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Sectoral Productivity, Structural Change and Convergence[1]

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The concept of convergence, defined either narrowly, through productivity or income per capita, or broadly, across a range of economic variables, has become fundamental to the way we assess, analyse and project economic growth in developing economies. To the extent that economic growth projections are designed to reflect empirical behaviour, there is a need to identify relationships between and within key projection variables. To date the empirical analysis of convergence has been controversial. There is a strong argument that economic growth should be projection at a detailed sectoral level (see McKibbin et al (2009)). In practice, data limitations mean that industry level relationships are difficult to uncover and macroeconomic aggregate behaviours are often imposed on disaggregated data. The analysis in this paper attempts to uncover the key cross country trends in sectoral level productivity data. Whilst productivity convergence is evident in some sectors, generally service sectors, it is not evident in others. In part, aggregate convergence trends across developed economies appear to be driven by structural change. We generalise this result and argue that a combination of convergence and structural development assumptions could improve the empirical relevance of economic growth projection models.

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1. Introduction

Economic growth projections are fundamental to both the design and the assessment of long term economic policy alternatives. The emergence of climate change as a key policy area has substantially stretched the time horizon over which such projections are necessary. In addition, our ability to analyse the impact of long term policy alternatives is linked to our ability to model and understand the impact of global economic shocks. In both cases, growth projections are complicated by the need to account for endogenous interactions within economies and between economies, and the need to model developing and emerging economies where empirical data availability is limited. Assumptions must be made and there is a need to balance the empirical relevance of such assumptions against robust model design.[2] Convergence assumptions are attractive, particularly when long time horizons are necessary, because they can be relatively easy to understand and are not particularly data intensive. They can be problematic, however, if there is confusion over exactly what is assumed to converge (income, technology,

[2] The Intergovernmental Panel on Climate Change (IPCC) attempted to achieve this balance in its Special Report on Emissions Scenarios (2000), which included long term projections of economic growth and greenhouse gas emissions. The report was a comprehensive and substantial contribution to the debate over climate change, but the assumptions used to underlie growth projections were controversial and generated considerable criticism. In particular, criticism focused on the use of convergence assumptions for some scenarios, combined with the inappropriate application of market exchange rates to compare output levels across countries. There was considerable debate over the relationship between these growth projections and the corresponding projections of emission levels. In McKibbin, Pearce and Stegman (2007, 2009) we provide a comprehensive review of this debate and a detailed analysis of the implications of using market exchange rates (instead of purchasing power parities) to compare international output levels and project economic growth and emission levels.

productivity, preferences?), what the elements of the convergence are, and how the model relates to theory and empirical evidence. The aim of this paper is to uncover empirical relationships that can be used to support (or oppose) the use of convergence assumptions in economic growth projections.

If we consider some comparable measure of productivity in two different economies, convergence occurs if the difference or the gap in the (relative) level of productivity between these two economies declines over time.[3] There are various ways to measure convergence over a larger sample. Here, convergence is measured as a reduction in the overall spread or variance of a data sample over time. This definition is referred to as sigma convergence in the literature.[4]

With respect to theoretical foundation, often the use of convergence assumptions in projection exercises is associated with neoclassical growth theory.[5] The use of neoclassical growth theory to support convergence assumptions in economic growth projection models is problematic for a number of reasons. Firstly, the empirical evidence in favour of the type of convergence predicted by neoclassical growth theory is limited. There is

[3] Relative productivity can be measured relative to the leader country (usually the US), relative to the cross sectional average or in logarithms.
[4] Four broad approaches to convergence analysis can be identified in the literature: beta convergence, sigma convergence, time series (co-integration) analysis, and distributional analysis. Sala-i-Martin (2002) and Quah (1995) provide summaries of the alternative approaches to convergence analysis.
[5] This is true of both the SRES (IPCC, 2000) and our own research using the G-Cubed model). Steady state approximations of key neoclassical growth model equations lead to the Barro or beta convergence equation (see previous footnote). Beta convergence is necessary but not sufficient for sigma convergence (Sala-i-Martin (1996)).

support for convergence (in labour productivity or GDP per capita) among developed country groups, such as the OECD. Across a broad cross section of economies, however, and, in particular, in samples where developing economies are included, strong support for convergence is not found.

Secondly, studies that include developing economies may be complicated by the existence of heterogeneous steady states[6] across regions and by the likelihood that developing economies may be quite some distance from their respective steady state. Neoclassical growth theory predicts convergence of an economy to its own individual steady state. In empirical studies, different steady state characteristics can be controlled for but it is difficult to then translate these *conditional* convergence findings into modelling assumptions.[7]

Acknowledgement that the nature of developing economies may be more consistent with transitional dynamics (that is, the steady state approximations widely used in the growth literature may not be appropriate for developing economies) has led to the development of various econometric techniques that attempt to account for transitional behaviour.[8] There remains, however,

[6] In neoclassical growth theory, this is an equilibrium for the economy where output growth and living standards are constant or "steady". Factors that affect steady state values depend on the theoretical model under consideration; in empirical work, consideration is given to socio-demographic and political structures.

[7] If we are to assume that countries are converging towards each other, we need to assume that either (i) countries share the same steady state characteristics or (ii) that they are characterised by steady states that are in turn converging towards each other. The use of (i) may be appropriate for a small group of developed economies but is not likely to be appropriate across a wide sample that includes developing economies. The use of (ii) is complicated by our limited understanding of the determinants of steady states and their evolution over time, particularly for developing economies.

[8] See Reiss (2000) and Mathunjwa and Temple (2007).

no strong evidence in favour of convergence when developing economies are included in any broad cross sectional sample.

Thirdly, in addition to the empirical complications, the theoretical framework is problematic, in that, by focusing on convergence at the aggregate level and formulating convergence tests based on the single sector neoclassical growth model, a fundamental feature of development has been ignored: the role of structural change. Investigation of this issue through the analysis of convergence at the sectoral level is, however, restricted by the limited availability of cross country data at the disaggregated level.

The analysis of convergence is therefore complicated by limitations in our understanding of the driving forces that lead to interactions in economic growth across countries; limitations in our ability to econometrically test convergence given the complicated structure these driving forces are likely to exhibit; and by limitations in the availability of empirical data necessary to investigate these complications.

Given these limitations, the approach to the analysis of convergence in this paper is collaborative. The available data sets are utilised and a range of results are presented that together inform our understanding of aggregate convergence.

Our variable of interest is labour productivity, measured as output per hours worked or, more crudely, as output per person employed.[9]

We analyse productivity at both the aggregate and the disaggregated (sectoral) level and argue that the empirical evidence is consistent with a convergence model based on structural change. New productivity data published by the Groningen Growth and Development Centre (GGDC) is utilised and a graphical analysis of convergence at the sectoral level is provided. The analysis is limited in data coverage and we therefore attempt to synthesis these results with the evidence on aggregate productivity trends over a wider cross section of countries by considering the role of structural change in the development process. This allows us to develop an empirically consistent story of productivity convergence.

2. Convergence and Divergence along the Development Path

Our overall approach in this section is motivated by a series of papers by Phillips and Sul (2003, 2007a, 2007b, 2009). Their approach to convergence analysis is based on the concept of a model of convergence to a common steady state growth path that is consistent with the observed pattern of empirical growth divergence. Convergence rates are heterogeneous across

[9] As discussed in the following section, we also provide a limited analysis of total or multi factor productivity.

both economies and time and are a function of heterogeneous technological progress paths. The model is based on their observation that countries appear to follow a similar development path but at different speeds and are currently at different stages on that path. Their model assumes that although technology is a widely available common good, countries differ in their ability to learn and utilise it. Poor economies with low levels of technological accumulation converge to the common steady state path slowly. As the 'speed of learning' in these economies increases, through, for example, improvements in education and technology diffusion, the speed of convergence increases. If the speed of learning in these economies exceeds the rate of technological creation in advanced economies, then the rate of convergence will accelerate. If, on the other hand, countries are slow or unable to learn, economies may transitionally diverge.

Consider Figure 1, in which labour productivity levels for 86 countries over the period 1960 to 2008, is plotted in grey.[10] Because no clear pattern can be discerned by considering the data in this way, we follow Phillips and Sul (2003) and sort the sample, based on initial (1970) labour productivity levels, group the sample into five clusters based on this ordering (each cluster contains 17 countries, the final cluster contains 18 countries), and overlay the original graph with the average labour productivity level for each group.

[10] The sample coverage is detailed in Appendix A and GDP is measured using 1990 GK PPPs. The data is sourced from Maddison (www.ggdc.net/Maddison (March 2010)).

Rather than presenting these average productivity levels simultaneously along the same x-axis, Phillips and Sul present averages along sequential x-axes, as we have done in Figure 2.[11] It is within this innovative framework that Phillips and Sul define their concept of convergence. They remark that the cross country development path viewed in this way is remarkably similar to the average growth path of OECD countries over the last century or two. Countries, therefore, could be considered to be on a *path of development* and convergence can be analysed by considering the way countries move along this path. The position of countries along this path is affected by technological progress and the speed with which countries travel along the path is affected by their speed of learning. Technological progress, in the Phillips and Sul model, is exogenous and remains unspecified. In this paper it is argued that if we take a disaggregated view of development, we can expand the model to include structural change and, in doing so, enrich our understanding of the development process. The sectoral composition of economies becomes critical to their position on the development path and structural change becomes integral to movement along the path. In Sections 3 and 4, empirical support for this type of model and the link between structural change and convergence is provided.

[11] Phillips and Sul consider GDP per capita levels. Our variable of interest is productivity and we therefore construct GDP per worker. In empirical studies of growth 'income per capita', 'income per worker' and 'income per effective worker' variables are often used interchangeably. Largely, this is due to limitations in data availability.

The importance of the empirical analysis of convergence at the sectoral level was highlighted by Bernard and Jones (1996a, 1996b). Bernard and Jones (1996a) compared sectoral and aggregate convergence trends in labour productivity and multi factor productivity (MFP) across 14 countries. The often cited finding of their seminal paper was a strong tendency towards convergence in the service sector, in accordance with the aggregate convergence trend across their sample, but a lack of convergence, in both labour productivity and MFP, for the manufacturing sector. Importantly, Bernard and Jones noted several limitations in their analysis: the application of aggregate purchasing power parity (PPP) conversion factors to sectoral data; the exclusion of developing economies; and the limited time frame of their sample. These comments, along with the influential findings of their analysis, generated a literature concerned with replicating and building on the results in the Bernard and Jones paper. Fundamental to this literature is the development of new and improved international datasets and those published by the Groningen Growth and Development Centre are an invaluable source. Papers relevant to the analysis in this paper that utilise GGDC databases include Inklaar and Timmer (2008, 2009a, 2009b) and de Vries, Los, and Castellacci (2010).

Inklaar and Timmer (2008) provide a detailed description of the GGDC Productivity Level Database, which provides detailed industry level

comparisons of output, inputs and productivity for thirty OECD countries. The major contribution of the database is the publication of a set of industry level purchasing power parities (PPPs) that can be used to compare industry level outputs across countries. The major drawback is the limited set of countries for which these PPPs are available.

Inklaar and Timmer (2009a) combine the GGDC Productivity Level Database with the industry level growth rates published in the EU KLEMS database to construct a time series of comparable industry level productivity estimates for 20 OECD countries. They use these estimates to analyse convergence within the sample. Their findings confirm those of Bernard and Jones (1996a) and support the existence of convergence in market service industries, but not in manufacturing, and highlight considerable heterogeneity in convergence trends across industries.

De Vries, Los, and Castellacci (2010) combine the industry level productivity growth rates from the EU KLEMS database (which covers 30 developed economies) with the industry level productivity growth rates for Asian and Latin American developing economies published under the GGDC's 10 sector database to construct a sample of industry level productivity growth rates that covers both developing and developed economies. To undertake an analysis of convergence using this data, output must be compared using purchasing power parities and, because these are not currently available at

the industry level for developing economies, de Vries et al (2010) use aggregate (economy wide) PPPs as a proxy for each (every) industry level PPP. De Vries et al (2010) consider convergence in labour productivity for sub-samples and sub-periods and find significant heterogeneity in the results. Their results contrast with those of Bernard and Jones (1996a) and Inklaar and Timmer (2009) in that they do find evidence of convergence in manufacturing across the sample, although further analysis suggests that it is driven by 'growth miracle' economies within the sample. Their overall finding is that convergence results are not robust to sample variations. Furthermore, in contrast to Bernard and Jones (1996a) who suggest that convergence in market services drives aggregate convergence trends, de Vries et al (2010) argue that convergence trends within sectors cannot explain aggregate convergence trends and other factors must be examined.

A comparison of de Vries et al (2010) and Inklaar and Timmer (2009) highlights the data limitations involved in analysing industry level convergence using currently available data sets. Inklaar and Timmer (2009) devote considerable energy to their productivity estimates and the calculation of industry level PPPs. The cross country coverage of their dataset is, however, limited. DeVries et al (2010) expand their dataset to include developing economies but must, as a consequence, apply aggregate economy wide PPPs as an approximation. The analysis in Inklaar and Timmer (2009a)

suggest that the effect of this approximation on productivity levels can be substantial and de Vries et al (2010) concede that this may explain some of the inconsistencies in their results. Furthermore, both analyses are limited in the time dimension and this limits the application of econometric techniques that rely on asymptotic results.

In this paper, we construct databases similar to those used in Inklaar and Timmer (2009a) and de Vries et al (2010). Given the limitations of these data sets, we attempt to gain further insight by extending the scope of our analysis.

A summation of the literature suggests that aggregate convergence trends are not reflected at the industry level. There is considerable heterogeneity in convergence results across industries. Structural change appears to be important in determining aggregate convergence trends (see Paci and Pigliaru (1997a, 1997b), Chanda and Daalgard (2005), Landesmann and Stehrer (2000)) but the process by which this occurs is not clear.

In this paper we bring these results together and attempt to develop a consistent story of convergence based on structural change. We argue that the heterogeneous nature of development and convergence is inconsistent with the current state of econometric testing when applied to the currently available data sets. Furthermore, the literature clearly demonstrates that convergence analyses are very sensitive to sample coverage, data construction

and estimation methods. The empirical analysis undertaken in this paper provides the empirical foundation for a theory that can be tested through economic modelling and calibration.

3. Aggregate and Sectoral Productivity Convergence

In this section we use a simple graphical tool for analysing convergence – changes in spread, measured by the standard deviation of the logarithm of our variable of interest over time.[12] This measure accounts for changes in the level of the variable under consideration over time and, when graphed, provides a clear visual indication of how the spread of a particular data set may be changing over time. If we think of convergence as a reduction in the cross country spread or variation of our variable of interest, then this measure provides us with a graphical indication of convergence.[13] We also apply a statistical test of significance for the difference between our spread estimates at the beginning and at the end of our sample period[14].

We are interested in the relationship between aggregate economy wide productivity trends and sectoral productivity trends. Stegman and Stegman

[12] For a discussion of alternative measures of spread in the analysis of convergence see McKibbin and Stegman (2005). Here we use the standard deviation of the logarithm in our graphical analysis to ensure consistent with the statistical tests in Table 1.
[13] This type of convergence is known as sigma convergence. See footnotes 3 and 4.
[14] This is a relatively simplistic test for convergence. We are limited by data availability. We do not believe the Phillips and Sul (2003, 2007a, 2007b, 2009) methodology is appropriate due to our limited data set. More complex testing procedures are problematic because either they are not very robust to departures in normality or they require asymptotic assumptions.

(2001) argued that changes in aggregate labour productivity, measured as output over employment, are a reflection of (i) within sector changes in productivity; (ii) changes in aggregate average hours worked per person employed; and (iii) changes in the structure of the economy which change the relative contribution of sectors with differing productivities.[15] Here, we consider the contribution of each of these factors to aggregate labour productivity convergence trends.

Our first data set, Sample A, consists of 19 developed economies and, given previous study results, we expect to see convergence in productivity at the aggregate level. Our interest will be in the relationship between this aggregate trend and individual sectoral trends. We begin by disaggregating the economy into the Market sector and the Non-Market Services sector. Our measure of spread for these two sectors, along with that for the total economy, is plotted in Figure 3. This disaggregation is important because the measurement of productivity in the Non-Market Services sector may be complicated by the use of output measures based on input values. To the extent that aggregate productivity trends are being driven by trends in the Non-market services sector, we must be careful about the robustness of conclusions regarding convergence. Over our sample period however, labour

[15] In Stegman and Stegman (2001) our interest was in the output – employment ratio, a crude measure of labour productivity. Here, our interest is in labour productivity, ideally measured as output per hour worked; however we use the output - employed ratio to remain consistent with the literature in this are and the available data utilised in other sections of this paper.

productivity in the Market Sector also appears to be converging and we disaggregate this sector further to investigate the source of this trend. Figure 4 contains graphs of the standard deviation for 9 sectors, grouped by dominant trend. The service sectors show the strongest tendency towards convergence. Table 1 contains the results of significance tests of the difference between the variance (the square of the standard deviation) at the beginning and at the end of the sample. Details of the test statistics are contained in a note to the table. Consistent with our graphical analysis, the difference is significant for all three aggregates and for the service sectors.

When labour productivity is constructed by measuring the labour input as employed persons, changes in average hours worked can affect the measurement and, therefore, the analysis of productivity convergence. We therefore repeat our analysis of convergence in labour productivity, measuring labour input as hours worked rather than persons employed. The results are contained in Figures 5 and 6 which is comparable to Figures 3 and 4. The graphs are broadly consistent. In comparing labour input measures from this database, Inklaar and Timmer (2009) note that average hours worked varies significantly across the sample, but this does not seem to substantially affect our measure of convergence.

Inklaar and Timmer (2009) consider convergence in total factor productivity (TFP). Trends in total factor productivity may be relevant to researchers

interested in cross country trends in technological progress and to researchers involved in the long term projection of economic growth. Although, the output – employed ratio is a crude measure of labour productivity, its construction is relatively straightforward and easy to understand. The construction of total factor productivity, however, requires the imposition of strong assumptions[16] that, in turn, create controversy in the interpretation of convergence results based on the constructs. Appendix A contains industry level standard deviation estimates and tests of significance for MFP. The service sectors show the strongest tendency towards convergence but overall the trends are not strong. A comparison with the results in Inklaar and Timmer (2009) suggests that the results are quite sensitive to the level of disaggregation. Given the issues involved in estimating and constructing MFP, our focus in this paper remains on labour productivity.

The next step in our analysis is to examine the extent to which aggregate labour productivity convergence trends are being driven by structural change. In Figure 7, we provide a simple indication of the effect of structural change on convergence. To gauge the effect of changes in the sectoral composition of output, we construct, for each country, a hypothetical labour productivity series, weighting each sector's contribution to aggregate labour productivity according to its relative share of total employment in the initial

[16] Generally, perfect competition with constant returns to scale.

period. Aggregate labour productivity is the weighted sum of individual sector productivities where the weights are the sectoral output shares in each period. If we fix these shares over time, the resulting series, when compared with the actual aggregate labour productivity series, provides an indication of the effect of structural change on productivity. After constructing this fixed weight aggregate productivity series for each country, we estimate our measure of spread across the sample and compare it to that for actual aggregate labour productivity.[17] Figure 7 contains these two series. Structural change drives the observed convergence in labour productivity. Whilst the test statistics support the hypothesis of convergence for the original series, as expected, the statistics do not conclusively support convergence for the adjusted series (see Table 2). Without structural change, we would not find convergence in labour productivity.

4. Structural Change and Development

In order to tie changes in the structure of economies to changes in productivity and convergence trends over time, we need to take a closer look at economic structure across countries and changes that occur in economic structure over time. Our framework for this analysis is inspired by the

[17] Note that this series and its associated test statistic is slightly different to that contained in Figure 3, due to a small difference within the database in the disaggregated data used to construct the two series for Korea.

development path model of Phillips and Sul (2003, 2007a, 2007b, 2009) and the empirical results on the relationship between economic structure and development contained in McKibbin and Stegman (2005). The theoretical literature concerned with structural change and development is comprehensive, but the link between structural change and convergence literature is not as well developed.

In Figure 2, we used a cross section of economies in different stages of development to create a *development path*. It is natural to now ask: how does economic structure evolve as countries move through this type of development path?

In the previous section, data limitations restricted our sample to 19 developed economies. In this section we are able to expand the sample and, importantly, include developing countries and regions.

McKibbin and Stegman (2005) disaggregate total output into three sectors: agriculture, industry and services; and examine cross country trends and relationships. Across the sample, there is no evidence in favour of convergence in output shares but there is evidence of a clear relationship between sectoral output share and GDP per capita. Figure 8 contains this relationship for each of the three sectors. There is a strong negative relationship between agricultural share and GDP per capita and a strong

positive relationship between service sector share and GDP per capita. Middle income economies are characterised by the highest industry sector shares. This evidence is consistent with the development literature that theorises that countries develop by restructuring their economies from predominantly agriculture into industry and then expanding into services.[18] Given the patterns in Figure 8, we replicate the cross sectional development path in Figure 2, replacing aggregate labour productivity with sectoral share for each of the three sectors: agriculture, industry and services. The resulting graphs are contained in Figure 9. The graphs for agriculture and services reflect the clear relationships seen in Figure 8. The graph for the industry sector also reflects the hump shape apparent in Figure 8, but the results are more varied. This reflects the diverse nature of the industry sector.

The trends in Figure 8 also help explain why McKibbin and Stegman (2005) failed to find evidence of convergence in output shares. Whilst some economies are restructuring away from agriculture into either industry or services or both, others are restructuring away from industry. If we restrict our analysis to the 19 economies considered in the previous section, we do see evidence of convergence in the output shares of agriculture and services and in the employment shares of agriculture and services (Figure 9). When we

[18] See Maddison (1980) and Jorgenson and Timmer (2011) for a more recent consideration of this issue utilising the same database we draw on in this paper.

disaggregate these broad sectoral groupings further however there are no strong trends, reflecting the diverse nature of the development process.

Important distinctions between sectors within industry, as well as sectors within the services classification, has led to the increasing use of alternative classifications, such as the disaggregation of activity into 'high tech' and 'low tech' sectors.[19] The growth experience of the Asian Tigers over second half of the 20th century, and comparisons with other economies in the region, supports the importance of this disaggregation. The growth experiences of Taiwan, Singapore, Hong Kong and Korea were characterised by structural change towards high tech, high productivity industry and service sectors.

Consider Figure 10, in which we have decomposed productivity growth over the period 1975 to 2003 into sectoral productivity and reallocation contributions for the four 'Asian Tiger' economies; as well as the Latin American developing country Argentina; and the developed countries, the United States and Australia. Singapore, Hong Kong and Taiwan all experienced strong contributions from the service and manufacturing sectors, reflecting the reallocation towards high productivity specialisations within these sectors. Even when pure productivity contributions are low, reallocation towards these sectors positively contributes to overall productivity growth. In

[19] Jorgenson and Timmer (2011) argue that, due to the increasing importance of service sectors in value added, employment and productivity growth and because of the high degree of heterogeneity within the services sector the "classical trichotomy" (p26) of agriculture, manufacturing, and services is no longer relevant.

Korea, structural reallocation was focused more towards high tech manufacturing and the productivity gains in this sector are clear. Reallocation towards service sectors was also important in determining overall productivity growth, even though the contribution to overall productivity growth from productivity within some service sectors was negative, due to the relatively high productivity *levels* with these sectors.

Compare this experience to the Latin American developing economy of Argentina. Reallocation has occurred away from agriculture into services where productivity has been relatively low and falling and has not occurred towards the relatively high productivity manufacturing sector.

If we consider the developed economies of the United States and Australia we see high productivity contributions from manufacturing and large contributions from reallocations towards service sectors. This appears to be a relatively consistent story across developed economies (see Appendix Table 1 for the full sample data). The largest productivity gains come through productivity increases in the manufacturing sectors and through reallocation towards relatively high productivity service sectors. In developing economies with low income levels the reallocation towards services is not as productive (that is, the reallocation is towards low productivity service industries) and this trend suggests the possibility of varied driving forces at different development levels. The structure of service sectors is very different in

developing and developed economies due, in part, to the effect of living standards on domestic demand. Overall, across the sample countries, reallocation effects contribute positively to productivity growth, although the sectoral contributions can be quite variable.

Structural change is important for development and it is an important determinant of convergence trends. In Section 3, we presented empirical evidence that convergence trends are not uniform across sectors, at least among medium to high income economies. Furthermore, changes in the structure of economies are an important determinant of convergence trends at the aggregate level. The sample used in section 3 was limited and left us asking what this evidence implies for convergence trends in general and for developing countries, in particular? Data limitations prevent us from undertaking the analysis in Section 3 over a wider cross section of countries; therefore, in this section, we have approached the issue differently. We have presented sectoral output data across a large cross section of countries and argued that countries appear to be on a 'development path', as suggested by Phillips and Sul (2003).[20] We argue that structural change, and the development of economies from predominantly agricultural through to

[20] Testing convergence, and considering possible drivers and determinants of convergence behaviour, is difficult in model with such a high degree of heterogeneity. Phillips and Sul (2009) provide empirical support for this type of model at the aggregate level using a new and innovative approach to convergence analysis based on the estimation of "transition parameters". Importantly, heterogeneity is allowed for in both the speed of convergence and rate of technological progress, through time and across countries. The application of this test to our sectoral data is restricted by limitations in our sample in the time dimension.

industry, high tech manufacturing and service orientated, is fundamental to movement along the path. Under this hypothesis, convergence and the mechanisms that drive it are significantly more complex than in a single sector neoclassical framework.

The empirical analysis of convergence presented in this paper suggests that:

- Rates of convergence are not uniform across countries, across industries or through time.

- Convergence studies based on developed economies consistently support a finding of aggregate convergence. These are economies that have restructured towards service sectors. At the industry level, service sectors exhibit convergence across a sample of developed economies. The combination of convergence in service sectors and structural change drives aggregate convergence across these economies.

- The growth experiences of developing economies are highly variable. Evidence across a large cross section of economies has been limited. The process of development is accompanied by continuous structural change. Although, at a point in time, countries appear very heterogeneous, if we consider their development path, they are remarkably similar.

- Broadly, as countries develop they appear to follow a similar pattern in terms of aggregate labour productivity and in terms of economic structure and broad industry composition. We interpret this as a "development path". As countries transition along on the path, they appear heterogeneous in their growth experience. Countries in the middle of the development distribution may exhibit a strong tendency towards convergence if they have restructured towards high tech manufacturing and are experiencing high rates of productivity growth whilst countries at the lower end may appear to diverge if they are slow to restructure or they restructure towards relatively low productivity level sectors. There are a range of possible variations in between.

- As countries develop and approach the frontier and their structures become similar and increasingly service sector orientated, standard convergence tests become significant.

5. Conclusions

The aim of this paper has been to uncover patterns in labour productivity trends that can be used to project long term economic growth. We focus on convergence and the relationship between sectoral productivity trends and

aggregate productivity trends. Our analysis suggests that convergence trends in labour productivity are quite heterogeneous across countries, across sectors and through time. The finding of aggregate labour productivity convergence across developed economies is not uniformly reflected at the sectoral level; only the service sectors exhibit trends consistent with convergence. Structural change is critical to the translation of sectoral labour productivity trends into aggregate convergence behaviour.

Although the analysis of convergence across developed and developing economies is limited by data availability, we argue that there does appear to be a consistent path of development that, ultimately, could imply aggregate convergence. Structural change is integral to the dynamics of this path.

With respect to projections of economic growth, if the analysis is restricted to developed economies, then an assumption of convergence in aggregate labour productivity is relatively simple to apply and consistent with empirical observation. If economic growth projections are undertaken at the sectoral level, however – and we believe that they should be[21] – it does not follow that an assumption of convergence at the sectoral level is necessarily appropriate. An alternative approach could be to combine convergence assumptions, for those sectors where the empirical evidence suggests such an assumption is

[21] See McKibbin, Pearce and Stegman (2007, 2009) for comprehensive argument of why a disaggregated approach to projections is needed.

appropriate, with development assumptions based on structural change.[22] Projections that involve developing economies are more complex, but the same idea could be utilised, where convergence assumptions are combined with assumptions regarding, or leading to, structural change along the development path.

The next step in our research is to undertake this type of modelling exercise; to develop a model of sectoral development that can be calibrated and used to test the existence of convergence and the role of structural change in determining development paths.

In conclusion, we return to the need for balance in model design. In practice, the process of development and structural change is complex. The assumptions that underlie projection exercises, however, should be straightforward and easily understood. Otherwise, debate will be focused on model design rather than policy design, as was recently the case in climate policy debate. We hope the results in this paper help to encourage robust and empirically relevant model design.

[22] For example, we could assume that countries follow a path of convergence in labour productivity with respect to service sectors and that they develop in such a way that they restructure their economies towards service sectors. In a well defined model this could result from changes in demand, and therefore relative prices, that occur through development.

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Figure 1: Labour Productivity
86 Countries and 5 Panel Averages

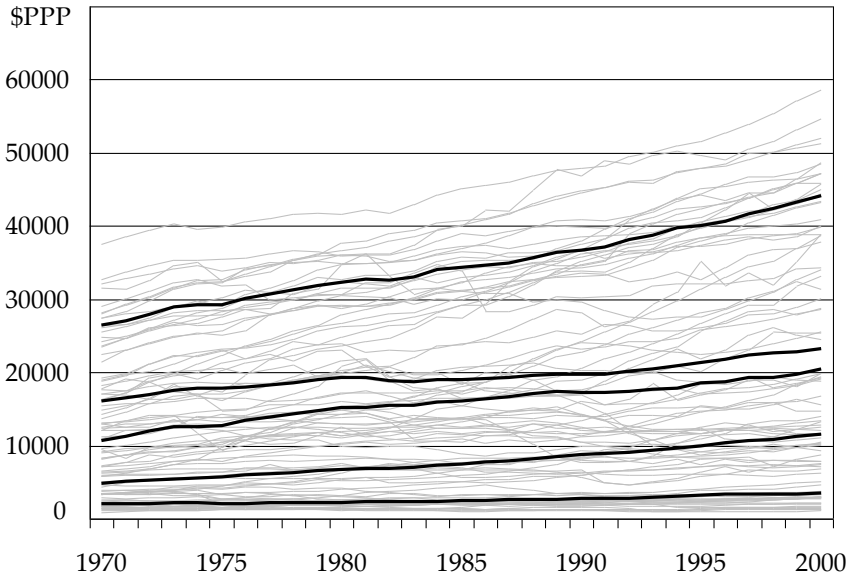


Figure 2: Labour Productivity for 5 Panel Averages over 30 years

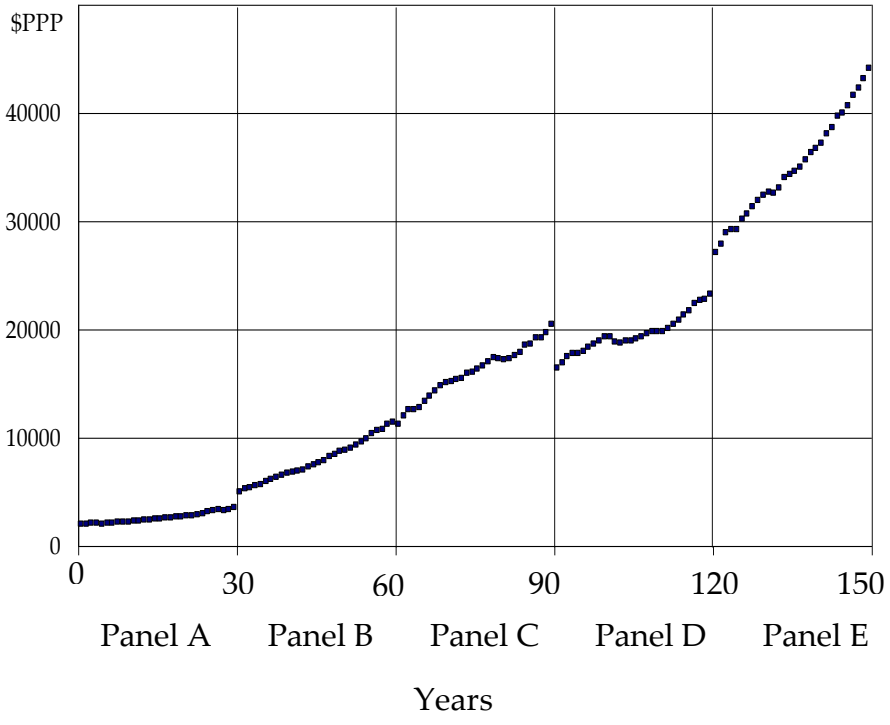


Figure 3: Measure of Spread for Labour Productivity

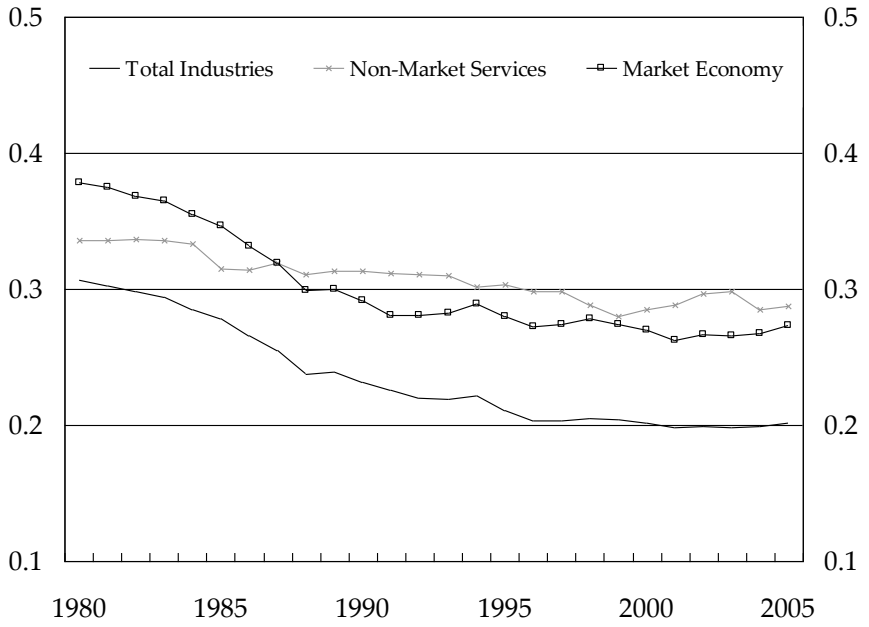
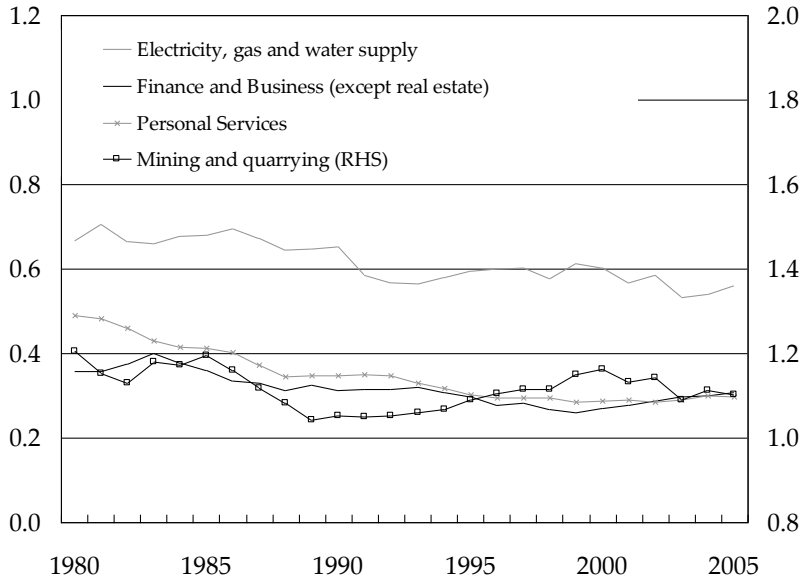
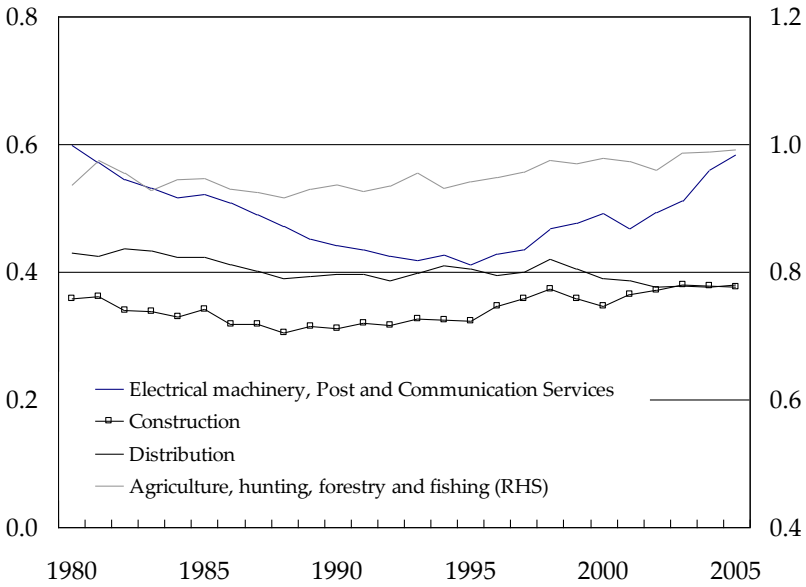


Figure 4: Measure of Spread for
Labour Productivity by Sector





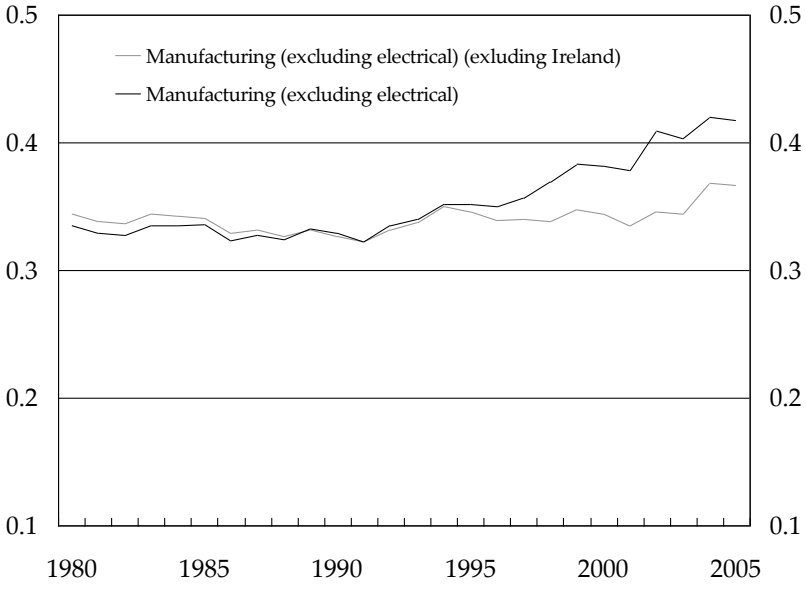


Table 1: Tests of Variance Equality, 1980 and 2005		
	Test 1	Test 2
Total Industries	7.02***	4.16***
Market Economy	4.80**	3.03***
Electrical machinery, Post and Communication Services	0.29	0.65
Manufacturing (excluding electrical)	0.29	-0.52
Mining and quarrying (RHS)	0.31	-0.58
Electricity, gas and water supply	0.50	0.79
Construction	0.02	-0.15
Agriculture, hunting, forestry and fishing	0.23	-1.00
Distribution	0.50	0.64
Finance and Business (except real estate)	2.82*	2.24**
Personal Services	10.94***	4.5***
Non-Market Services	3.53*	1.70**
Structural Adjustment Analysis		
Original	4.78**	2.82***
Adjusted	2.45	1.80*
Notes: ***, **, * indicates significance at the 1%, 5% and 10% level, respectively. Test 1 and Test 2 are the T2 and T3 test statistics derived in Carree and Klomp (1997).		

Figure 5: Coefficient of Variation for Labour Productivity Measured in Hours

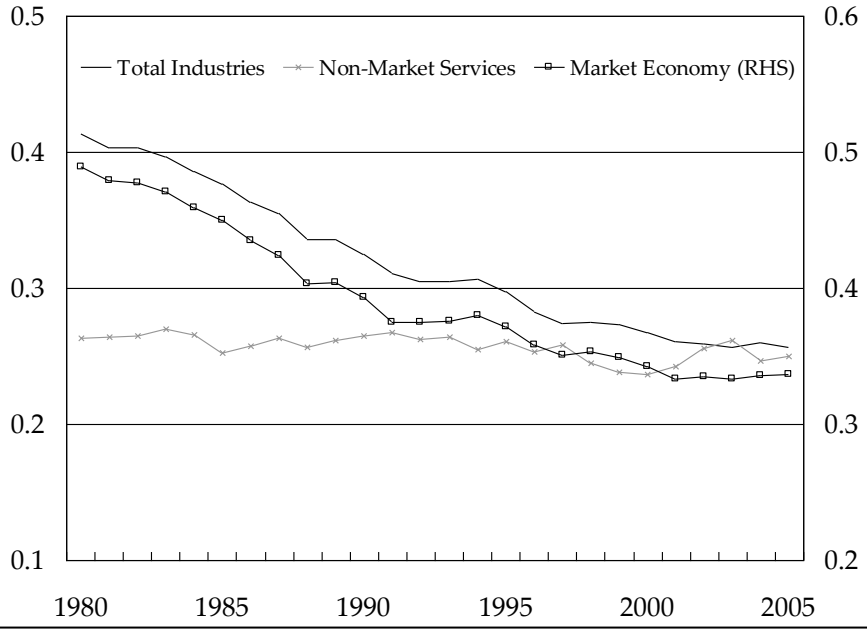
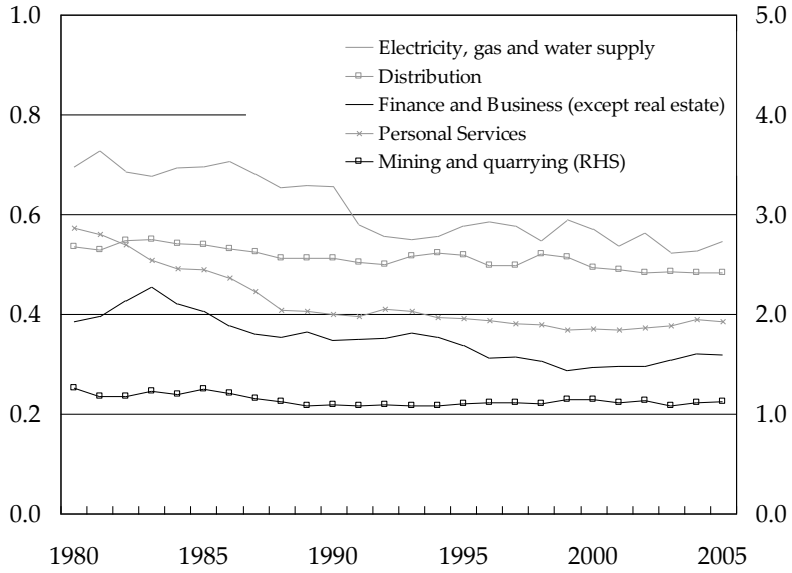


Figure 6: Coefficient of Variation for Labour Productivity Measured in Hours by Sector



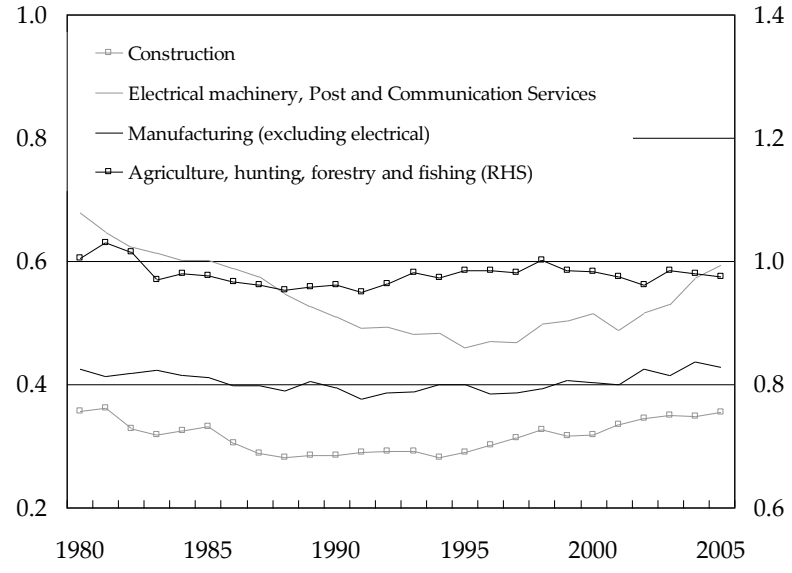


Figure 7: Spread Index for
Labour Productivity (Adjusted)

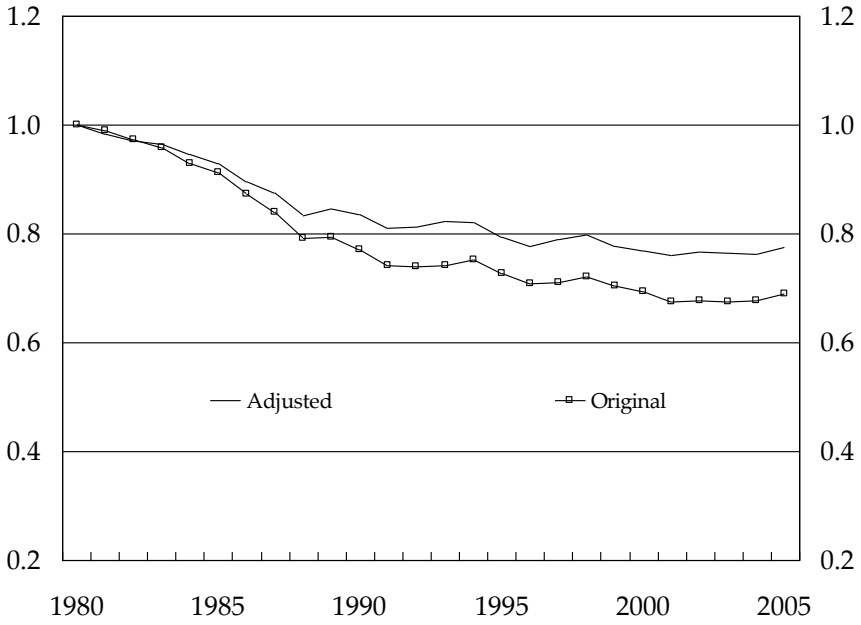
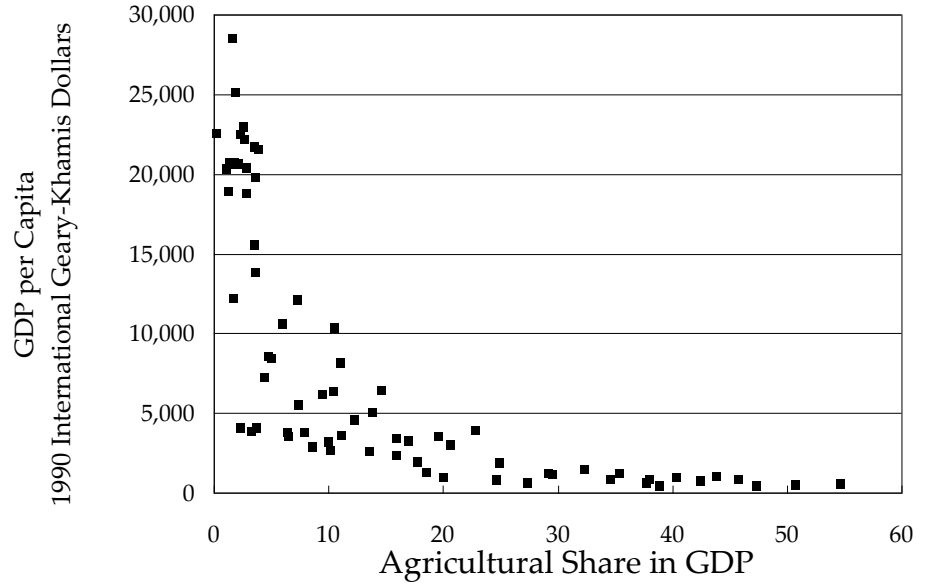
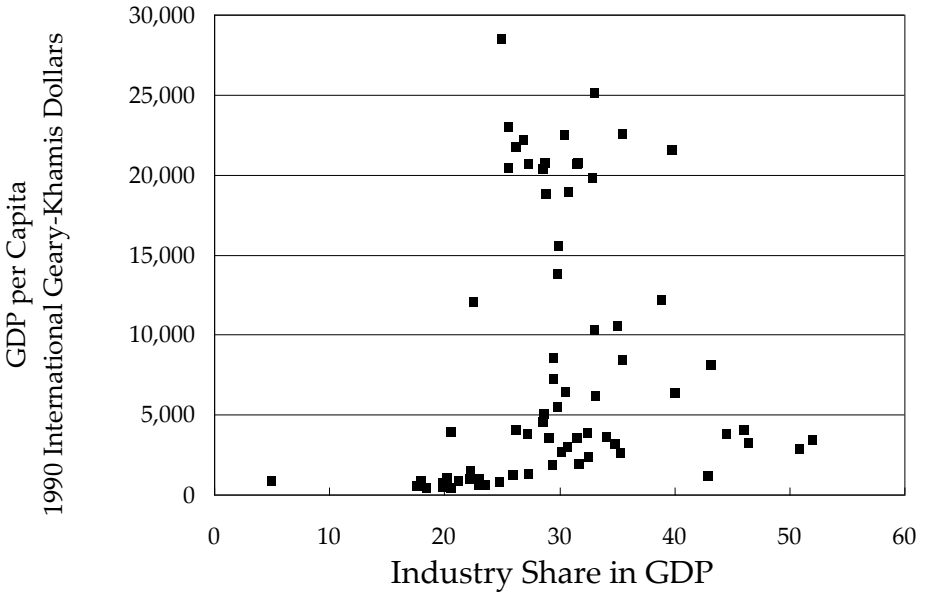


Figure 8: GDP per Capita and Sectoral Shares, 2000





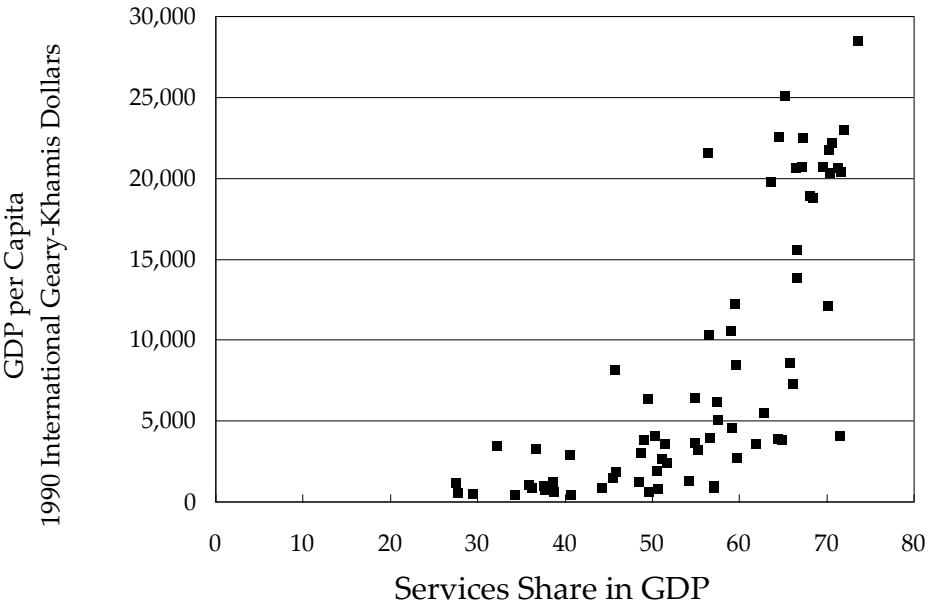


Figure 9: Consecutive Sectoral Shares
Ordered Panels by GDP per Capita in 1970
1970 - 2000

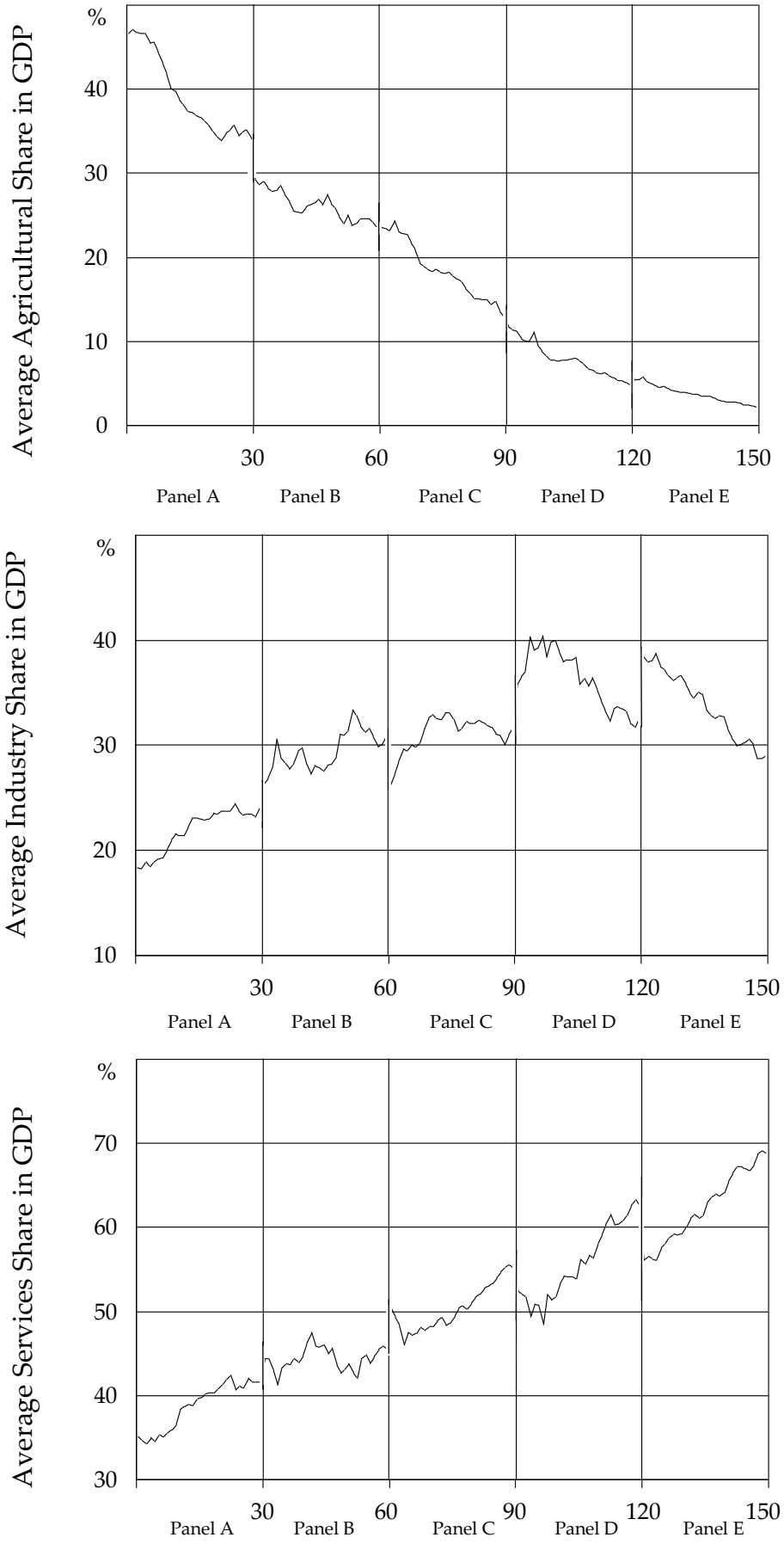
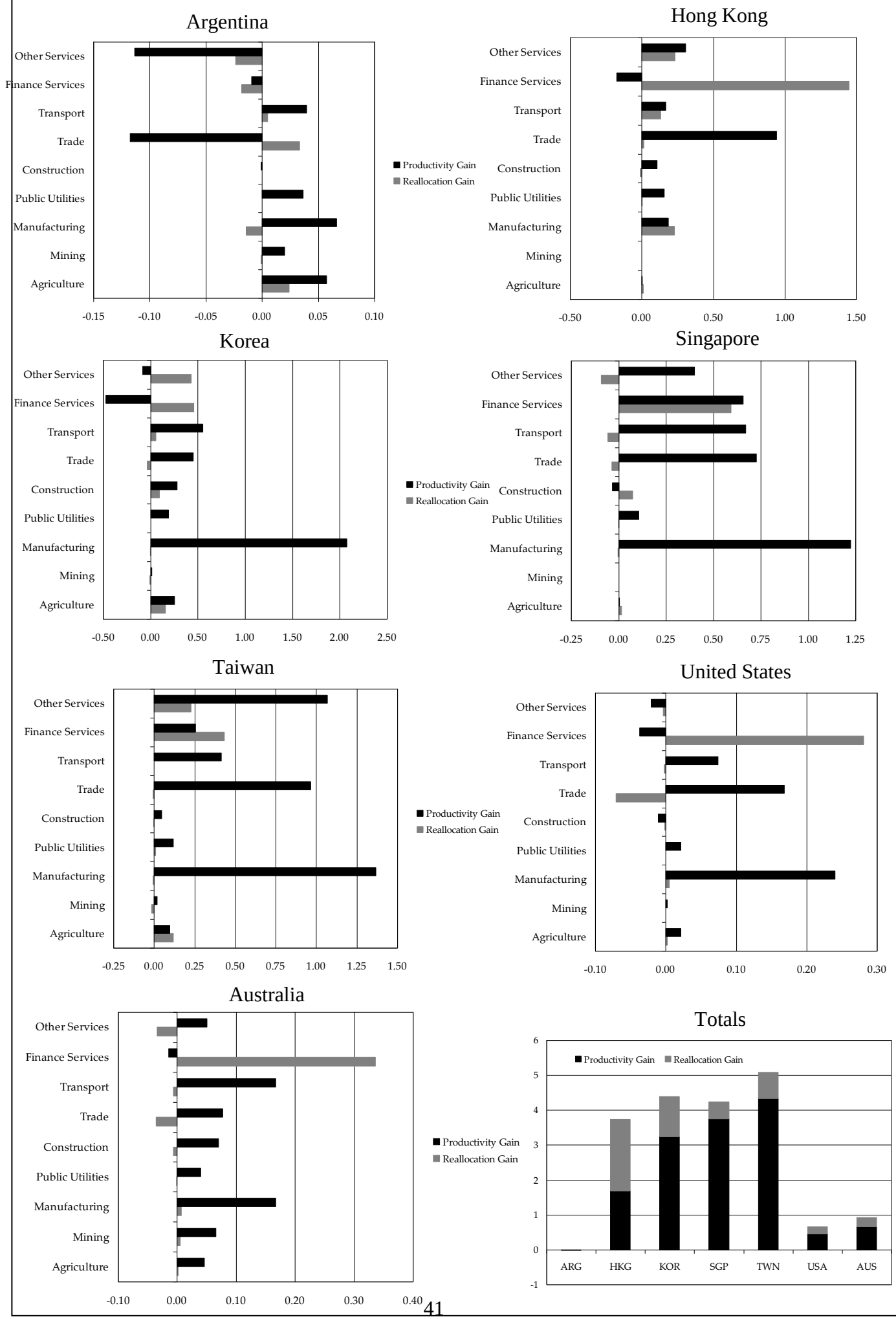


Figure 10: Disaggregation of Productivity Growth, 1975 – 2003



Appendix

Data Sources

Figure 1 and 2: The Conference Board Total Economy Database, January 2011, http://www.conference-board.org/data/economydatabase/. Countries included in the Figures are Albania, Algeria, Angola , Argentina, Australia, Austria, Bangladesh, Barbados, Belgium, Bolivia, Brazil, Bulgaria, Burkina Faso, Cambodia, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Cyprus, Czechoslovakia, Denmark, Dominican Republic, Ecuador, Egypt, Ethiopia, Finland, France, Germany, Ghana, Greece, Guatemala, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Italy, Jamaica, Japan, Kenya, Luxembourg, Malawi, Malaysia, Mali, Malta, Mexico, Morocco, Mozambique, Myanmar, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Senegal, Singapore, South Africa, South Korea, Spain, Sri Lanka, St. Lucia, Sudan, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Trinidad & Tobago, Tunisia, Turkey, Uganda United Kingdom, United States, Uruguay, USSR, Vietnam. Yugoslavia, Zambia

Figures 3, 4, 5, 6, 7, Appendix Figures A1 and A2, and Table 1: Author's calculations from data sourced from Inklaar, R. and Timmer, M.P. (2008). 'GGDC Productivity Level Database: International Comparisons of Output, Inputs and Productivity at the Industry Level', Groningen Growth and Development Centre Research Memorandum GD-104, Groningen: University of Groningen, September 2008 and the EU KLEMS database (described in O'Mahony and Timmer, 2009). Countries included calculations are Australia, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxemburg, Netherlands, Portugal, Spain, Sweden, United Kingdom and United States.

Figures 8 and 9: World Development Indicators 2002, The World Bank, SourceOECD (2004) http://www.sourceoecd.org/, Maddison (2004) http://www.eco.rug.nl/~Maddison/Historical_Statistics/horizontal-file.xls

Figure 10: Author's Calculations from data sourced from the Groningen Growth and Development Centre 10-sector database, www.ggdc.net, Timmer, Marcel P. and Gaaitzen J. de Vries (2009), "Structural Change and Growth Accelerations in Asia and Latin America: A New Sectoral Data Set" Cliometrica, vol 3 (issue 2) pp. 165-190.

Figure A1: Coefficient of Variation for
Total (Multi) Factor Productivity

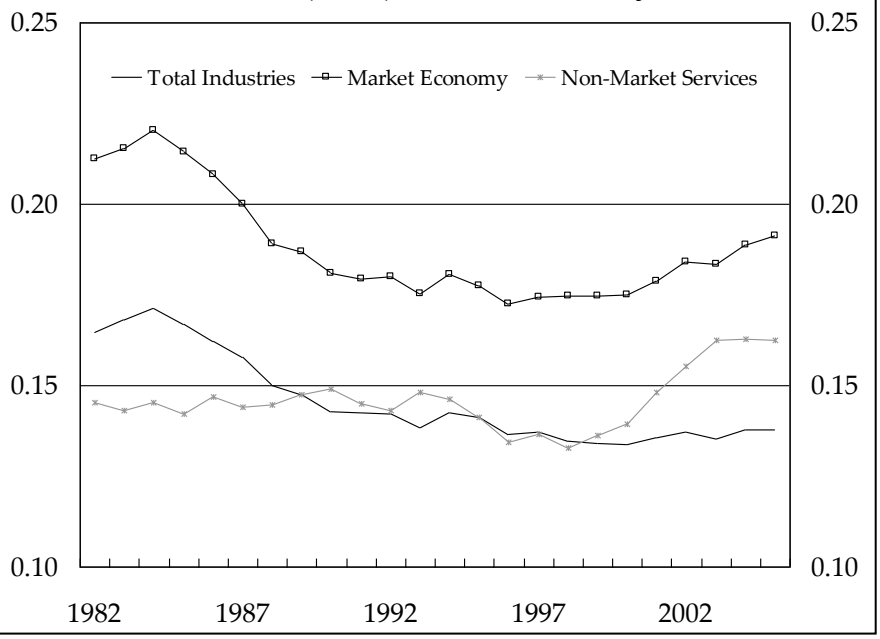


Figure A2: Coefficient of Variation for
Total (Multi) Factor Productivity