Explaining the gaps in labour productivity in some developed countries

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Abstract:

Modern economic theories explain differences in productivity and economic growth across countries by differences in political and economic institutions, and differences in culture, geographical location, policies, and laws. The success of any of these theories in explaining the gap in productivity between any two countries depends on the countries in the sample. We argue in this paper that differences in the above variables might explain gaps in economic performance between developed and developing countries, but are too small to explain the productivity gaps between developed countries. We test this hypothesis for two pairs of developed neighbouring countries: New Zealand and Australia and Canada and the United States, hence New Zealand – Australia and Canada – United States. In this paper, more than eighty percent of labour productivity gaps between New Zealand and Australia and Canada and the United States are explained by endogenous technology shocks (TFP) and capital intensities.

Keywords: Labour Productivity, TFP, Real exchange rate
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1. Introduction

Productivity gaps between countries have always been an interesting problem for economists and policymakers. The literature is large and has several different strands. The neoclassical explanation of productivity gaps focuses on *exogenous* Total Factor Productivity shocks (TFP), for example see, Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), and Parente and Prescott (2000). Recently, Cordoba and Ripoll (2005) provide a model of *endogenous* TFP and show, analytically, that allowing for endogenous TFP increases the role of input factors, i.e., capital and labour, in explaining the gap in income between countries.

In endogenous growth model(s) economic institutions are cited as fundamental “causes” of cross-country differences in economic development because they influence economic outcomes by shaping economic incentives, e.g., Acemoglu *et al.* (2004), Diamond (1997) and Myrdal (1968) (for a literature review about the role of institutional differences, see for example, Nelson and Sampat, 2001).

Other strand of the literature related to the “New Economy” hypothesis focuses on the role of GPT, e.g., Helpman and Trajtenberg (1998) and Helpman (1999), and another focuses on the role of Information and Communications Technology, ICT (e.g., Basu *et al.* 2003) on TFP. They try to explain productivity gaps between the United States and the United Kingdom.[i]

In Helpman (1999), Lipsey *et al.* provides a discussion about the lagging pace of General Purpose Technology (GPT) growth in Canada relative to that of the United States and suggests that it can explain Canada’s poor productivity performance relative to the United States. Harris (2001) argued that the Canadian real exchange rate depreciation can explain gaps in labour productivity and provides empirical evidence for the case of Canada and United States.

Furthermore, Sachs (2000) argues that economic geography is a crucial explanatory factor of growth gaps. There is a new literature, where cross-country growth and productivity gaps are explained by differences in the legal systems, i.e., common versus civil laws, via their effect on the financial markets, see for example, Mahoney (2000), La Porta *et al.* (1998 and 1997) and King and Levine (1993).

Culture (e.g., religion, language etc.) that generates a set of beliefs, which emphasise thrift and saving, for example, affect economic development via the effect on the accumulation of capital as in Weber (1930), and Greif (1994). See Barro and McCleary (2003) and Tabellini (2005) for empirical evidence.

Economic institutions, geography, culture, etc. are undoubtedly plausible explanations for gaps in economic development say between a developed country, such as the United States, and a developing country like Morocco.

In this paper we argue that the above theories are more appropriate to explain the gap in productivity between developed and developing countries, but they cannot empirically explain a large portion of the productivity gap between developed countries.

To illustrate, think of New Zealand and Australia and Canada and the United States. Both New Zealand and Canada have poor productivity relative to their big neighbours Australia and the United States. We choose these two pairs of countries: New Zealand – Australia and Canada – United States because we could control for many of the variables mentioned above. These countries are highly developed; have similar cultures; language; and similar political and economic institutions.

They are among the world highly prosperous Western democracies. According to OECD they have relatively highly educated labour forces and flexible product and labour markets.

New Zealand, Australia and Canada have similar monetary policy framework, i.e., price stability, independent central banks etc, and the United States has a very similar monetary policy in the sense that the Fed also cares about price stability and it is independent. About 85 percent of the banking system in New Zealand is owned by Australians. Capital moves freely between New Zealand – Australia and Canada – United States, and in New Zealand – Australia, labour also moves freely.

New Zealand – Australia and Canada – United states are neighbours so geographically speaking they are equally distant from the rest of the world. The laws in New Zealand and Australia are pretty similar or at least have a similar origin – i.e., common law. We conjecture that a similar argument applies to Canada and United States and differences in the laws cannot possibly account for the large and persistent gap in labour productivity.

Canada – United States' differences in GPT investments might be big and could explain some of the productivity gap. However, Tullett *et al.* (2002) argue that New Zealand's ICT intensity (expenditures as a percent of GDP) is among the highest in the world, and ahead of Australia so it is possible that ICT and GPT can explain productivity gaps in developed countries on a case by a case basis.[ii]

Both New Zealand and Australia embarked on a wide reform process in the mid 1980s so we chose a post-reform sample.[iii] The sample is from 1989q1 – 2003q4. The period before the reform (1984) is irrelevant for the objective of this paper, i.e., we want to explain the gap in labour productivity that has occurred despite similar economic reforms in both countries. For Canada – United States we choose the period 1985q1-2004q4 because Canada experienced a lower labour productivity than the US in the 1990s and that is what we want to explain.

New Zealand has the "Closer Economic Relations" with Australia, which came into effect in 1983. However, it has developed overtime; for instance, services weren't incorporated into the agreement until 1988. The WTO considers CER to be the most comprehensive free trade agreement in the world. Canada and the United States signed a free trade agreement in 1989.

Section 2 provides stylised facts and outlines the problem. Section 3 discusses the model. Results of estimation are reported in sections 4. Conclusions are in section 5.

2. Stylized facts

All the data are found in the data appendices. Table 1 reports the PPP-adjusted data for New Zealand – Australia and Canada – United States.[iv] It decomposes real GDP per person into real GDP per hour-worked and hour-worked per person ($\frac{Y_t}{\hat{P}_t} = \frac{Y_t}{H_t}.\frac{H_t}{\hat{P}_t}$), where Y_t is real GDP, H_t is hour-worked and $\hat{P}_t$ is working age population.

Table 1 shows that real GDP per person is lower in New Zealand compared with Australia (73 percent of Australia's), thus, New Zealand is poorer. Real GDP per hour-worked is also lower in New Zealand (71 percent of Australia's) so New Zealanders are less productive than the Australians. Although New Zealand's productivity might have improved relative to its own past history (i.e., after the reform in 1984), its income remained low relative to Australia because Australia has been even more productive.

Similarly, Canada's PPP-adjusted GDP per person is smaller than that of the US (71 percent of the United States') and GDP per hour-worked is substantially lower than that of the United States (67 percent of the United States'). Interestingly, both New Zealanders and Canadians work only slightly longer hours than their next doors' neighbours over the two samples. Also, relative GDP per person and GDP per hour in the case of Canada – United States are more variable (i.e., larger standard deviations) than those of New Zealand – Australia.

There is a widespread belief among New Zealanders that the Australian's productivity superiority is due to having a vast mining industry, which has a huge capital investments and hence, a higher marginal product of labour, e.g., Matheson and Oxley (2004). Table 2 reports the same decomposition of table 1 for New Zealand and Australia, except that GDP of the mining industry is removed from the Australian GDP. Clearly, removing the Australian mining industry makes only a small difference. Table 3 shows that mining is not an issue for the growth rate of the gap in GDP per hour-worked in New Zealand – Australia case. The mean and the standard deviation of the productivity gap (GDP per hour-worked) growth rate are identical.

3. The model

We use simple neoclassical production functions for tradables and nontradables:

1 $$Y_t^T = A_t^T \mathrm{K}(K_t^T, H_t^T),$$

2 $$Y_t^N = A_t^N G(K_t^N, H_t^N),$$

The superscripts T and N denote tradables and nontradables respectively. where Y_t is real output, K_t is the stock of capital, H_t is hour-worked, and A_t^T is a technology shock to tradables, TFP and A_t^N is technology shocks to nontradables. To keep things simple, it is assumed that there are no intermediate inputs in production. Normalizing by H_t :

3 $$\frac{Y_t^T}{H_t^T} = A_t^T \mathrm{K}(\frac{K_t^T}{H_t^T},1)$$

4 $$\frac{Y_t^N}{H_t^N} = A_t^N G(\frac{K_t^N}{H_t^N},1)$$

Taking logs –lower-case:

5 $$(y-h)_t^T = a_t^T + \kappa(k-h)_t^T$$

6 $$(y-h)_t^N = a_t^N + g(k-h)_t^N$$

Summing (5) and (6) gives us:

7 $$(y-h)_t = (a_t^T + a_t^N) + F(k-h)_t,$$

where $(y-h)_t$ and $(k-h)_t$ are the aggregates including both tradables and nontradables. TFP in tradables and nontradables are left separated. Thus, the gap in GDP per hour-worked or the gap in labour productivity is a function of the TFP shocks in tradables and nontradables, and the gap in capital intensity.

The foreign country has the same functions, where f denotes foreign country.

$$8 \quad (y-h)_t^f = (a_t^{Tf} + a_t^{Nf}) + F^f (k-h)_t^f$$

Subtracting (8) from (7) and letting double prime on the variables denote the gaps between the home and the foreign magnitudes. We arrive at:

$$9 \quad (y-h)_t'' = (a_t''^T + a_t''^N) + F''(k-h)_t''$$

In this paper, TFP in tradables and nontradables are endogenous and depend on a variety of variables linearly. TFP in tradables at home, abroad and the gap are given by the linear functions:

$$10 \quad a_t^T = \Gamma(\mu_t, \psi_t, o_t, \alpha_t) + \varepsilon_t^T$$
$$10' \quad a_t^{Tf} = \Gamma^f(\mu_t^f, \psi_t^f, o_t^f, \alpha_t^f) + \varepsilon_t^{Tf}$$
$$10'' \quad a_t''^T = \Gamma''(\mu_t'', \psi_t'', o_t'', \alpha_t'') + \varepsilon_t''^T$$

Where μ denotes manufacturing; ψ denotes the stock of knowledge; o denotes openness; and α denotes aging. We explain the hypotheses underlying the choice of these variables.[v]

Manufacturing: The relationship between manufacturing output and productivity is known as the Verdoorn's Law (1949). It says that there is a strong statistical relationship between manufacturing *output* and labour productivity and that causality runs from the former to the latter. This is usually interpreted as evidence of increasing returns to scale. Arrow (1964) cited The Verdoorn's Law and recently, McCombie *et al* (2002) provides a collection of articles on this relationship. See Libanio's book review in the Economic Journal (2005). This is also consistent with Delong and Summers (1991), where they document a robust relationship between productivity growth and changes in the stock of capital machinery and equipment in the United States.

Manufacturing and industrialisation are usually perceived as processes associated with industries like steel, cement, cars…etc with their negative environmental and social consequences. However, there is a lot of productivity gains associated with manufacturing, whether it is old or new. Today, most industrial nations think of new and green manufacturing, where production involves lots of R&D and human capitals in addition to capital and labour intensities. The future is for this *new* type of manufacturing, which is environmentally friendly, smart, and involves a lot of R&D and human capitals. Countries which seek growth and productivity gains are willing to leap and skip steps directly into new manufacturing. New Zealand, for example, have potentials to produce new goods and services along these lines, e.g., fuel from sheep manures (there are more than 40 million sheep in New Zealand); a new generation of healthy dairy products with medicinal properties; marine products; marine drugs and bio-technology; wine; movies and related fields etc, which are *new* goods and services with potentially very large productivity gains.

A variable that best proxy manufacturing is the stock of manufacturing. It is defined as the sum of stocks of materials and finished goods on the factory floor including work in progress. Goods and Services Taxes (G.S.T.) are excluded. A country that exports furniture, for example, would have timber, processed timber, and furniture in its stock of manufacturing while a country that exports timber will have nothing on its manufacturing floor.

Knowledge: The relationship between knowledge and productivity us well understood in economics. For theoretical models see for example, Barro and Sala-i-Martin (1995), Grossman and Helpman (1991) and Aghion and Howitt (1992) for growth models that include R&D spillovers. Romer (1986) and Lucas (1988), Mankiw *et al.* (1992) and Rangazas (2005) are examples, where technical progress occurs in human capital (the level and the growth rate), and is very similar to R&D. For empirical literature see Wieser (2004) for a survey of the literature at the micro-level. The stock of R&D is a widely used proxy for knowledge.

Openness: Economic theory is not ambiguous about the effect if trade on economic growth. There is a positive relationship. At the micro-level, the hypothesis is that openness or increasing trade would expose local firms to foreign competition, which forces weak unproductive ones to exit and strong ones to expand and prosper. Also, openness brings with it foreign goods, which embodies foreign R&D technologies and there might be positive spillovers into domestic production.[vi] There are measurement issues and openness could be measured in a variety of ways. In this paper we use a common measure of openness: Total trade (sum of exports and imports) as a percentage of GDP is used as measure of openness.

Aging: It affects technical progress by affecting the relationship between workers and technology, i.e., use, adoption and creation of new technologies along the growth and development process, where old jobs are destructed and new ones are created continuously. A commonly stated hypothesis that older workers resist changes and fight against new ideas and technologies and thus adversely affect labour productivity growth, is tested.[vii] There are, however, other hypotheses, where older workers might be more experienced, loyal etc and thus, have positive effect on productivity of the firm. The literature stretches across various disciplines. The empirical evidence is mixed. In this paper we measure the aging gap as the gap between employed workers age 55+ to total labour force in the two countries.

There is another important aspect of the aging data in New Zealand. Davey (p.46, 2003) reports that 1/3 of the people aged over 50 have no qualifications and the educational achievement declines with age. In the past, the proportion of workers with no formal qualification was quite substantial, 30 percent in 1985. However, this percentage has been falling over time. It is 18 percent in 2003. Unfortunately, similar data for Australia are not readily available.[viii]

The variables μ_t, μ_t^f, ψ_t, ψ_t^f o_t, o_t^f, α_t and α_t^f are assumed to follow a random walk processes with drift. It is assumed that the foreign country has a similar model in specifications and parameters and only differs in the realization of the shocks. This implies that the two country's growth rates can differ in the short-run and converge in the long run.

Similarly, a_t^N and a_t^{Nf} are assumed to be functions of productivity in the services industries, and that these service productivity data are random walk with drift. It is further assumed that productivity in the service sector is measured with error.[ix] Substituting back in (9) and assign some parameters, we get:

11 $$(y-h)_t'' = \beta(k-h)_t'' + [\pi_1\mu_{t-1}'' + \pi_2\psi_{t-1}'' + \pi_3 o_{t-1}'' + \pi_4\alpha_{t-1}''] + \theta\, sr_{t-1}'' + u_t''$$

Where u_t'' is a composite error term that is also iid .

In terms of growth rates,

12 $$\Delta a_t'' = \Delta v_t''$$

and

13 $\Delta(y-h)''_t = \beta\Delta(k-h)''_t + [\pi_1\Delta v''_{\mu,t} + \pi_2\Delta v''_{\kappa,t} + \pi_3\Delta v''_{o,t} + \pi_4\Delta v''_{\alpha,t}] + \theta\Delta v''_{sr,t} + \Delta u''_t$

Thus, labour productivity gap is a function of (1) capital intensity gap $(k-h)''_t$, where we expect $\beta > 0$ and (2) TFP shocks in tradables and nontradables at home and abroad. The variables $\Delta v''_{\mu,t} \ldots \Delta v''_{\alpha,t}$ are the shocks to the gap in manufacturing stock, gap in knowledge, the gap in the degree of openness and the gap in aging of the labour force. The model predicts that TFP in tradables drives labour productivity, and that countries become richer mostly through improvements in productivity in tradables. The model predicts that all coefficients to have positive signs, i.e.,$\pi_1 > 0$, $\pi_2 > 0$, $\pi_3 > 0$, $\pi_4 > ?$ and $\theta > 0$. The coefficient π_4 (the shock to aging) might have an ambiguous sign.

All data are plotted and fully defined in the appendix 1 and 2. In the appendix we examine the time series properties of data, i.e., test for unit root. We used a variety of time series tests for unit root with different specifications (see appendix for details). The hypothesis of unit root could not be rejected for the gaps in the levels, but easily rejected in the growth rates. We have no theory for cointegration. In other words, there is no a priori reason to expect the gap in labour productivity between two countries to be cointegrated with gaps in aging or openness etc.

Note that the plotted real exchange rate is the inverse of the real exchange rate used in the regressions later for illustrative purpose. In the plots, an increase in the real exchange rate denotes an appreciation. In the regressions, an increase in the real exchange rate denotes depreciation. The data are PPP-Adjusted. We do not have adequate data for human capital stock and for this reason we drop it from estimation.

4. Estimation and results

4.1. New Zealand – Australia

We begin with estimating a single equation model in both the level and the growth rate.[x]

Two estimators are used, OLS and GMM (Generalised Method of Moments).[xi] There are a few good reasons to use GMM. First, it is appropriate because the RHS variables are not strictly exogenous. Second, it is flexible in the sense that it will not require a priori assumptions about the errors terms. Third, Instrumental Variable estimators in general are more appropriate for models where variables are measured with errors. Fourth, the true data-generating process is unknown to fully trust FIML so GMM is the second best choice. The drawback for GMM is that there are no good instruments. For instruments, lags of the regressors and a constant are used.[xii]

Visually examining the data in appendix 1 shows that productivity gap is highly correlated with the real exchange rates, the gap in capital stocks, the gap in manufacturing stocks and in R&D gaps. This is true in the levels and in growth rates. This is also true for the Canada-United States data.

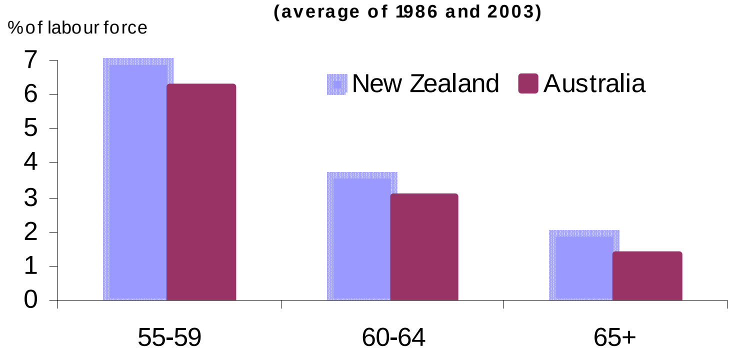
Single-equation regressions are reported in table 4.[xiii] All the regressions include lagged dependent variable. The gap in capital intensity is statistically significant and has a positive sign in all four regressions. The magnitude of coefficient is the same in three regressions; GMM in the level, GMM in the growth rate, and OLS in the growth rate. The coefficient is smaller in OLS level regression. A similar result is obtained for the gap in the manufacturing stock. For the gap in R&D, the parameter estimates are positive and highly significant in all regressions. The magnitudes vary slightly across estimators. These three variables seem to have most of the explanatory power.

The parameter estimate for openness is insignificant in all four regressions and in the level regressions the coefficients have negative signs. But one would not have guessed this from visual inspection of the data in figures a21 and a22. These results are not surprising since the empirical literature provides no or very little evidence for association between openness measured by export plus imports as a percentage of GDP and GDP growth in cross-sectional growth regressions.

The majority of the evidence in the literature is cross-section. Rodriguez and Rodrik (2001) and Rodriguez (2006) examine the international evidence carefully and show that measurements of openness and methods of estimation are the main reasons for obtaining different results in growth regressions. They argue strongly that no significant statistical relationship is found between openness and growth in cross-sectional growth regressions. We will further discuss this issue in the next section and show that this may not be necessarily true in general.

The effect of aging is positive. We argued that the international evidence is mixed. The effect seems to be statistically significant in the level regressions with significantly different magnitudes. It is insignificant in the growth rate regressions. Note that in figure a17, New Zealand has more workers age 55 and over in the labour force than Australia. The trend is positive. The growth rate of this variable is constant. To shed more light on this figure 1 is an age profile for New Zealand and Australia. On average over the period 1986-2003, Australia's share of older workers in the labour force is smaller for all ages over 55. The Australians retire at age 55.

Figure 1: Age profile of the labour force (average of 1986 and 2003)



Services productivity, which is a proxy for productivity in nontradables is negative and only significant in the growth rate regressions. This coefficient has the wrong sign. It is either because the equation is misspecified in this variable or the measurement of the variable caused the sign reversal. We suspect that measurement is an issue.

The residuals are thoroughly tested for serial correlation and normality using a battery of tests. We found no evidence of serial correlation and they appear to be normal.[xiv] The goodness of fit is not very high in GMM regressions, but 80 percent of the variations in the productivity gap are explained by OLS and FIML. Next, we will provide more evidence by considering the joint effect of effect of TFP shocks on the real exchange rate and labour productivity.

4.2. Productivity and the real exchange rate

A few Canadian papers associate the gap in productivity between Canada and the United States with the real depreciation of the Canadian dollar. Harris (2001) argues that causality runs from the real exchange rate to productivity. He explains why Canada's productivity is lower than that of the United States by estimating a productivity convergence equation, where changes in productivity in industry i in country c at time t depends on country and industry fixed effects and a set of explanatory variables such as R&D investments, human capital intensity, openness, and trade specialisation in addition to the real exchange rate.

There are a few hypotheses, where real depreciations increase the cost of imported capital equipments and R&D, affect exports then output, or induce firms to substitute investments in R&D with output-expanding activities. He finds evidence that real depreciation affects productivity growth. Sustained real deprecations have negative effects for the long term productivity growth.

Visual examination of the data plotted in figures a1-a4 confirms a high correlation between productivity and the real exchange rate. Running a regression of productivity on the real exchange (in level or in differences) or vice-versa confirms the existence of the observed high correlation in the data. However, we will argue in this paper that causality probably runs both ways and that both labour productivity and the real exchange rate are highly correlated because they are driven by a third variable: TFP shocks.

The real exchange rate (the relative price of nontradables) and relative productivity are related via the HBS effect. Given the production functions in tradables and nontradables the representative firm maximises its intertemporal profit, which is given by:

14 $$Max\int_0^{\infty}[Y_t^T(K_t^T,H_t^T)+PY_t^N(K_t^N,H_t^N)-W_tH_t-I_t)e^{-Rt}dt$$

subject to:

15 $$\Delta K_{t+1}=I_t-\delta K_t$$

The variables are the same that we defined earlier, P_t is the relative price of non-tradables in terms of tradables; W_t is the wage rate, which equalises across tradables and nontradables overtime; the aggregate labour supply is the sum of H_t^T and H_t^N; I_t is investment; R_t is the foreign real interest rate and δ is the depreciation rate of capital. In equilibrium, we get the typical FOC:

16 $$\partial Y_t^T/\partial K_t^T = P_t(\partial Y_t^N/K_t^N)=R_r$$

17 $$P_t(\partial Y_t^N/\partial H_t^N)=\partial Y_t^T/\partial H_t^T = W_t$$

18 $$\lambda=1$$

Thus, the relative price of nontradables is equal to the ratio of the marginal product of labour in tradables and nontradables, i.e., relative productivity:

19 $$P_t=(\partial Y_t^T/\partial H_t^T)/(\partial Y_t^N/\partial H_t^N)$$

Given that the log real exchange ($q_t = s_t + p_t^* - p_t$) is also the relative price of nontradables, the general price levels p_t^* and p_t are linear combinations of tradables and nontradables prices, and Purchasing Power Parity (PPP) holds, the HBS is typically expressed as follows:

20 $q_t = \tau(a''^T_t - a''^N_t) + \xi_t$

And $\tau < 0$, which implies that the home country will experience real appreciation, i.e., a rise in its relative price of nontradables, if its technical progress (TFP) in tradables exceeds its technical progress (TFP) in nontradables.

We substitute for the technology shocks gaps in the real exchange rate equation above and maintain the assumption that nontradables productivity is approximated by service sector productivity, which is observed with error as described earlier; we arrive at:

21 $q = \tau[\pi_1\mu''_{t-1} + \pi_2\psi''_{t-1} + \pi_3 o''_{t-1} + \pi_4\alpha''_{t-1} - \theta sr''_{t-1}] + \xi_t$

The relative price of nontradable is driven by the same TFP shocks that drive labour productivity. Given the way we measure the real exchange rate, τ is expected to have a negative sign, i.e., an increase in TFP shocks in the tradable sector appreciates the real exchange rate.

The real depreciation rate is:

22 $\Delta q_t = \tau[\pi_1\Delta v''_{\mu,t} + \pi_2\Delta v''_{\kappa,t} + \pi_3\Delta v''_{o,t} + \pi_4\Delta v''_{\alpha,t} - \theta\,\Delta v''_{sr,t}] + \Delta\xi_t$

The cross-equation restrictions in equations (13) and (22) suggest that the coefficients π_1 to π_4 are the same with opposite signs.

The empirical literature and evidence for HBS effect is mixed.[xv] Rogoff (1992) noted that most of the evidence in favour of the HBS effect was found in countries that have closed capital markets. None of the countries in our sample has a closed capital market. Effects of government expenditures, oil prices and the term of trade as additional explanatory variables in the Harrod – Balassa – Samuelson equation are also mixed.

New Zealand – Australia: We start testing the New Zealand – Australia data. We estimate unrestricted two-equation system. We are more interested in the growth regressions than the levels because of the time series property of the data. But we also estimated the model in levels. We don't report the results to save space, but they are available upon request.[xvi]

We follow the same estimation strategy. We estimate an unrestricted system in growth rates. We test the restriction that the four coefficients of the shocks to the stock of manufacturing, shocks to R&D stock, openness shocks and ageing shocks are the same in the productivity gap equation and the real depreciation equation. The coefficients are expected to have same magnitudes, but differ in the sign. Results are reported in table 5.

In the GMM regression, the restriction that the R&D shock has the same magnitude in the productivity gap and the real exchange rate equations is rejected. The P value of the Wald test statistic is 0.00. Also, the restriction that the coefficients of the services productivity in the two equations are equal is rejected. In the FIML regression, the restriction that the coefficient of the aging shock is equal in both equations is rejected. The P value of the Wald test statistic is 0.0016. All other restrictions seem to hold.

In table 6 the estimation results of the restricted system in growth rates are reported. We imposed the restrictions that passed the tests in table 5 on the system. The capital intensity gap has significant, positive and robust coefficients across estimators. The magnitudes of the coefficients are 0.25 and 0.19 for GMM and FIML respectively.

Shocks to the manufacturing stock have the expected positive signs and the coefficient estimates are 0.19 and 0.20 in GMM and FIML respectively. Knowledge shocks proxied by R&D stocks enter with two different coefficients in the GMM regression. In the productivity gap equation the coefficient is 0.27, positive and significant. In the real exchange rate equation it is insignificant. In FIML, the restriction is imposed and the coefficient estimate is 0.25 and significant.

Openness shocks are insignificant. We got the same result in the single-equation regression earlier. Trade gaps measuring the degree of openness have no direct impact on labour productivity. What matters for productivity is perhaps the domestic value added of exports per unit of output. Data are not readily available and this might be a subject for future research.

Aging has a significant negative effect on labour productivity with a coefficient 0.14 in GMM. In FIML, the restriction that aging affects both labour productivity and the real depreciation rate is not imposed. The coefficient π_{14} has a negative sign, but insignificant. However, π_{24} is large 0.35 and positive, which along with τ being negative implies that aging appreciate the real exchange rate. We don't have an obvious explanation to this result.

In GMM, we don't impose any restrictions on productivity in nontradables so we have two coefficients θ_{11} and θ_{21}. Nontradables productivity seems to have a significant negative impact on labour productivity and no impact on the real exchange rate. The size of θ_{11} is 0.60, which is much larger than all other coefficients in the model. In FIML, the restriction that the two coefficients are the same is imposed. It turned out that the sign is negative, but the coefficient is insignificant.[xvii]

In the real depreciation equation, the coefficient τ is negative as expected. The coefficient estimate is also highly significant in both the GMM and FIML regressions. The negative sign along with the positive signs of the coefficients of $\Delta v''_{\mu,t}$ and $\Delta v''_{\psi,t}$ implies that an increase in the shocks to manufacturing stocks and R&D stocks appreciate the real exchange rate, which is difficult to explain. Aging appreciates the real exchange rate, which is not intuitive. An increase in the nontradables shock proxied by services has no effect on the real exchange rate and this is consistent with international evidence and most likely due to measurement problems. The real depreciation rate is highly persistent.

Canada – United States: Again, we estimated unrestricted two-equation system in the levels for Canada – United States. We don't report the results to save space, but we tested the restriction on the coefficients.[xviii]

We then estimated unrestricted system in growth rates and tested the same restrictions we tested earlier in the New Zealand – Australia case. We report the Wald test statistics in table 7. All restrictions hold in the GMM regression. In FIML, only one restriction is rejected; aging seems to enter separately in the productivity gap and the real depreciation rate equations. The P-value of the Wald test statistic is 0.0130 in FIML. These are more reasonable results than the ones we obtained earlier in the case of New Zealand – Australia.

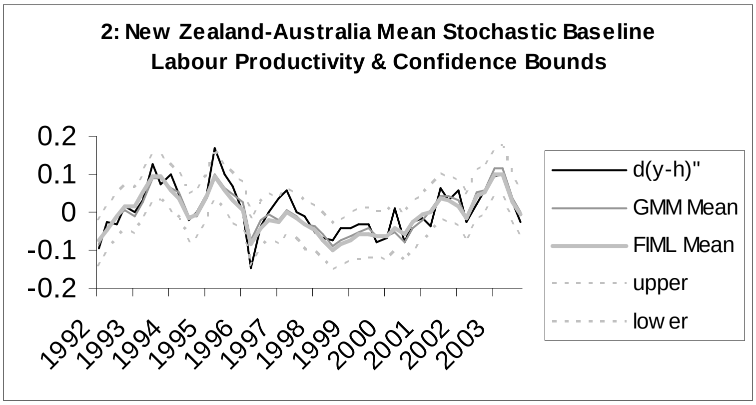
We then impose these restrictions and estimate the system. Results are in table 8. Labour productivity is more persistent, with coefficient of the lagged dependent variable ranging between 0.51 and 0.45 compared with 0.06 in New Zealand –Australia data. In GMM, all variables are statistically significant and have the predicted signs. The capital intensity gap has a coefficient estimate of 0.15 and 0.11 in GMM and FIML respectively. The sizes of these coefficients are smaller than the ones in the New Zealand – Australia case, 0.27 and 0.19 respectively.

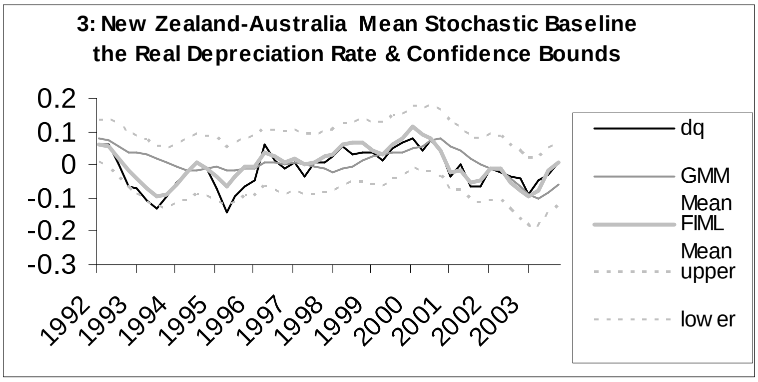
Shocks to the stock of manufacturing and the stock of R&D have similar magnitudes to those in the New Zealand –Australia data. However, unlike the case in the New Zealand – Australia case, openness shocks are positive and significant with large coefficients in GMM and FIML. Ageing shocks are negative and significant in GMM. In FIML, aging enters with two separate coefficients in the productivity gap and the real depreciation equations. It is negative, but insignificant in the productivity gap equation. It is insignificant in the real depreciation equation. The real depreciation rate is also highly persistent. The Canada – United States data seem to fit the model pretty well.

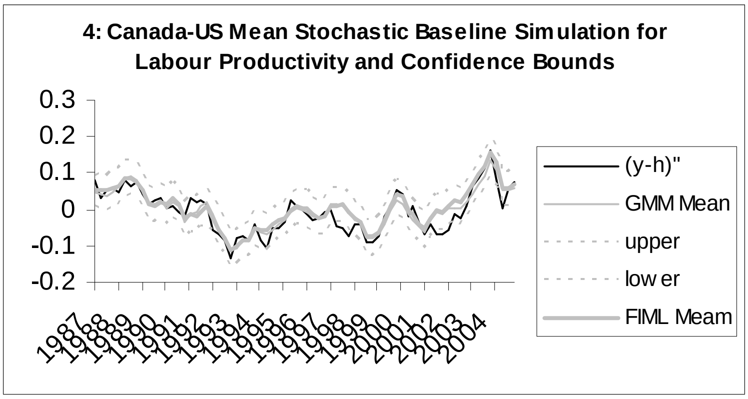
Services productivity has the expected positive sign and significant in both GMM and FIML. It means it positively affects labour productivity and because τ is negative it means that it appreciate the real exchange rate, which is inconsistent with the Harrod – Balassa – Samuelson theory. Again, these results are consistent with international evidence.

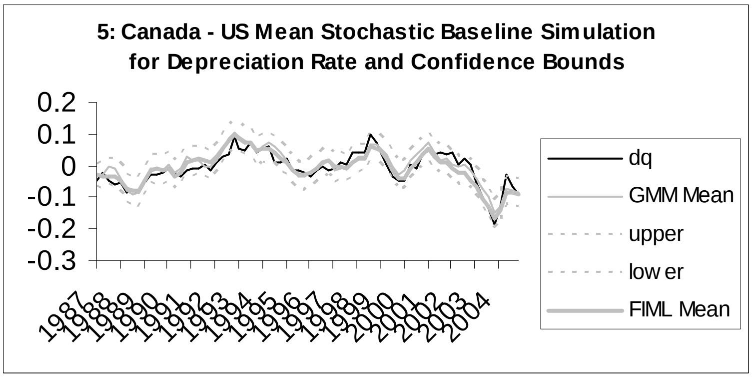
We thoroughly test the residuals of each equation using a variety of tests for whiteness such as the Fisher-Kappa and the Bartlett – Kolomogrove – Smirnov tests in the frequency domain even though the Newey-West procedure is used to estimate a consistent variance-covariance matrix, thus serial correlation and heteroscedasticity-robust estimates. The R^2 statistics of the individual equations are pretty high ranging from about 0.76 to 0.90.
To assess the goodness of fit further stochastic simulation is used to assess the goodness of fit for both the New Zealand – Australia and Canada-United States systems. The two-equation system is solved forward and backward over the sample periods. A Monte Carlo simulation solved the model 10,000 times using random shocks and generated distributions for the two endogenous variables in the model. The method is Gauss-Seidel. Initial starting values are last period's solutions, not actual. At each observation of a stochastic simulation, a set of independent random draws are taken from the standard distribution. These numbers are multiplied by Cholesky factor of the co-variance matrix. Confidence bounds are sample quantile estimates of the underlying distribution computed not from the entire sample, but using Jain and Chlamtac (1985) to conserve on memory use and with 10,000 repetitions. The tails of the distributions are pretty well estimated.

The plots 2 to 5 are the actual GDP per hour-worked gap and the real deprecation rate against the mean stochastic baseline solutions and the confidence bounds. The actual data are plotted in solid black lines. The mean stochastic baseline solution from GMM is in a light grey colour and that from FIML is in a thick grey colour. I also plot the average of the upper and lower confidence bands from GMM and FIML. These are plotted in the same colour, but the lines are dotted. In the case of New Zealand – Australia, TPF shocks – condition on capital per hour – explain about 80 percent of labour productivity growth gaps and 60 percent of the real depreciation rate. FIML fits the data better; TFP explains about 80 percent of labour productivity growth gaps and more than 80 percent of the real depreciation rate. In the Canada – United States data, more than 80 percent and close to 90 percent of data are explained by TFP shocks.









5. Conclusions

There are many different economic theories to explain economic growth and productivity gaps across countries. While many economists showed that exogenous TFP shocks can explain differences in labour productivity others cited institutional differences as the main variables to explain cross-country differences. Still others suggested differences in laws and cultures as the main explanatory variables for cross-country persistent gaps in productivity. Geography is also cited as a crucial variable. Others attempted to explain differences in productivity between countries by differences in GPT (General Purpose Technology) and ICT (Information and Communication Technology) gaps for the cases of the United Kingdom – United States and Canada – United States. Finally, the real exchange rate was cited as the variable that explains the Canadian – United States productivity differences.

There is a web of specifications and estimation issues in these literatures. The definition and measurement of productivity varies from one paper to another. Even when the relationship between productivity and the real exchange rate is the main issue (i.e., Harrod –Balassa – Samuelson) it is not clear whether productivity is labour productivity or TFP.

While it is highly conceivable that differences in institutions, culture, laws, and geography can explain productivity differentials between developed and developing countries they are too small to explain productivity differentials between two neighbouring fully developed industrial countries like New Zealand and Australia and Canada and the United States. There must be a large gap in ICT and GPT between the United States and all other developed Western industrial countries in the 1990's, but Prescott (1997) argues convincingly that the home country need not be the centre of R&D in the world nor need to have massive R&D infrastructures to support growth in productivity because openness ensures that the small country can adopt certain foreign technologies. New Zealand, for example, is on the top of the OECD countries in the expenditures and use of ICT and it is hard to argue that there are large differences between New Zealand and Australia's institutions, culture, laws, distance from the rest of the world to explain the persistent gap in productivity.

To explain the gaps in labour productivity between New Zealand and Australia I use a simple neoclassical production function approach, where GDP per hour-worked is a function of capital intensity (capital per hour-worked or capital per unit of output) and technical progress, TFP. The real exchange rate is a function of TFP differential in tradables at home and abroad and TFP differential in nontradables at home and abroad. In this model TFP is endogenous, and modelled as a linear function of the stock of manufacturing, the stock of knowledge proxied by R&D stock, the degree of openness measured as the sum of imports and exports as a percent of GDP and ageing, measured by of employed workers aged 55 and more as a percent of the labour force.

The relationship between manufacturing and productivity goes back to the Verdoorn's Law cited in Arraw (1964) classic paper on learning-by-doing and consistent with Delong and Summers (1991) – increasing returns to scale. R&D stocks is a familiar proxy for knowledge in economic literature, and openness is said to enhance productivity because competition with foreign firms and imported products that embody foreign R&D forces less productive firms either to exit or to work hard to compete. Older labour force is less adoptive to new technologies and hence less productive. These variables are assumed to follow random walk with drifts. It is also assumed that the foreign country has a similar model in specifications and parameters and only differs in the realization of the shocks.

Because the real depreciation rate – the relative price of nontradables – is also a function of the same variables, TFP shocks drive both, the growth rate of labour productivity gap and the real exchange depreciation rate with appropriate and testable cross-equation restrictions.

The two-equation system model is estimated for New Zealand – Australia (1989q1-2003q4) and Canada – United States (1985q1-2004q4). The model fits the data well, especially in the Canada – United State case, where most of the predictions of the model seem to hold. Stochastic simulation indicates that it explains between 80-90 percent of the growth rate gaps in labour productivity and the depreciation rates in the four countries. The cross-equation restrictions implied by the model hold well. Given that TFP shocks can explain 80-90 percent of the real exchange rate depreciation rate, no attempt was made to test the effect of demand side variables on the real exchange depreciation rate.

We conclude that (1) gaps in growth rates of labour productivity measured in terms of real GDP per hour-worked and the real exchange depreciation rate – are driven by the same random TFP shocks and ought to be modelled and estimated jointly as a system with appropriate and testable cross-equation restrictions. Hence, there is evidence for the HBS effect; (2) TFP is endogenous and it depends on many variables important among them are the gap in the stock of manufacturing, which we proxy by the stocks of manufacturing and knowledge, which is proxied by the stock of R&D, the degree of openness measured as the share of imports plus exports in GDP and ageing, which we proxy by employed workers 55 and over as a percentage of total labour force; (3) mixed evidence is found in favour of openness. It does not seem to explain labour productivity gaps between New Zealand and Australia, but it does for Canada and the United States. This issue has not been resolved in cross-country regressions and it seems to be evidence on a case-by-case situations. Further research is needed. (4) Ageing is found to have a negative effect on labour productivity in the Canada-United States and New Zealand-Australia data. But the level of significance is higher in the former than the latter. It reduces labour productivity.

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Table 1: GDP per person decomposition

	GDP per person	GDP per hour worked	Hour per person
	PPP adjusted (GDP) 1989q1-2003q4		
Australia	100	100	100
New Zealand	73.6	71.7	105.7
Standard Deviation	5.0	4.3	3.7
PPP adjusted (GDP) 1985q1-2004q4			
United States	100	100	100
Canada	71.4	67.2	106.4
Standard Deviation	9.9	9.5	3.8

1. Person is working age population 15-64
2. Prices are GDP deflators in the case of New Zealand – Australia and CPI in the case of Canada – United States.
3. PPP is measured as $s_t\, p_t^* / p_t$, where p_t^* is the foreign country prices index, s_t is the spot exchange rate defined such that an increase means appreciation, and p_t is the home country price index. The home countries are New Zealand and Canada respectively and the foreign countries are Australia and the United States.
4. For New Zealand and Australia, the sample is chosen because the period before 1989 is not relevant for analysis. New Zealand in particular started a comprehensive reform process in the mid 1980s; Australia started a little earlier. We also wanted to avoid high variability in the data, which is related directly to changes in policy and the reform process. In the econometric analysis which will follow the sample will even be shorter.

Table 2: GDP per person decomposition–without the Australian Mining Sector
Averages over the period 1989-2003

	GDP per person	GDP per hour worked	Hour per person [a]
	PPP adjusted (GDP)		
Australia	100	100	100
New Zealand	77	75	105.7
Standard Deviation	5.2	4.5	3.7

a Similar results are obtained if we use employment instead of population.

Table 3: GDP per Hour Worked (New Zealand – Australia gap) Growth Rate
Averages over the period 1989-2003

	With Mining	Without Mining
Mean	0.000790	0.000940
Standard Deviation	0.06	0.06

Table 4: Estimates of a single-equation model for New Zealand – Australia
Effective Sample is March 1992 – December 2003

$(y-h)''_t = \delta(y-h)''_{t-1} + \beta(k-h)''_t + \pi_1\mu''_t + \pi_2\psi''_t + \pi_3 o''_t + \pi_4\alpha''_t + \theta sr''_t + u''_t$					$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\Delta(k-h)''_t + \pi_1\Delta v''_{\mu,t} + \pi_2\Delta v''_{\kappa,t} + \pi_3\Delta v''_{o,t} + \pi_4\Delta v''_{\alpha,t} + \theta\Delta v''_{sr,t} + \Delta u''_t$			
	Level Regressions-Equation				Growth Rate Regressions Equation			
	OLS		GMM		OLS		GMM	
	Estimate	P Value	Estimate	P Value	Estimate	P Value	Estimate	P Value
δ	0.33	0.0003	0.04	0.6065	0.02	0.8170	-0.16	0.0290
β	0.15	0.0019	0.26	0.0002	0.31	0.0000	0.24	0.0001
π_1	0.11	0.0077	0.20	0.0003	0.16	0.0009	0.18	0.0001
π_2	0.10	0.0512	0.28	0.0002	0.32	0.0001	0.45	0.0000
π_3	-0.06	0.5726	-0.27	0.0715	-0.07	0.3313	0.008	0.9402
π_4	0.39	0.0014	1.03	0.0000	-0.03	0.7945	0.25	0.1196
θ	0.17	0.1625	-0.13	0.3478	-0.46	0.0213	-0.71	0.0005
J	NA		0.13		NA		0.13	
$\bar{R}^2$	0.80		0.66		0.80		0.65	
σ	0.02		0.04		0.02		0.04	

1. Double prime on top of the variables denote gaps between New Zealand and Australia's magnitudes. All variables are in log forms.
2. y is real GDP; h is hours-worked; k is fixed capital formation; μ is the stock of manufacturing; ψ is the stock of R&D; o is openness measured as the sum of imports and exports as a percentage of real GDP; α is aging measured by workers aged 55 and above as a percentage of total labour force; Sr is labour productivity in the services sector;
3. Δ is the forth difference operator;
4. J is The Hanson test for over-identifying restrictions of the instruments distributed chi-squared with degrees of freedom equal to the number of over-identifying restrictions; 5. σ is the standard error of the regression; and
6. Instruments included lags 5 to 8 of the right-hand side variables in differences and a constant. The standard errors are estimated by the Newey-West method with a fixed kernel bandwidth =3.
7. GMM number of observations used is 48 and FIML number of observations used is 55.

Table 5: New Zealand – Australia unrestricted two-equation system

$$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\Delta(k-h)''_t + \pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta_{11}\,\Delta v''_{sr,t} + \Delta u''_t$$

$$\Delta q_t = \gamma\Delta q_{t-1} + \pi_{21}\Delta v''_{\mu,t} + \pi_{22}\Delta v''_{\kappa,t} + \pi_{23}\Delta v''_{o,t} + \pi_{24}\Delta v''_{\alpha,t} + \theta_{21}\,\Delta v''_{sr,t} + \Delta\zeta_t$$

GMM Sample March 1992 – December 2003			FIML Sample June 1989 – December 2003	
Restriction	TEST Value	Probability	TEST Value	Probability
$\pi_{11} = -\pi_{21}$	1.29	0.2560	0.30	0.5837
$\pi_{12} = -\pi_{22}$	19.80	0.0000	0.70	0.4014
$\pi_{13} = -\pi_{23}$	0.2351	0.6277	1.21	0.2705
$\pi_{14} = -\pi_{24}$	1.02	0.3115	10.0	0.0016
$\theta_{11} = -\theta_{21}$	19.555	0.0000	2.3989	0.1215

Total system observations are 96, GMM estimates: Kernel=Bartlett, Bandwidth=fixed (3), no pre-whitening, linear estimation after 1step weighting matrix.
FIMl total system observations 110 and convergence achieved after 21 iterations.

The Wald test is distributed chi-squared with 1 degree-of-freedom.

Double prime on top of the variables denote gaps between New Zealand and Australia's magnitudes. GMM – fixed bandwidth (3).
All variables are in log forms.

y is real GDP; h is hours-worked; k is fixed capital formation; μ is the stock of manufacturing; ψ is the stock of R&D;
o is openness measured as he sum of imports and exports as a percentage of real GDP; α is aging measured by workers aged 55 and above as a percentage of total labour force; Sr is labour productivity in the services sector. All these variables are random walks.
Δ is the forth difference operator.

Table 6: Estimating the restricted system for New Zealand – Australia

	GMM Sample March 1992- December 2003		FIML Sample June 1990 – December 2003	
	$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\Delta(k-h)''_t + [\pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta_{11}\,\Delta v''_{sr,t} + \ldots$ $\Delta q_t = \eta\Delta q_{t-1} + \tau[\pi_{11}\Delta v''_{\mu,t} + \pi_{22}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta_{21}\,\Delta v''_{sr,t}] + \Delta\zeta_t$		$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\Delta(k-h)''_t + [\pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta\,\Delta v''_{sr,t} + \Delta u''_t$ $\Delta q_t = \eta\Delta q_{t-1} + \tau[\pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{24}\Delta v''_{\alpha,t} + \theta\,\Delta v''_{sr,t} + \Delta\zeta_t$	
	Estimate	P value	Estimate	P value
δ	0.07	0.0267	0.06	0.4660
β	0.25	0.0000	0.19	0.0002
π_{11}	0.19	0.0000	0.20	0.0007
π_{12}	0.27	0.0000	0.25	0.0001
π_{22}	0.004	0.8980	NA	NA
π_{13}	0.04	0.1842	0.05	0.4560
π_{14}	-0.14	0.0004	-0.05	0.7223
π_{24}	NA	NA	0.35	0.0141
θ_{11}	-0.60	0.0000	NA	NA
θ_{21}	0.03	0.7497	NA	NA
θ	NA	NA	-0.07	0.7151
η	0.57	0.0000	0.25	0.0006
τ	-2.0	0.0045	-1.02	0.0000
J	0.2375		NA	NA

Double prime on top of the variables denote gaps between New Zealand and Australia's magnitudes. GMM total observations 96, kernel=Bartlett, fixed bandwidth (3), no pre-whitening, iterate coefficients after one-step weighting matrix and convergence was achieved after 1 weight matrix and 18 total coefficient iterations . FIML total observations are 110 and convergence was achieved after 21iterations. All variables are in log forms. y is real GDP; h is hours-worked; k is fixed capital formation; μ is the stock of manufacturing; ψ is the stock of R&D; o is openness measured as the sum of imports and exports as a percentage of real GDP; α is aging measured by workers aged 55 and above as a percentage of total labour force; Sr is labour productivity in the services sector. All these variables are random walks. Δ is the forth difference operator; J is The Hanson test for over-identifying restrictions of the instruments distributed chi-squared with degrees of freedom equal to the number of over-identifying restrictions.

Table 7: Canada-United States unrestricted two-equation system

$$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\Delta(k-h)''_t + \pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta_{11}\,\Delta v''_{sr,t} + \Delta u''_t$$

$$\Delta q_t = \gamma\Delta q_{t-1} + \pi_{21}\Delta v''_{\mu,t} + \pi_{22}\Delta v''_{\kappa,t} + \pi_{23}\Delta v''_{o,t} + \pi_{24}\Delta v''_{\alpha,t} + \theta_{21}\,\Delta v''_{sr,t} + \Delta\zeta_t$$

GMM sample March 1988 – December 2004			FIML Sample June 1985 – December 2004	
Restriction	TEST Value	Probability	TEST Value	Probability
$\pi_{11} = -\pi_{21}$	2.17	0.1407	0.57	0.4473
$\pi_{12} = -\pi_{22}$	0.34	0.5579	0.00	0.9831
$\pi_{13} = -\pi_{23}$	1.11	0.2904	0.60	0.4353
$\pi_{14} = -\pi_{24}$	0.24	0.6260	6.17	0.0130
$\theta_{11} = -\theta_{21}$	0.67	0.4130	0.34	0.5461

Total system observations are 96, GMM estimates: Kernel=Bartlett, Bandwidth=fixed (3), no pre-whitening, linear estimation after 1step weighting matrix.
FIMl total system observations 110 and convergence achieved after 21 iterations.

The Wald test is distributed chi-squared with 1 degree-of-freedom.

Double prime on top of the variables denote gaps between New Zealand and Australia's magnitudes. GMM – fixed bandwidth (3).
All variables are in log forms.

y is real GDP; h is hours-worked; k is fixed capital formation; μ is the stock of manufacturing; ψ is the stock of R&D;
o is openness measured as he sum of imports and exports as a percentage of real GDP; α is aging measured by workers aged 55 and above as a percentage of total labour force; Sr is labour productivity in the services sector. All these variables are random walks.
Δ is the forth difference operator.

Table 8: Estimating the restricted system for Canada – United States

	GMM Sample March 1988- December 2004		FIML Sample June 1990 – December 2003	
	$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\Delta(k-h)''_t + \pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta\Delta v''_{sr,t} + \Delta u''_t$ $\Delta q_t = \eta\Delta q_{t-1} + \tau[\pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta\Delta v''_{sr,t}] + \Delta\zeta_t$		$\Delta(y-h)''_t = \delta\Delta(y-h)''_{t-1} + \beta\,\Delta(k-h)''_t + \pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{14}\Delta v''_{\alpha,t} + \theta\Delta v''_{sr,t} + \Delta u''_t$ $\Delta q_t = \eta\Delta q_{t-1} + \tau[\pi_{11}\Delta v''_{\mu,t} + \pi_{12}\Delta v''_{\kappa,t} + \pi_{13}\Delta v''_{o,t} + \pi_{24}\Delta v''_{\alpha,t} + \theta\Delta v''_{sr,t}] + \Delta\zeta_t$	
	Estimate	P value	Estimate	P value
δ	0.51	0.0000	0.45	0.0000
β	0.15	0.0000	0.11	0.0075
π_{11}	0.18	0.0000	0.28	0.0000
π_{12}	0.12	0.0017	0.18	0.0007
π_{13}	0.22	0.0000	0.21	0.0188
π_{14}	-0.14	0.0882	-0.15	0.3780
π_{24}	NA	NA	0.14	0.2705
θ	0.35	0.0275	0.46	0.0060
η	0.62	0.0000	0.56	0.0000
τ	-1.65	0.0000	-1.04	0.0000
J	0.2224		NA	NA

Double prime on top of the variables denote gaps between Canada and the US' magnitudes. GMM total observations 136, kernel=Bartlett, fixed bandwidth (3), no pre-whitening, iterate coefficients after one-step weighting matrix and convergence was achieved after 1 weight matrix and 18 total coefficient iterations . FIML total observations are 150 and convergence was achieved after 21iterations. All variables are in log forms. y is real GDP; h is hours-worked; k is fixed capital formation; μ is the stock of manufacturing; ψ is the stock of R&D; o is openness measured as the sum of imports and exports as a percentage of real GDP; α is aging measured by workers aged 55 and above as a percentage of total labour force; Sr is labour productivity in the services sector. All these variables are random walks. Δ is the forth difference operator; J is The Hanson test for over-identifying restrictions of the instruments distributed chi-squared with degrees of freedom equal to the number of over-identifying restrictions.

Data Appendix 1

Figures a1- a4 plot the labour productivity gap for New Zealand – Australia and Canada – United States in log levels $(y-h)''_t$ and in growth rates $d(y-h)''_t$.[2] The gap is defined as the log of the ratio of GDP per hour-worked in the two countries, and the level of the real exchange rate defined in the text. We tried different measures of the real exchange rate and found no significant differences so we used the deviations from PPP. As defined in the text, Y is real GDP, H is hour-worked, and Q is the deviation from PPP. Lowercase denotes log and double prime on the variable denotes the gap between two countries' magnitudes. The Australian data and the United States data are PPP-adjusted to the New Zealand and Canadian data such that Australia and the United States are set to 100. The levels have trends. The correlation is obviously very high.

In what follows a variety of tests for unit root such as the Dickey-Fuller, the Augmented Dickey-Fuller, the Phillips-Perron test, Elliott (1999) and Perron (1997) using a variety of specifications (different information criteria for testing lags, drift, drift and trend models) will be used. For GDP per hour worked and the real exchange rate, all tests failed to reject the unit root hypothesis in the level time series. Elliot's test rejects the null more often than other tests, and especially in the case of the differenced data. Causality is much harder to test. Although the correlations are high one cannot tell at least by eyeballing the data which variables causes which. The HBS effect suggests that it runs from productivity to the relative price of nontradables or the real exchange rate, while Harris (2001) argues that the depreciation rate causes productivity gaps. We argued earlier that maybe causality runs both ways, and that both the productivity gap and the real exchange rate are affected by the same TFP shocks.

Figures a5-a8 plots the level and growth rates of labour productivity gap shown above against the level and growth rates of capital per hour-worked gap $(k-h)''_t$ and $d(k-h)''_t$. The stock of capital data are not readily available, and especially at quarterly frequency. We use fixed capital formation expenditures instead as a proxy. The levels of capital intensity gaps in all countries have trends and the hypothesis of unit root could not be rejected by any of the tests statistics we reported earlier. The results do not vary with the specifications of these tests.

Figures a9-a12 plot the gap in the stocks of manufacturing μ''_t and labour productivity gap in levels, which we labelled ms''_t and $d(ms)''_t$ and growth rates. Visually, the correlations are striking in the case of New Zealand and Australia, but less so in the Canada – United States case. We tested the levels of the stock of manufacturing gaps in both New Zealand – Australia and Canada – United States pairs for unit roots, and the hypothesis could not be rejected in all tests with many different specifications.

Figures a13-a16 plot the stock of R&D gaps ψ''_t in levels, which we labelled rd''_t and growth rates $d(rd'')_t$ against GDP per hour-worked gaps. We observe downward trends in the R&D gap, New Zealand stock of R&D is much smaller than that of Australia and keeps falling, or Australia's stock keeps increasing. For the Canada – United States case, the correlation is also visually clear. Canadian's R&D stock must have picked up in 2003 as the trend is positive and sharp. The data have unit roots. The hypothesis could not be rejected by any of the tests outlined earlier.

[2] The letter (d) is the rate of growth, which is the change $\Delta_4 = \ln X_t - \ln X_{t-4}$ of the log.

The aging gap α_t'' is plotted in figures a17-a20. Aging is the percentage of workers age 55 and over in the labour force and the hypothesis was that this affects labour productivity adversely. Figures show negative (no clear positive) correlation between ageing and labour productivity. The ratio is greater than1 for New Zealand; and is lower than 1 for Canada.

Figures a21-a24 plot the openness variable – total trade (imports plus exports) as a percent of GDP gaps o_t'' in levels and differences. New Zealand's trade exceed that of Australia. The correlation is pretty clear in the levels. The openness gap in the case of New Zealand – Australia is stationary. All tests reject the null hypothesis that there is a unit root in the data. Canada also trade more than US, as a percent of GDP, openness gap is correlated with labour productivity gap, trend downwards, but has a unit root.

Figures a25-a28 plot the services' productivity gap in levels and differences against the real exchange rate and the real depreciation rate. The data are annual indices taken from OECD website and interpolated to get quarterly data. The method is explained in the data appendix. The correlations appear negative as the theory would suggest and the data have unit roots. The Canada – United States data seem smoother.

Figure a1: Labour Productivity Gap & Real Exchange Rate New Zealand-Australia Australia=100

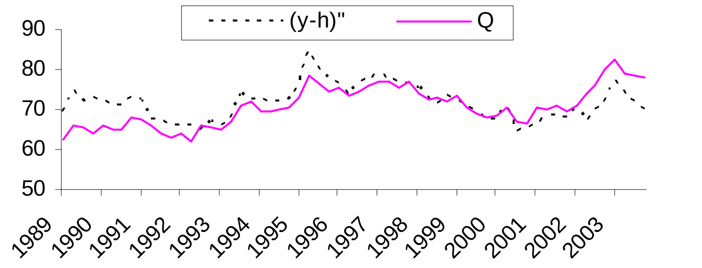
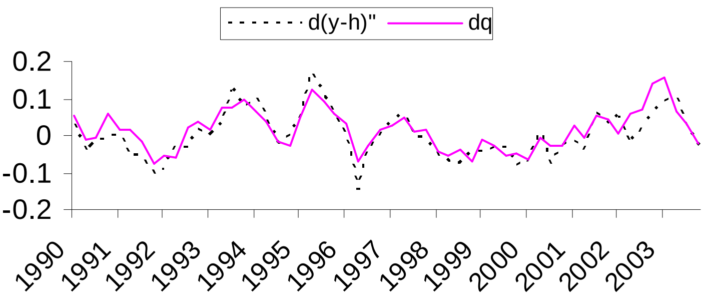


Figure a2: Growth rate of Labour Productivity Gap and Real Depreciation Rate New Zealand & Australia



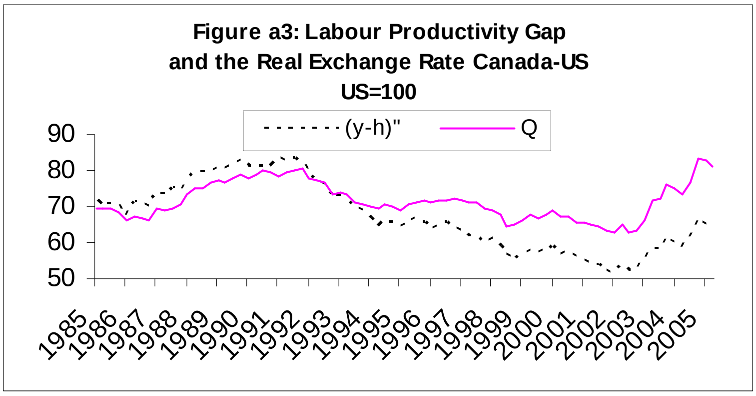


Figure a3: Labour Productivity Gap and the Real Exchange Rate Canada-US US=100

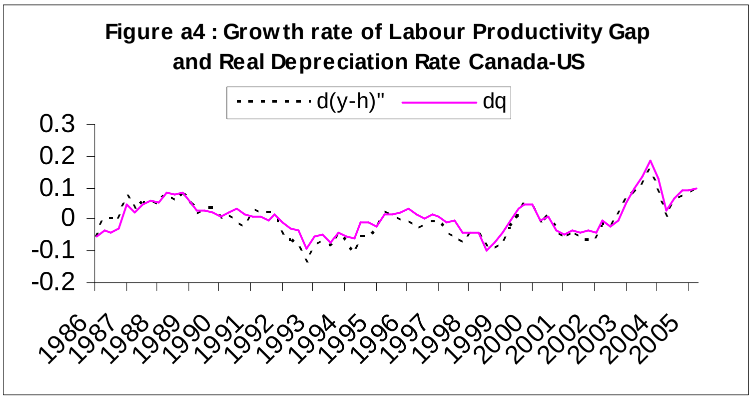


Figure a4 : Growth rate of Labour Productivity Gap and Real Depreciation Rate Canada-US

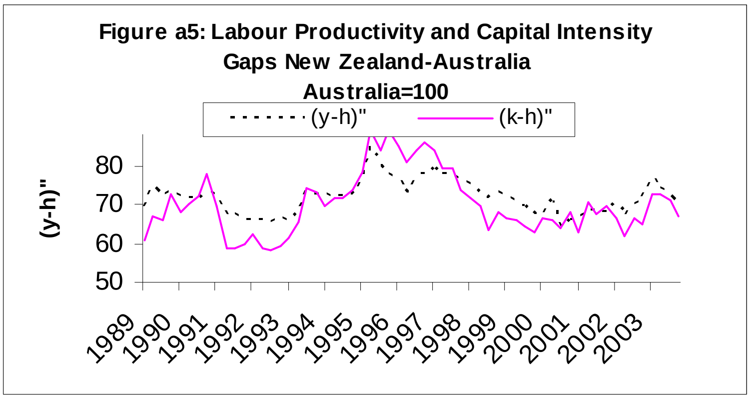


Figure a5: Labour Productivity and Capital Intensity Gaps New Zealand-Australia Australia=100

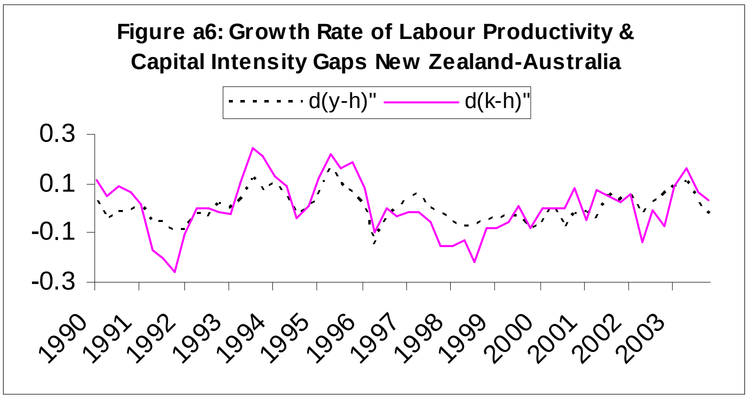


Figure a6: Growth Rate of Labour Productivity & Capital Intensity Gaps New Zealand-Australia

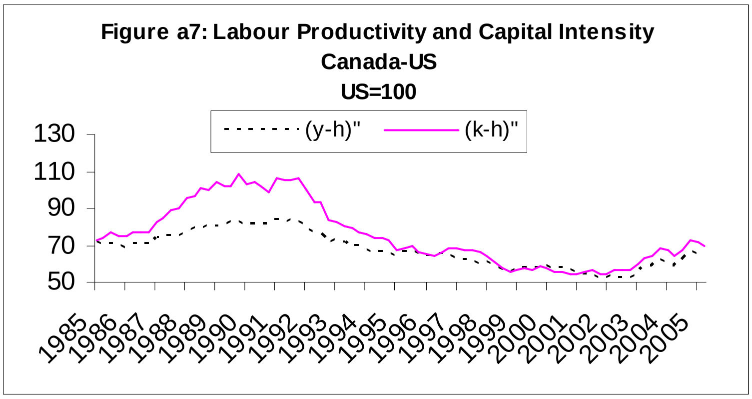


Figure a7: Labour Productivity and Capital Intensity
Canada-US
US=100
(y-h)"
(k-h)"

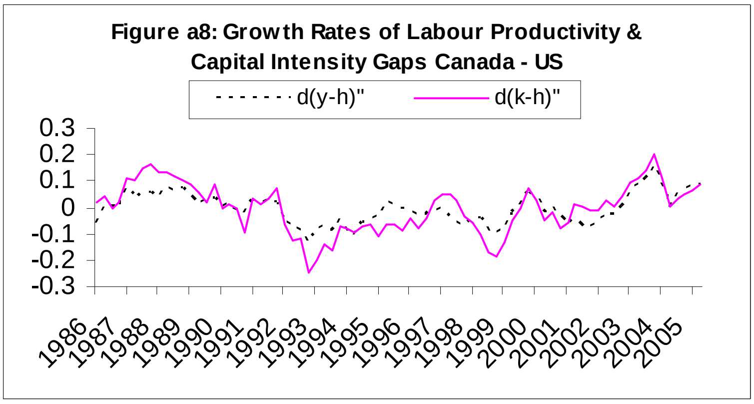


Figure a8: Growth Rates of Labour Productivity &
Capital Intensity Gaps Canada - US
d(y-h)"
d(k-h)"

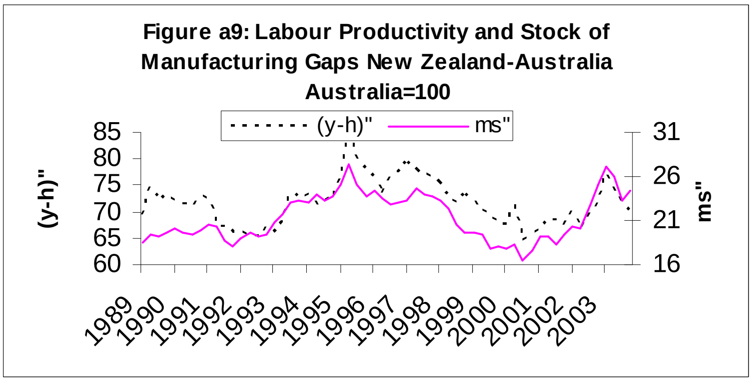


Figure a9: Labour Productivity and Stock of
Manufacturing Gaps New Zealand-Australia
Australia=100
(y-h)"
ms"

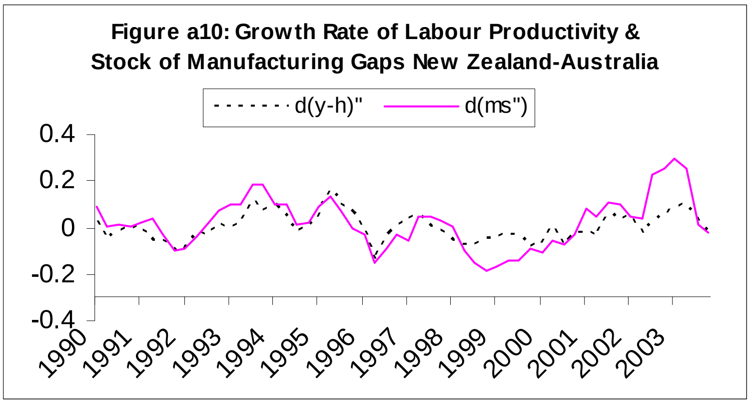


Figure a10: Growth Rate of Labour Productivity &
Stock of Manufacturing Gaps New Zealand-Australia
d(y-h)"
d(ms")

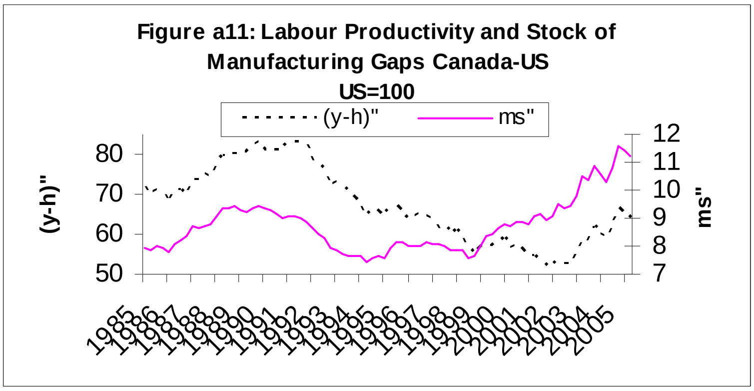


Figure a11: Labour Productivity and Stock of Manufacturing Gaps Canada-US
US=100
(y-h)"
ms"
80
70
60
50
12
11
10
9
8
7
1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005

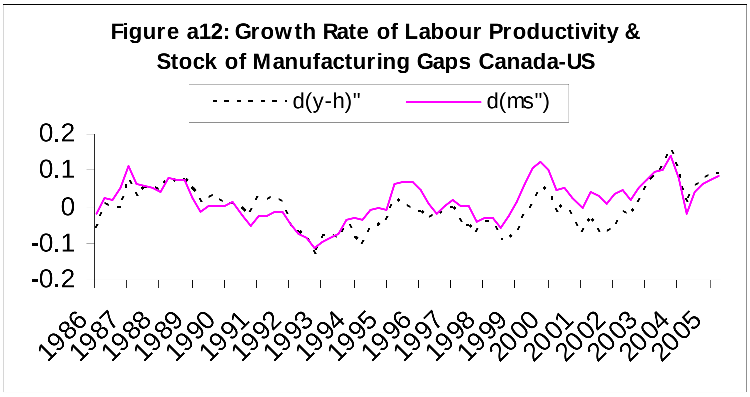


Figure a12: Growth Rate of Labour Productivity & Stock of Manufacturing Gaps Canada-US
d(y-h)"
d(ms")
0.2
0.1
0
-0.1
-0.2
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005

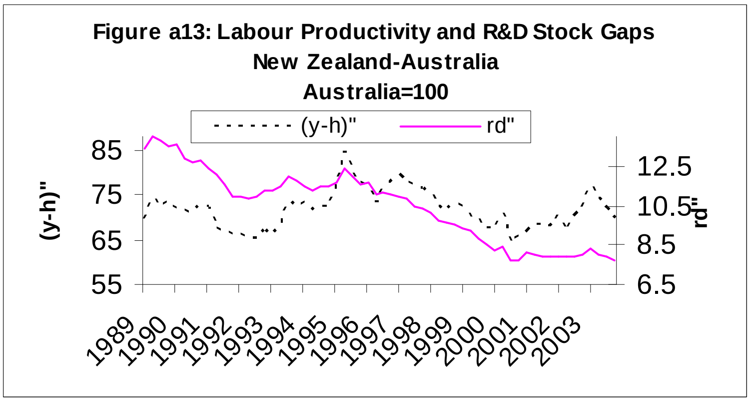


Figure a13: Labour Productivity and R&D Stock Gaps New Zealand-Australia
Australia=100
(y-h)"
rd"
85
75
65
55
12.5
10.5
8.5
6.5
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003

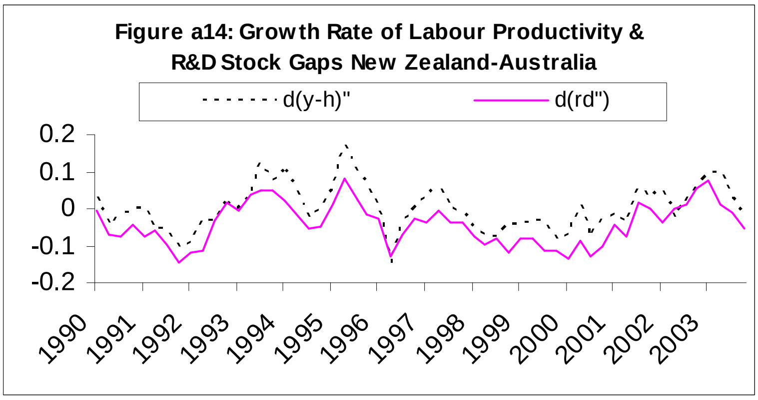


Figure a14: Growth Rate of Labour Productivity & R&D Stock Gaps New Zealand-Australia
d(y-h)"
d(rd")
0.2
0.1
0
-0.1
-0.2
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003

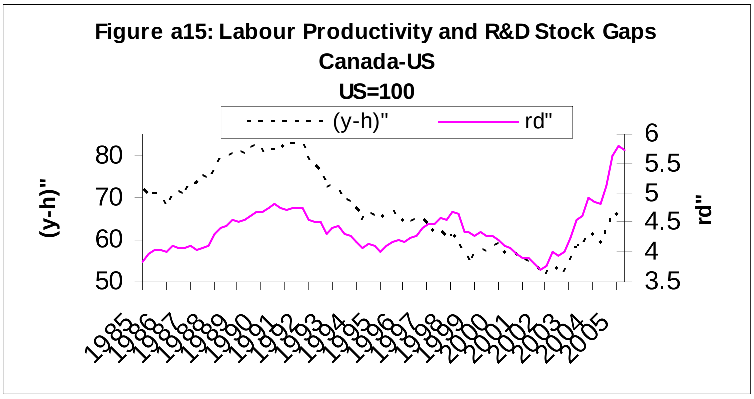


Figure a15: Labour Productivity and R&D Stock Gaps Canada-US US=100

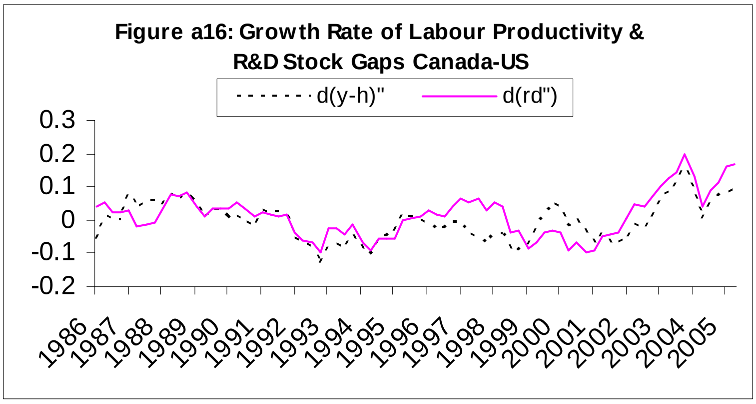


Figure a16: Growth Rate of Labour Productivity & R&D Stock Gaps Canada-US

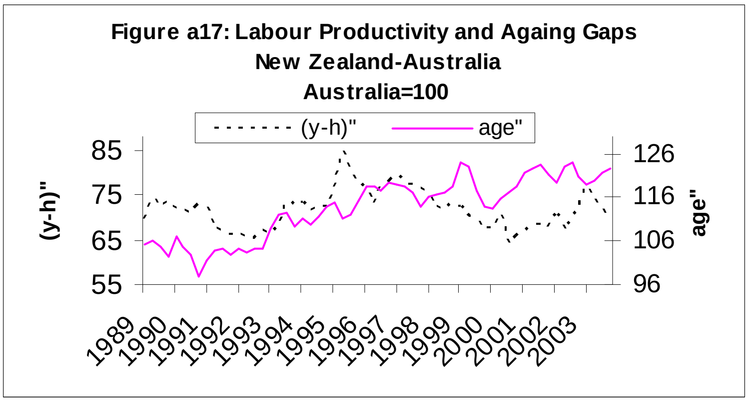


Figure a17: Labour Productivity and Aging Gaps New Zealand-Australia Australia=100

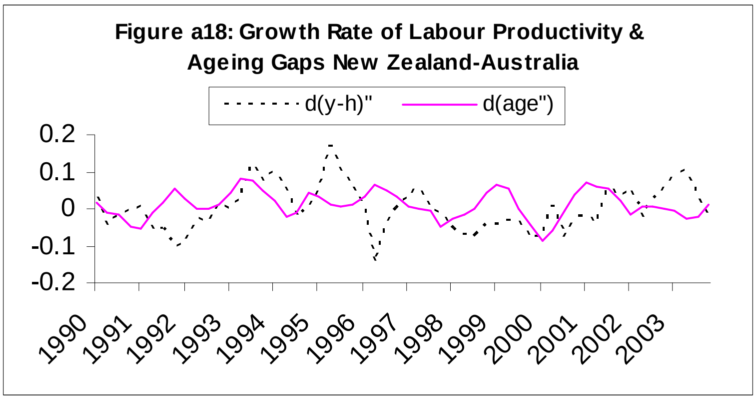


Figure a18: Growth Rate of Labour Productivity & Ageing Gaps New Zealand-Australia

Figure a19: Labour Productivity and Ageing Gaps Canada-US US=100

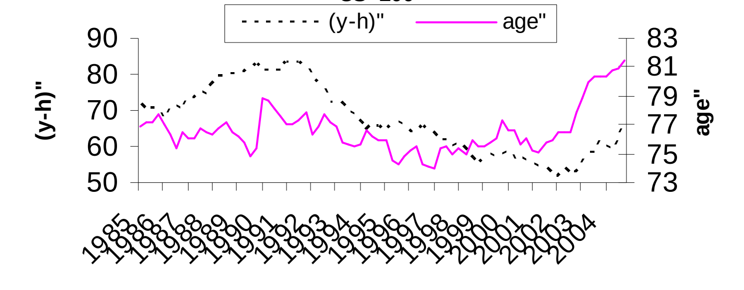


Figure a20: Growth Rate of Labour Productivity & Ageing Gaps Canada-US

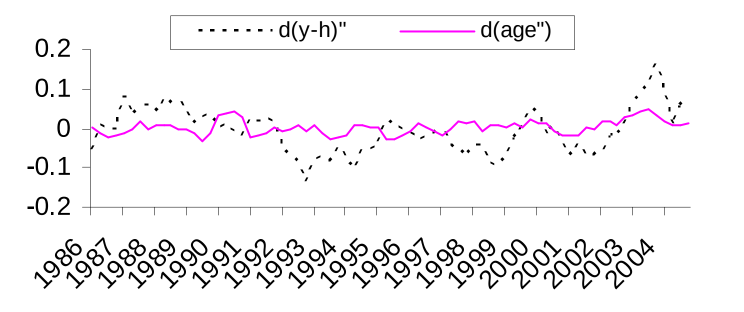


Figure a21: Labour Productivity and Openness Gaps New Zealand-Australia Australia=100

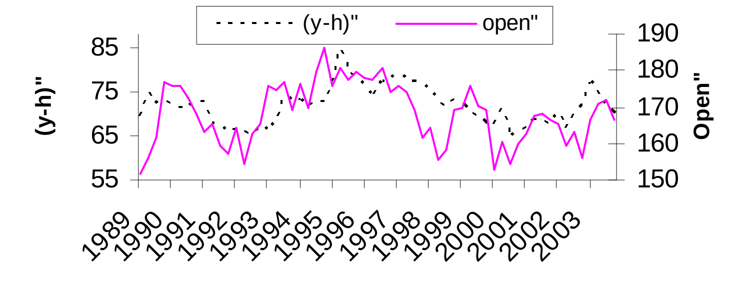
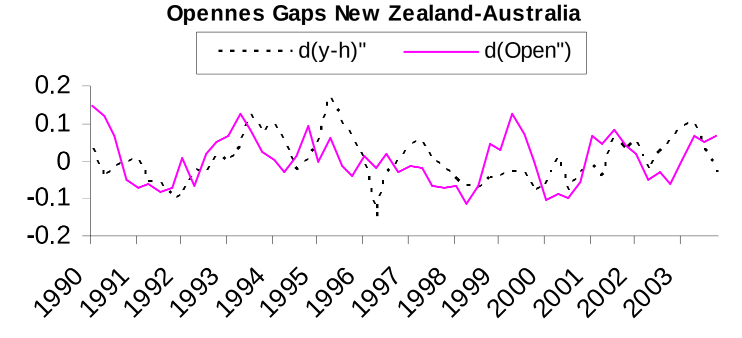


Figure a22: Growth Rate of Labour Productivity & Opennes Gaps New Zealand-Australia



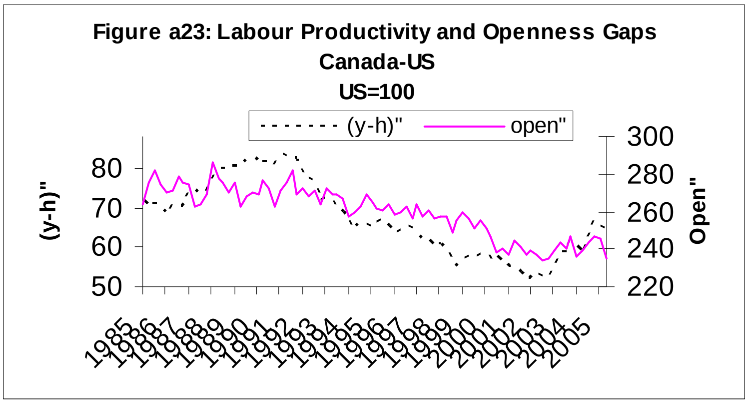


Figure a23: Labour Productivity and Openness Gaps
Canada-US
US=100
(y-h)"
open"
(y-h)"
Open"
80
70
60
50
300
280
260
240
220
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

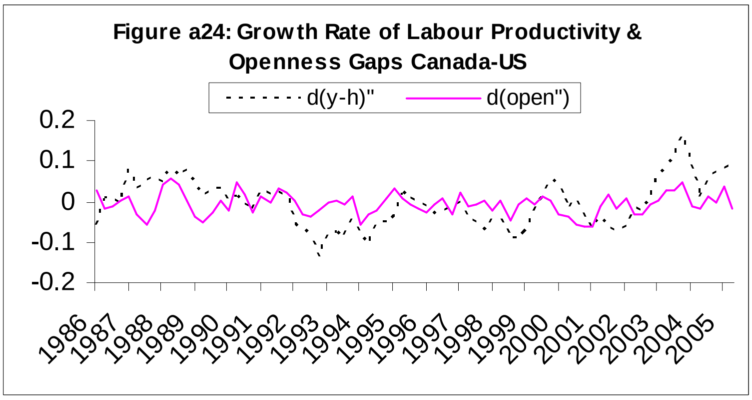


Figure a24: Growth Rate of Labour Productivity &
Openness Gaps Canada-US
d(y-h)"
d(open")
0.2
0.1
0
-0.1
-0.2
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

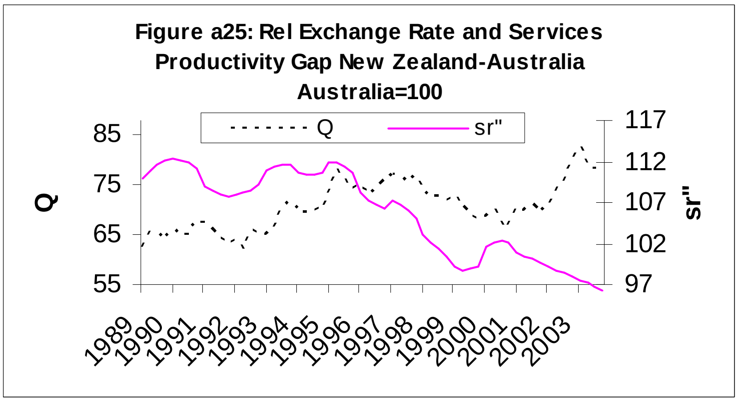


Figure a25: Rel Exchange Rate and Services
Productivity Gap New Zealand-Australia
Australia=100
Q
sr"
Q
sr"
85
75
65
55
117
112
107
102
97
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

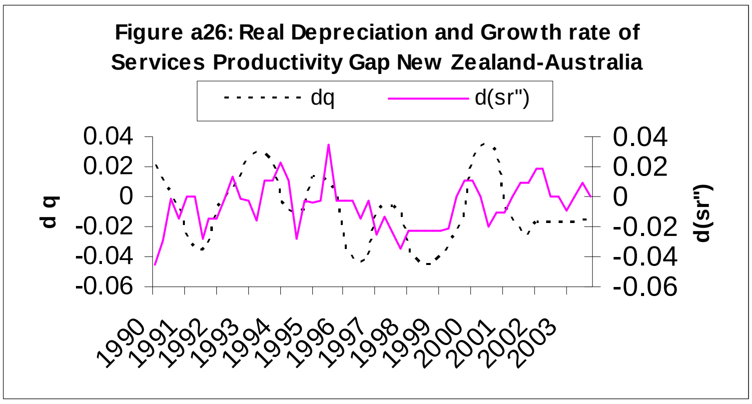


Figure a26: Real Depreciation and Growth rate of
Services Productivity Gap New Zealand-Australia
dq
d(sr")
d q
d(sr")
0.04
0.02
0
-0.02
-0.04
-0.06
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

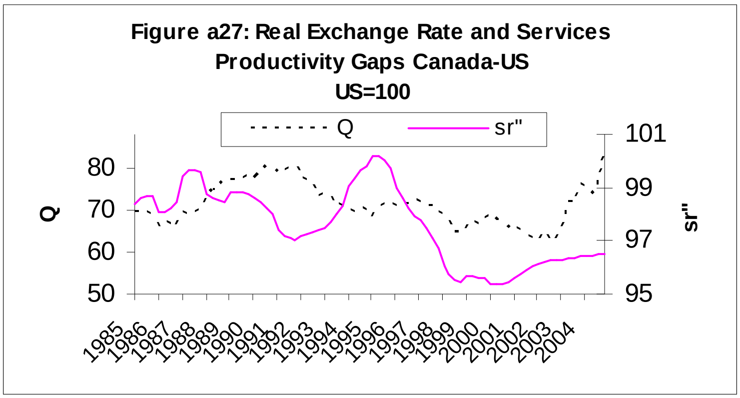


Figure a27: Real Exchange Rate and Services Productivity Gaps Canada-US
US=100
Q
sr"
80
70
60
50
101
99
97
95
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

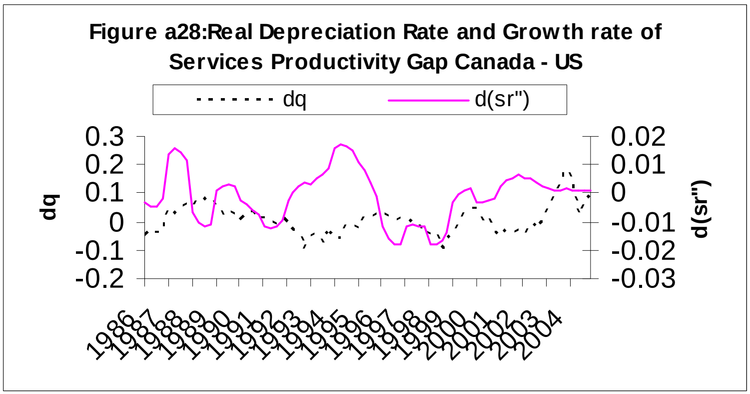


Figure a28:Real Depreciation Rate and Growth rate of Services Productivity Gap Canada - US
dq
d(sr")
0.3
0.2
0.1
0
-0.1
-0.2
0.02
0.01
0
-0.01
-0.02
-0.03
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

Data Appendix 2

New Zealand and Canada are home countries. Australia and the United States are with the superscript f which denotes the foreign countries.

Variable	Description	Source
Y	Real production GDP at 2000 constant prices	SNZ, OECD
Y^f	Real production GDP at 2000 constant prices	OECD
H	New Zealand average of total weekly hour worked. For Canada, Average weekly earnings (SEPH), seasonally adjusted, for all employees, by selected industries classified using the North American Industry Classification System (NAICS), monthly (Dollars).	SNZ – HLFS and Statistics Canada
H^f	Average of total weekly hour worked. For the US, Average Weekly Hours: Total Private Industries.	ABS and Bureau of Labour Statistics
$\hat{W}$	Working age population 15+ (000 people). Data for Canada are annual extrapolated to quarterly using Quadratic Match Average method described at the end of this table.	SNZ – HLFS-Statistics Canada
$\hat{W}^f$	Working age population 15+ (000 people). For the United States the data are annual extrapolated into quarterly using Quadratic Match Average method described at the end of this table.	ABS and Bureau of Labour Statistics
Y^A	New Zealand agricultural GDP ($NZD)	OECD
Y^{Af}	Australia agricultural GDP ($AUD)	OECD
lf	New Zealand labour force (000 people). Civilian labour force is the sum of the unemployed and the employed as defined in the labour force survey.	SNZ and Statistics Canada
lf^f	Australia labour force (000 people). Civilian labour force is the sum of the unemployed and the employed as defined in the labour force survey.	ABS and Bureau of labour Statistics
μ	Stock of manufacturing. Data refer to the sum of stocks of materials and finished goods, including work in progress. Goods and Services Taxes (G.S.T.) are excluded. ANZSIC Code is used.	SNZ and OECD
μ^f	Stock of manufacturing ($ AUD). Data are compiled from the results of the Quarterly Survey of Stocks and Manufacturers' Sales. The sample includes 8 000 Australian private businesses, each with over 140 employees. This sample is revised each year. Data refer to the end of period. ANZSIC code is used.	OECD
Services Productivity	Labour productivity represents the amount of output per unit of input, output being defined as value added. The series are presented as indices. The reference year is 1995 for all countries, except for Australia 2000; and Canada: 1997.	OECD-LPDTY
α aging	Employed workers age 55+ / labour force.	SNZ
α^f aging	Employed workers age 55+ / labour force.	ABS
K	Fixed capital formation ($ NZD).	OECD
K^f	Fixed capital formation ($ AUD).	OECD
X	Exports FOB ($ NZD).	[3] OECD

X^f	Exports FOB ($ AUD).	
$\hat{I}$	Imports CIF ($ NZD)	
$\hat{I}^f$	Import CIF ($ AUD)	
P	CPI, rebased, 1989:1 = 100	OECD
P^f	CPI rebased, 1989:1 = 100.	OECD
κ R&D	Stock of R&D computed using Griliches Perpetual inventory formula with depreciation rate of 5%. The expenditures are from Johnson (1999). The data are annual. I converted the data into quarterly using Quadratic Match Average method described at the end of this table.	
κ^f	Stock of R&D computed using Griliches Perpetual inventory formula with depreciation rate of 5%. The data are annual. A similar method is used to convert the data. For Canada and the US the data are annual from OECD converted into quarterly using Quadratic Match Average method described at the end of this table.	"Research and development fiscal incentives in Australia: impacts and policy lessons" by R Lattimore, Industry Commission, Canberra, 1997. Updated data are from The Industry Commission
S	The spot exchange rates.	OECD

Annual data include R&D, WAP, and Service's productivity indices were converted into quarterly by fitting a quadratic polynomial for each observation and use the polynomial to fill in all observations. The method is Quadratic Match Average, which involves taking sets of three adjacent observations from the original time series and fitting a quadratic so that the average of the quarterly frequency observations matches with the annual data. One observation before and after the currently interpolated period are used to make up three observations. For the end points, the two periods are both taken from the one side where the data are available. This method does not impose any constraint on the data between adjacent observations and it seems most suitable because the original data are very smooth and the sample is small.

[i] They provide a model of complementary capital investment, where output growth is contemporaneously low when complementary investment is high and high in periods after such investment has taken place when the stock of complementary capital is high. Complementary investment is high when observed ICT investment times its share is high.

[ii] Adequate time series data are not available to test this hypothesis for New Zealand – Australia case.

[iii] It is believed that New Zealand reforms were more extensive and very consistent with the so called Washington Consensus, yet its productivity performance has been disappointing when compared with Australia.

[iv] PPP is measured as $s_t\, p_t^* / p_t$, where p_t^* is the foreign country prices index, s_t is the spot exchange rate defined such that an increase means appreciation, and p_t is the home country price index. The home countries are New Zealand and Canada respectively and the foreign countries are Australia and the United States, hence we are comparing New Zealand to its neighbour Australia and Canada to its neighbour the United States. For New Zealand and Australia we used the GDP implicit deflators and for Canada and the United States we used the CPI's because they are readily available.

[v] Taxes and the relative price of capital goods could also be important determinants of technical change. It is unclear what tax we use in estimation. There seems to be different effects for different taxes on the economy, e.g., Arin and Koray (2005). Future research will study this subject carefully and find compatible data to generate appropriate gaps. The gap of the relative price of capital goods is too small to explain the gap in productivity because Australia and New Zealand face very similar relative prices of imported capital goods. However, it could well be a very important variable for Canada and the United States. The US is a major exporter of capital goods; however, adequate time series data are not readily available.

[vi] There is a huge literature on openness and there are a variety of measures, but we used this simple measure because the data are readily available.
There is a large literature on cross-sectional trade and growth. For example see, Rodriguez (2006), Rodriguez and Rodrik (2001), Rodrik (2003), Sala-i-Martin et al. (2004), Dollar and Kraay (2002), Edwards (1998), Frankel and Romer (1999) and Krueger (1997).

[vii] Davey (2003) is a useful survey of the international literature on ageing. It concludes that international evidence leads to a general conclusion that age has little effect on work performance. The research varies greatly in terms of methodology, data, and measurements.

[viii] Future research must consider examining this variable in more detail.

[ix] Let $a_t^N = f_1(sr_t^*)$ and $a_t^{Nf} = f_2(sr_t^{*f})$, where sr_t is service sector productivity. We assume $sr_t^* = sr_t + e_{1t}$ and similarly $sr_t^{*f} = sr_t^f + e_{2t}$ so the service productivity is measured with error. So $a_t^N = f_1(sr_t + e_{1t})$ and $a_t^{Nf} = f_2(sr_t^f + e_{2t})$. We further assumed that services productivity is a random walk with a drift and that the coefficients at home and abroad are the same, but the two countries differ in the realizations of the shocks. Therefore, $sr_t = b + \theta\, sr_{t-1} + w_{1t}$ and $sr_t^f = b + \theta\, sr_{t-1}^f + w_{2t}$ thus, $a_t^N = b + \theta\, sr_{t-1} + (e_{1t} + w_{1t})$ and $a_t^{Nf} = b + \theta\, sr_{t-1}^f + (e_{2t} + w_{2t})$. The gap is $a_t''^N = \theta\, sr_{t-1}'' + \xi_t$

[x] We controlled for productivity in agriculture, but do not report the results because it does not change significantly whether we have agriculture or not. Agriculture has a positive significant effect on labour productivity.

[xi] GMM estimator is obtained by minimizing the criteria function $u'z\hat{\Omega}^{-1}z'u$ given the moment condition $E(m(y,\theta)) = 0$. The moment condition is replaced by a sample analog and this criteria function is written as $m(\theta, y, x, z) = z'u(\theta, y, x)$, where y_t is the dependent variable, x_t is the explanatory variable, θ is a set of coefficients, z is a vector of instruments and u_t is the residual. In computing the weighting matrix, we choose a Bartlett spectral for the Kernel to weigh the covariance and ensure that $\hat{\Omega}$ is positive semi-definite. The bandwidth determines

how the weights change with the lags when estimating $\hat{\Omega}$. The Newey-West method with fixed bandwidth that is a function of the sample size is used.

[xii] We do not report FIML results to save space. They are available upon request. The parameter estimates have identical magnitudes to those obtained by OLS, but the standard errors are different as expected.

[xiii] In GMM we used lag 5 to lag 8 of each of the RHS explanatory variables and a constant as instruments. Differenced data work much better as instruments so we used differenced data in both the level and the growth rate regressions.

[xiv] We use Q tests and the Kolmogorov-Smirnov tests for whiteness of the residuals. For normality the P value of the Jarque – Bera statistic is 0.589951, the skewness statistic is 0.30 and the Kurtosis statistic is 2.6.

[xv] Chinn and Johnston (1999) and Fitzgerald (2003) use TFP data, calculated presumably from growth accounting or output/input indices, and test for cointegration in time series. They found little evidence of stable long-run relationship between productivity gap and the real exchange rate in various countries. Chinn and Johnston also estimated a panel for 14 Asian countries and tested variables such as government expenditures and oil prices. Thomas and King (2004) extended Chinn and Johnston's sample and found mixed results depending on whether restrictions are imposed or not. Most of the older papers used labour productivity, Hsieh (1982), Marston (1990) and Micossi and Milesi-Ferretti (1994). DeGregorio and Wolf (1994) used TFP data from high growth countries seem to support the HBS. See also Lee and Tang (2003) and Kiyajima (2005).

[xvi] If the variables are cointegrated in the levels then the coefficient estimates are super-consistent, but we really don't know whether they should be cointegrated or not? We estimated the system in level, but we don't report the regressions results to save space. We estimated a two-equation system:

$$(y-h)''_t = \delta(y-h)''_{t-1} + \beta(k-h)''_t + \pi_{11}\mu''_t + \pi_{12}\psi''_t + \pi_{13}o''_t + \pi_{14}\alpha''_t + \theta_{11}sr''_t + \vartheta_t$$

$$q = \gamma q_{t-1} + \pi_{21}\mu''_t + \pi_{22}\psi''_t + \pi_{23}o''_t + \pi_{24}\alpha''_t + \theta_{21}sr''_t + \varsigma_t$$

and tested the restrictions $\pi_{11} = -\pi_{21}$; $\pi_{12} = -\pi_{22}$; $\pi_{13} = -\pi_{23}$ and $\pi_{14} = -\pi_{24}$. We also test whether $\theta_{11} = -\theta_{21}$. We found that in the GMM system regression the P values of the Wald test statistics for the restrictions above are: 0.0027, 0.8831, 0.3686 and 0.0838 respectively, which means that we reject the restriction $\delta_{11} = -\delta_{21}$ and probably $\delta_{14} = -\delta_{24}$, but we cannot reject the restrictions $\delta_{12} = -\delta_{22}$ and $\delta_{13} = -\delta_{23}$. In the FIML regression the P values of the Wald test statistics are 0.6392, 0.8795, 0.8311 and 0.6209 respectively, which means none of the restrictions could be rejected. We then estimated the model with the restrictions imposed on the system.

[xvii] We experimented with different measures such as the business sector productivity, but we could not get any better results.

[xviii] We test the restrictions that the coefficients of the manufacturing stock, R&D stock, openness and aging are equal in size, but have opposite signs in the productivity gap and the real exchange rate equations of the system. The P values of the Wald test statistics for GMM are 0.2239, 0.6631, 0.1311, and 0.4819 respectively and for FIML, they are 0.4362, 0.7806, 0.0115, and 0.2590. Only the restriction on the openness coefficients did not hold in the FIML regressions.