing had the highest MFP growth of any industry in the 1990-1997 period (6.8% a year), and accounted for about 9% of output leading to its sizable positive contribution. Wholesale trade went from negative average annual MFP growth in the 1990-1997 period (-0.4%), to the highest MFP growth rate of any industry in the 1997-2000 period (4.9% a year). Manufacturing's MFP growth was more modest than wholesale's in the 1997-2000 period (2.1%), but its large size resulted in a sizable contribution.

The small industry MFP component in the 2000-2008 period was not due to any single industry (Figure 11). Instead, it was due to low or negative growth across all industries. Industry MFP growth rates ranged from -2.3% a year in mining to 1.8% a year in information media & telecommunications. This compares to a range of -1.5% a year to 6.8% a year in the 1990-1997 cycle and a range of -2.3% a year to 4.9% a year in the 1997-2000 cycle.

Figure 9 Industry contributions to aggregate MFP growth, 1990-1997

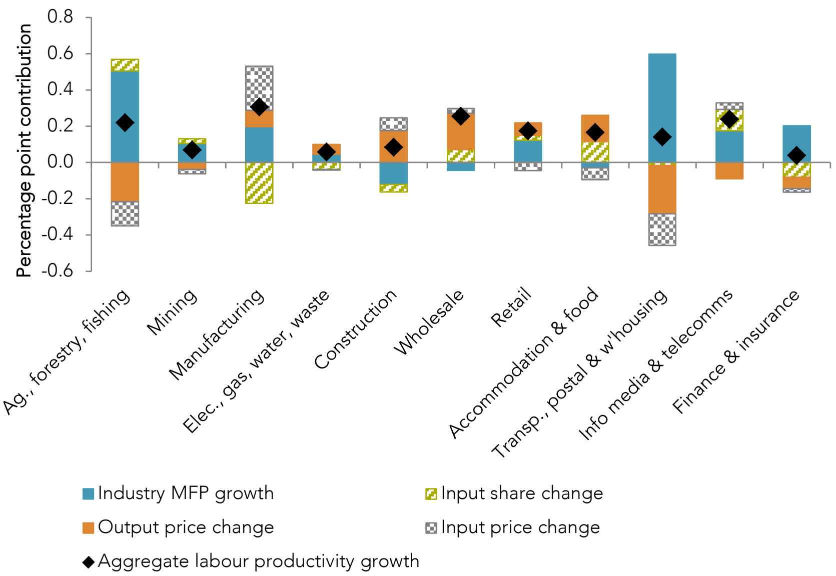


Figure 10 Industry contributions to aggregate MFP growth, 1997-2000

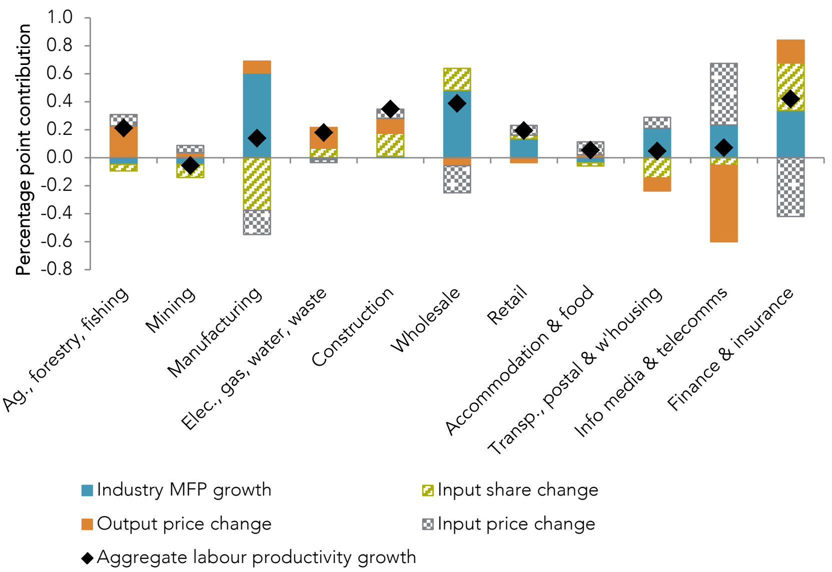
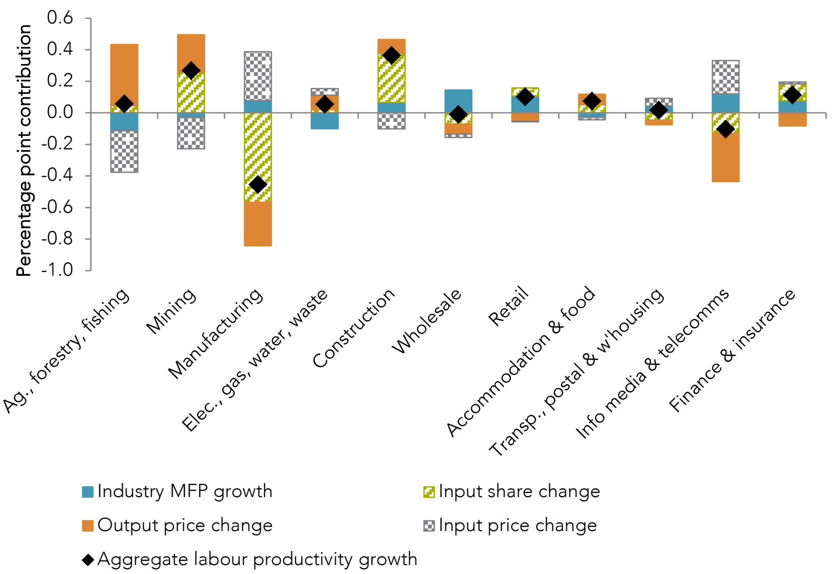


Figure 11 Industry contributions to aggregate MFP growth, 2000-2008



5 Conclusion

This note applies Diewert (2014a)'s method to decompose New Zealand's aggregate labour productivity and MFP growth. First, labour productivity growth is decomposed into three components: within-industry labour productivity growth, changes in industry labour input shares and changes in industry real output prices. As expected, the real output price change component nets out to close to zero in aggregate (Diewert, 2014b). Despite this, it is informative to look at all three components, including changes in real output prices, at the industry level.

Aggregate labour productivity growth in New Zealand was highest in the late 1980s and throughout the 1990s, with a considerable slowdown in growth in the 2000s. Consistent with Meehan (2014), within-industry labour productivity growth was a much larger component of aggregate labour productivity growth than changes in labour input shares. Over the whole 1978-2011 period, changes in the labour input shares reduced aggregate labour productivity growth, but only slightly. During the 1990s, changes in industry labour input shares made a more substantial negative contribution to aggregate labour productivity growth, particularly in the 1997-2000 period. Throughout the 2000-2008 period, the labour input share contribution was positive but small.

Across the whole 1978-2011 period, manufacturing made the largest contribution to the within-industry labour productivity component despite only modest growth in manufacturing's labour productivity growth due to the industry's large size. Conversely, information media & telecommunications, as a smaller industry, also made a large contribution due to its very high labour productivity growth rate.

Four industries had a decreasing share of labour input in the 1978-2011 period and therefore made a negative contribution to the labour input share change component: agriculture, forestry & fishing; manufacturing; transport, postal & warehousing; and information media & telecommunications Of the seven industries that made a positive contribution to the labour input share change component, accommodation & food services had by far the largest growth in labour input share but because this industry is small, its contribution was about the same as the construction, wholesale trade, retail trade and finance & insurance industries.

MFP growth is decomposed into four components: within-industry MFP growth, changes in industry combined (ie, capital and labour) input shares, changes in industry real output prices and changes in industry reciprocal real input prices. Although all but the within-industry MFP growth component almost nets out to zero in aggregate, it is still informative to look at the industry contributions to all four components.

Similar to aggregate labour productivity growth, aggregate MFP growth was also high in the 1990s. MFP growth was low in the late 1980s, suggesting that the high labour productivity growth in this period was due to capital deepening. There was also a substantial slowdown in MFP growth in the 2000s.

Over the whole 1978-2011 period, three industries made noticeably larger contributions to industry MFP growth than the other eight industries: agriculture, forestry & fishing; accommodation & food services; and information media & telecommunications. The biggest industry, manufacturing, made almost no contribution to the industry MFP growth component due to its negligible MFP growth rate.

Just three of the 11 industries made negative contributions to the combined input share component of MFP growth over the 1978-2011 period, with manufacturing the only industry making a sizable negative contribution. Most of the remaining industries made small positive contributions, with the exception of except for finance & insurance, contributed positively to the input share change component.

Manufacturing and information media & telecommunications both made sizable positive contributions to the *reciprocal* input price growth component of MFP growth. Agriculture, forestry & fishing and transport, postal and warehousing both made reasonable negative contributions to reciprocal input price growth, as reciprocal real input prices fell (ie, real input prices rose) in these two industries.

The most noticeable industry contribution to the output price change component for both labour productivity growth and MFP growth over the 1978-2011 period is information media & telecommunications. This industry's large negative contribution reflects a worldwide trend of substantial decreases in ICT product prices.

Even with the improved method of Diewert (2014a), there are still limits to industry decompositions. As discussed in Meehan (2014), each industry contains a diverse range of sub-industries, and each sub-industry has a distribution of firm productivities. To better understand firm-level reallocation and its contribution to productivity growth, the New Zealand Productivity Commission is undertaking micro-data research using Statistics New Zealand's longitudinal business database.[10]

[10] See Nolan (2014) for details of the Productivity Commission's research agenda.

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Appendix A Industry components over productivity growth cycles

This appendix provides figures of industry contributions to the components of MS-11 labour productivity growth and MFP growth for the productivity growth cycles that were not presented in Sections 4.1 and 4.2.

A.1 Industry contributions to aggregate labour productivity growth

Figure A.1 Industry contributions to aggregate labour productivity growth, 1978-1985

Figure A.2 Industry contributions to aggregate labour productivity growth, 1985-1990

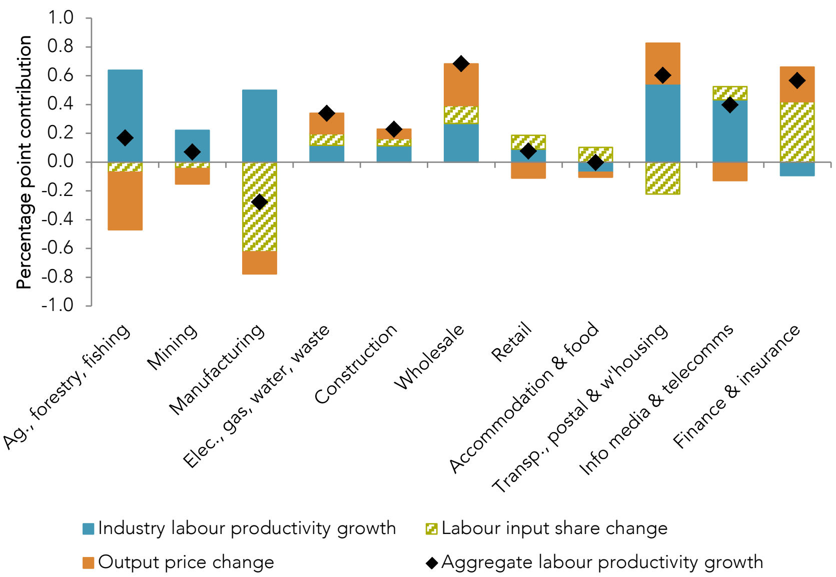


Figure A.3 Industry contributions to aggregate labour productivity growth, 1990-1997

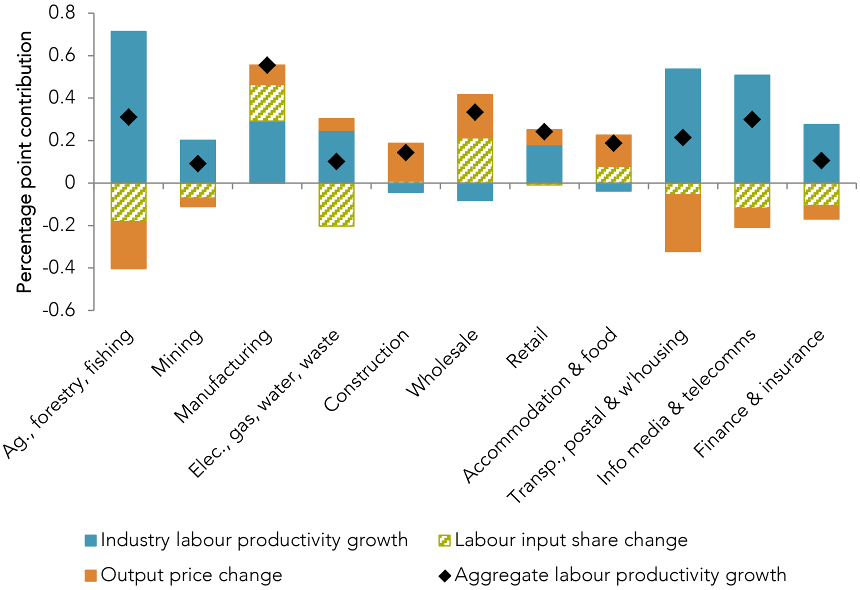
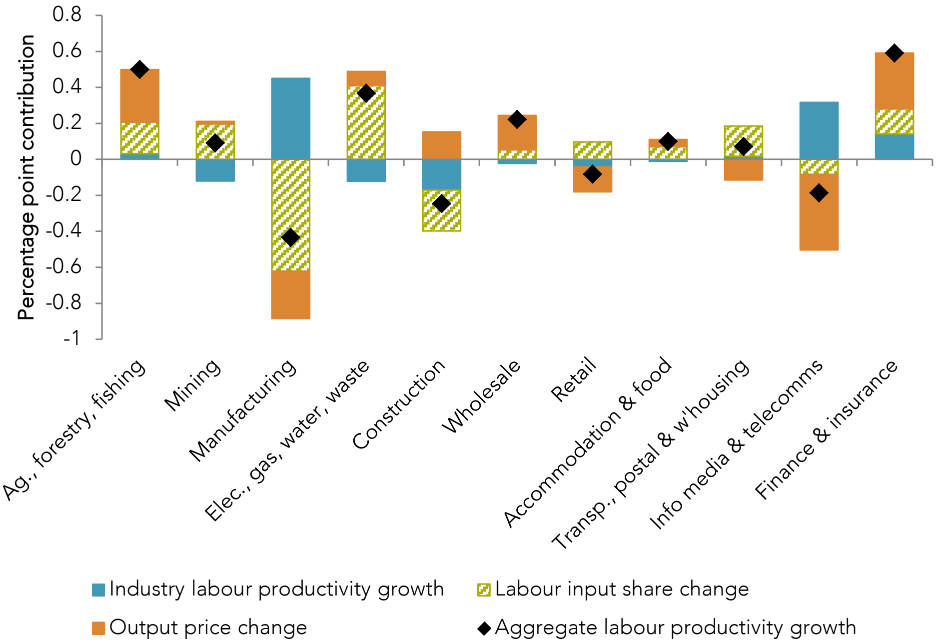


Figure A.4 Industry contributions to aggregate labour productivity growth, 2000-2008

Figure A.5 Industry contributions to aggregate labour productivity growth, 2008-2011



A.2 Industry contributions to aggregate MFP growth

Figure A.6 Industry contributions to aggregate MFP growth, 1978-1985

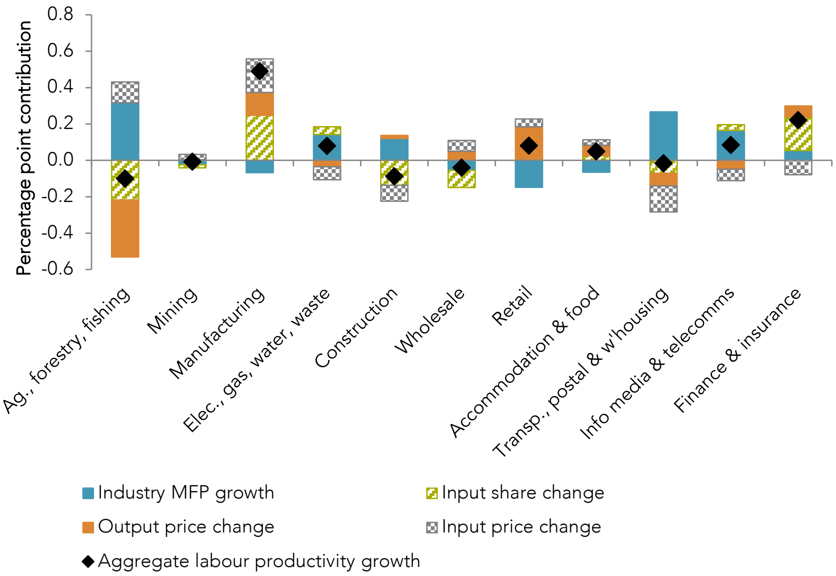


Figure A.7 Industry contributions to aggregate MFP growth, 1985-1990

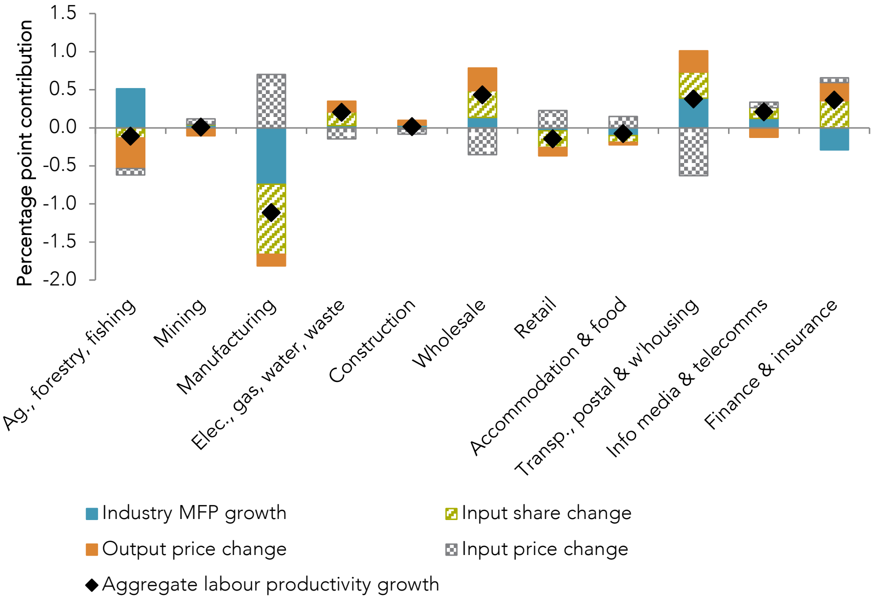


Figure A.8 Industry contributions to aggregate MFP growth, 2008-2011