Fertility, income inequality, and labour productivity

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ABSTRACT

There is mounting evidence of a complex system of multi-directional links between fertility, productivity and inequality. The contribution of this study is a multi-country analysis of these three variables as a simultaneous system in a VECM framework using annual time series data for the UK, USA, Australia, Japan and Sweden. The results highlight some differences between countries in the relationships between the variables. For the UK and Australia, the VECM analysis reveals a long run relationship between fertility and productivity to which both fertility and productivity adjust. This calls into question pro-fertility policies in these countries that aim to offset the costs of population ageing, because an increase in fertility may be associated with lower productivity in the long run. The results for the USA suggest that raising productivity in the long run will be associated with a decrease in both inequality and fertility. No significant long run relationships were found for Japan and Sweden.

Keywords: Fertility, productivity, inequality, VECM models.

JEL: C3, E6, H3, O4

1. INTRODUCTION

The population ageing that is underway in most developed economies has spawned a vast literature over the last two decades on the macroeconomic implications of demographic change - in particular, the implications for economic growth, national saving and government budgets.[1]

Population ageing is best understood as a stage in the process of the demographic transition that accompanies economic development in which both mortality and fertility rates are falling, which eventually causes the dependency ratio to rise and the working age share of the population to fall (Bloom et al. 2001). The rise in the dependency ratio is generally accepted as the main source of the macroeconomic costs of population ageing. Other possible costs, and perhaps even benefits, are more contentious although potentially important (see references in previous footnote). For example, the effect of ageing on labour productivity is important because it could either offset or worsen the costs of ageing, depending on whether the effect is positive or negative. The direction and magnitude of the link between ageing and productivity is unresolved in theory and empirically, notwithstanding the considerable literature on this question.[2]

This ambiguity is at odds with the apparent presumption among policy makers that falling fertility rates necessarily have negative consequences for economic welfare. This has led to calls for pro-fertility policies in many OECD countries, such as subsidies to women upon the birth of a child, more generous maternity leave policies, child care subsidies and family assistance packages via the tax and transfer system. However, it is quite possible that raising fertility through such policies could be harmful for labour productivity, both directly and via human capital creation. This link is discussed further in the next section.

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[1] The following books provide excellent comprehensive discussions of the macroeconomics of population ageing: Onofri (2004), Disney (1998), Birdsall et al. (2001), Mason (2001), Bloom et al. (2002).

[2] See for example Chapters 4 to 7 in Birdsall, et al. (2001) and Chapters 1 to 8 in Mason (2001).

Also ambiguous is the evidence on the links between fertility and inequality, and between inequality and productivity. There is a large literature on the relationship between inequality and productivity. The traditional view that inequality and productivity are positively related has been challenged by a body of work over the last decade indicating that a negative link is quite possible (see Aghion, Caroli and Garcia-Penalosa, 1999, for a survey). Similarly, the link between fertility and inequality can operate in both directions and can be positive or negative. These arguments are outlined in the next section.

Together, this literature points to a complex system of multi-directional relationships between fertility, inequality and productivity, as illustrated in Figure 1.[3] Each variable is endogenous in this system and the sign of the link between any two variables is ambiguous. Despite the evidence that each of these three variables is linked to the other two, directly and/or indirectly, there have been no attempts to study these relationships as a system where all variables are endogenous. Galor and Zang (1997) investigated all three variables in a cross-country regression analysis but they took productivity growth as the dependent variable with the other two variables being regarded as exogenous. Hondroyiannis and Papapetrou (1999) conducted a VAR analysis of fertility and growth in which both are endogenous, but they do not consider inequality. The latter study is a time series analysis for a single country, the U.S. Time series analyses such as that in the Hondroyiannis and Papapetrou study are unusual but useful, because the typical cross-country regressions applied in the literature cannot address the important policy question of how changes in one of the three variables for a particular country affect the other two variables for that country. Such a question requires time series evidence as Forbes (2000) pointed out in the context of the link between inequality and growth. Aghion et al.

(1999) also called for the need for more time series evidence on the link between growth and inequality.

The purpose of this paper is to fill this gap in the literature by conducting a multi-country VECM[4] analysis of all three variables: fertility, inequality and productivity, using annual time series data for five OECD countries: UK, USA, Japan, Sweden and Australia. These countries are representative of the range of demographic profiles, productivity outcomes, and income distributions found in OECD countries. The paper can be seen as an extension of Hondroyiannis and Papapetrou (1999) by including inequality as an endogenous variable, backed by strong *a priori* evidence, and applying a VECM analysis after finding at least one cointegrating vector. The inclusion of inequality and the distinction between short and long run relationships turn out to be important extensions, at least for the data applied here. In particular, the results indicate that changes in inequality are important drivers of negative changes in productivity for the UK, USA and Australia in the short run but not in the long run; changes in productivity may be associated with negative long run effects on fertility in the UK and Australia, and on inequality and fertility in the USA; and that fertility may be associated with long run negative effects on productivity in the UK and Australia, but not in the USA, Japan or Sweden.

These results can inform the intense policy debate currently underway in OECD countries about the appropriate policy response to the costs of population ageing. Productivity growth is a way of offsetting the costs of population ageing. Many people also advocate an increase in the fertility rate in order to arrest the ageing of the population in the long run. Some even worry about low fertility per se, on the basis that falling population is inherently bad. However, the

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[3] Human capital is not included explicitly in the empirical analysis because, firstly, reliable time series data is not available; also, the link between human capital and productivity growth is unambiguously positive – hence any effect on human capital should be reflected in productivity growth.
[4] VECM stands for Vector Error Correction Model. See Section 3 for explanation.

analysis in this paper suggests that boosting fertility may be harmful for productivity in the long run in at least some countries and therefore may not be effective in offsetting the costs of population ageing – rather, it would have the opposite effect. Hence the twin goals of raising productivity and fertility may be incompatible. Also, the results suggest that in the short run lowering inequality may boost productivity but this may also be accompanied by lower fertility, which may not please the pro-fertility advocates.

A note on the choice of variables is warranted. We investigate the effect of changes in fertility and inequality on labour productivity growth rather than on economic growth. The reason for choosing labour productivity growth rather than economic growth can be explained using the following identity, where Y/N is output per person, Y/L is labour productivity and L/N is the employment to population ratio.

$$\frac{Y}{N} \equiv \frac{Y}{L}\frac{L}{N} \qquad (1)$$

Economic growth (defined here as growth in Y/N) is therefore the sum of growth in labour productivity and growth in L/N. The latter reflects changes in the age structure as a result of, for example, changes in fertility. For instance, the temporary high rates of fertility between 1945 and 1960 are now starting to lower L/N and drag down economic growth. This is well-known and uncontroversial. What is less clear but potentially important, is whether changes in fertility can affect Y/L growth and therefore economic growth. This is the important channel that we are interested in investigating and explains why we choose labour productivity growth rather than economic growth as the variable of interest.

The next section reviews the extant evidence on the links between various pairs of the three variables, as illustrated in Figure 1. Section 3 describes the data and the VECM methodology. The results are discussed in Section 4, followed by the conclusions in Section 5.

2. THE EVIDENCE ON BIVARIATE LINKS BETWEEN FERTILITY, INEQUALITY AND PRODUCTIVITY

Figure 1 provides some examples from the theoretical and empirical literature on the links between pairs of the three variables: fertility, productivity growth and inequality. The aim of the Figure is to highlight several aspects of the evidence. First, the links are bi-directional between any two variables. Second, the evidence is contradictory in that the link between two variables in a given direction is positive in some studies but negative in others. Third, the bi-directional links between two variables do not always reinforce each other, implying that the overall link could be either positive or negative. The evidence in Figure 1 is summarized below.

2.1 Inequality and productivity growth

For an extensive review of the evidence on the link between inequality and growth see Aghion et. al. (1999). The old view was that greater inequality was positive for productivity growth. This argument was put by Stiglitz (1969) in the context of a Solow growth model. He argued that since the marginal propensity to save of the rich is higher than that of the poor, a redistribution of income to the rich would increase saving and therefore growth. A positive link but with the causation running the other way, from growth to inequality, was found by Kuznets (1963) for countries in the early stages of economic development. He explained this by the shift in population from mainly rural to mainly industrial/urban activities during the process of development. Given that industrial activity generates a more unequal distribution of income than does rural activity, the population shift during the development phase leads to greater income inequality. More recently, Barro (2000) found empirical support for the Kuznets hypothesis.

Further support for a positive link running from growth to inequality is provided by Aghion et al. (1999, op. cit.). They find that the increase in income inequality experienced by many developed countries in the last one to two decades can be traced to technical progress, because the latter raises the premium for skilled labour and therefore increases income inequality. A more complex story for the positive growth to inequality link is offered by Violante (1996). The idea is that productivity is embodied in new vintages of capital and that the growth process creates heterogeneous vintages of capital operated by workers who are therefore also heterogeneous in terms of their skill levels and wage income, giving rise to increasing inequality as productivity grows.

An emerging alternative view, supported by empirical evidence, tends to be that the growth-inequality relationship is negative; hence reducing inequality enhances growth. There are two main strands to this view. One derives from developments in political economy research in which fiscal policy is modelled as endogenous and determined by majority voting rule (for example, Persson and Tabellini, 1994). In these models greater inequality leads to political pressure for redistributive taxation, on capital in particular, which reduces growth. Also, inequality can create political instability and therefore macroeconomic volatility which inhibits investment (Perotti, 1996). The second strand to the new view draws on developments in new growth theory that emphasise heterogeneous consumers and imperfect capital markets (Aghion et. al, 1999, op. cit., p.1621). For example, greater inequality may cause greater dispersion in the distribution of investments into human capital. This increases the variance of workers' skills and therefore workers may not "mesh" as efficiently, reducing labour productivity (Hayes et al.1994). Similarly, in the model of Galor and Zang (1997), which is supported by their empirical evidence, greater inequality reduces growth because it reduces the proportion of the workforce who are skilled.

2.2 Fertility and productivity growth

Fertility has been linked to productivity growth both directly and indirectly. A direct negative link is argued, for example, by Becker and Barro (1988) and Galor and Weil (1996). In the former paper, technical progress implies a higher rate of discounting of future utility which, in that model, requires a lower fertility rate. In the latter paper, productivity growth implies a rising capital-labour ratio which raises women's wages relative to men's wages because female labour is more complimentary with capital than is male labour. This raises the cost of children relative to income and therefore lowers fertility.

Indirect links between fertility and productivity growth can occur via human capital, with a lag of approximately a generation. Parents who have high levels of human capital face a high opportunity cost of having children which typically outweighs any positive income effect; hence human capital and fertility are negatively related (Becker et al., 1990). Human capital and productivity are positively related in the new growth theory (Lucas, 1988, and Romer, 1990, for example). Therefore productivity growth and fertility are negatively related via human capital. Also, with borrowing constraints on the provision of human capital, large families cannot afford to provide as much human capital per child as smaller families (Galor and Zang, 1997).

2.3 Fertility and Inequality

The final relationship in the system is between fertility and inequality. Again the causal links can run both ways and they are not necessarily reinforcing. Two studies are cited in Figure

1. In De La Croix and Dopke (2003) an increase in income inequality, for a given mean income, increases fertility because low income parents have more children than do high income parents. Also, low income parents invest relatively little in their children's education; hence an increase in inequality raises fertility and lowers human capital and therefore growth, albeit with a considerable lag. The authors establish these relationships both theoretically and empirically.

However, this positive link between inequality and fertility tends to contradict the negative link found empirically by Deaton and Paxton (1997), although the causation runs the other way – from fertility to inequality. They find that in the four countries they studied – US, Great Britain, Taiwan and Thailand – within cohort inequality increases substantially with age. The effect is robust and large in magnitude. Therefore lower rates of population growth (through lower fertility) will increase inequality by increasing within-cohort inequality, as the share of older and more unequal age groups increases. These effects would tend to cancel out the effects found in De La Croix and Dopke, leaving the link between fertility and inequality ambiguous.

The indirect link between fertility and growth that occurs through human capital operates with a considerable lag, perhaps up to a generation. An advantage of the VECM methodology is that it is able to identify and distinguish between short run and long run relationships, as long as the time series is of sufficient length.

3. DATA AND METHODOLOGY

The data consist of annual observations for the following periods: UK, 1961 to 2000; USA, 1960 to 2001; Japan, 1960 to 2000; Sweden, 1960 to 2002; and Australia, 1951 to 2001.[5] The three dependent variables are the total fertility rate, average labour productivity and the Gini

[5] These are the longest continuous periods for which data on all three variables are available at the time of writing.

coefficient of the distribution of income of individuals. Full details on data sources for each country are given in the Data Appendix.

Inequality as measured by the Gini coefficient is calculated from the distribution of income in deciles, as follows[6]:

$$Gini = 0.9 - 0.2\sum_{i=1}^{9} S_i \qquad (2)$$

where S_i is the cumulative share of total income received by the lowest i^{th} decile of individuals ranked according to their income. Inferences on income inequality can differ significantly according to the income definition and population coverage.[7] For this reason, the Gini series for the UK, USA, Japan and Sweden were taken from the UNU/WIDER World Income Inequality Database using the quality rankings given in the database for guidance in the selection of the most reliable data series for each country over the period (UNU-WIDER, 2005). Where more than one high quality Gini series was available for a particular country, the trends in each were compared to ensure that data from different sources were comparable. For example, the Gini series chosen for the UK is an annual series from the IFS Inequality Spreadsheet that uses disposable income per household weighted according to family members. This series shows a similar pattern over the period to the Gini series for the UK from the Luxembourg Income Study, which uses a different methodology but is available at only around five yearly intervals.

The Gini data for Australia are taken from Leigh (2005), who constructs a longer annual series derived from taxation statistics. Leigh (2005) also conducts comparisons which show that using tabulated statistics from income tax returns produces results for Australia that are

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[6] This is derived from the following approximation for the Gini coefficient (see for example Yao 1997, 1999): $Gini = 1 - \sum_{i=1}^{n} p_i \left(2\sum_{k=1}^{i} S_i - w_i \right)$ where w_i is the income share of the ith group, p_i is the relative population frequency of the ith group and S_i is defined above.

consistent with the results from other studies using less frequently available sources such as income surveys.[8]

The indicator of economic growth adopted here is the growth rate of average labour productivity. This is best defined as real GDP per hours worked. However, data on GDP per hours worked for the whole economy are not available for the full period for any of the estimated countries except Australia. Data on GDP per employed person was therefore used to represent labour productivity for the UK, USA, Japan, and Sweden. To compare the effects of the two measures, the VECM for Australia was estimated for both real GDP per hours worked and real GDP per employed person. The results of both estimations were similar, suggesting that the specific definition of productivity used has little effect on the relationships found.[9] Figures 2 to 6 plot, in log form, the Gini coefficient, the total fertility rate (TFR), and average labour productivity (Y/L) for the full sample period for each country.

Stationarity testing of the variables was performed using Augmented Dickey-Fuller (ADF) tests. In all cases, the three variables in log form, Y/L, Gini and TFR, were non-stationary but their first differences were found to be stationary. That is, all variables (in log form) were I(1).[10] It is therefore appropriate to use cointegration analysis to estimate the relationships between the variables, provided that the method chosen allows for the possible joint endogeneity of all three variables that is suggested by the past theoretical and empirical literature discussed in Section 2. The Johansen Maximum Likelihood procedure was selected for this reason, as the estimation is performed within a system of equations in which all variables are explicitly endogenous. It also provides parameter

[7] See Atkinson and Brandolini (2001) for evidence on this from the Netherlands.

[8] See also Guest and Doraisami (1994) for further justification of the use of the taxable income of individual taxpayers as the annual income variable.

[9] The results for Australia given below are for the preferred measure of labour productivity as real GDP per hours worked. Results of the estimation using real GPD per employed person for Australia are available from the authors on request.

[10] Full results of the ADF tests are available on request.

estimates for all the cointegrating, or long run, relationships that may exist between the variables, and allows hypothesis testing of restrictions on the coefficients of individual variables.

The system of equations estimated in the Johansen method is a vector error correction model (VECM) derived from a standard unrestricted vector autoregressive model (VAR) of lag length *k*. The VAR system of equations can be algebraically re-arranged into a VECM, written as:

$$\boldsymbol{\Delta z_t} = \boldsymbol{\Gamma_1 \Delta z_{t-1}} + \ldots + \boldsymbol{\Gamma_{k-1} \Delta z_{t-k+1}} + \boldsymbol{\Pi z_{t-1}} + \boldsymbol{\mu} + \boldsymbol{\Psi D_t} + \boldsymbol{\varepsilon_t} \qquad (3)$$

where $\boldsymbol{z_t}$ is the vector of variables (here Y/L, GINI and TFR), $\boldsymbol{\mu}$ is a vector of constants, and $\boldsymbol{D_t}$ a vector of other deterministic variables such as a time trend. The first group of terms on the right hand side of (3), up to and including $\boldsymbol{\Delta z_{t-k+1}}$, represents the short run lagged effects of differences in the three variables in $\boldsymbol{z}$, or $\boldsymbol{\Delta z}$, on each variable in the system. The next term, $\boldsymbol{\Pi z_{t-1}}$, is the error correction term (ECT) that represents the long run cointegrating relationships between the levels of the variables in $\boldsymbol{z}$. As all three variables are non-stationary, there may be up to two cointegrating relationships between them, with the number of cointegrating relationships given by the rank *(r)* of the matrix of long run coefficients $\boldsymbol{\Pi}$. If at least one cointegrating relationship exists, $\boldsymbol{\Pi}$ can be factorised into $\boldsymbol{\Pi} = \boldsymbol{\alpha\beta'}$ where $\boldsymbol{\beta'}$ is the coefficients on the individual variables in the long run or cointegrating vectors, and $\boldsymbol{\alpha}$ is the coefficients on the ECT itself, which represent the speed of adjustment to disequilibrium (Johansen, 1988, 1991; Johansen and Juselius 1990).

Johansen uses a canonical correlation technique, solved by calculating eigenvalues (λ_i), to provide a set of eigenvectors that form the maximum likelihood estimate of the long run coefficients $\boldsymbol{\beta}$. A likelihood ratio (LR) statistic, the Trace statistic is used to test the significance of the eigenvalues and thus to determine the maximum number of statistically significant vectors

(r) within β. Lag lengths for the Johansen estimation were determined by LR tests of paired comparisons of different lag lengths in the original VAR system, as described in Enders (1995). The choice was confirmed by residual analysis of the systems which showed that the included lags were sufficient to avoid serial correlation (see Table 2). Deterministic components were also included in the cointegrating relationships where indicated by tests of the joint hypothesis of both the rank order and the deterministic components using the Pantula principle, as described by Johansen (1992).

4. ESTIMATION RESULTS

The test statistics for the number of cointegrating vectors (r) in the Johansen estimation for each country are given in Table 1.[11] The trace statistic indicates the presence of one cointegrating vector in each of the systems for the UK, Australia and the USA. However, the null of no cointegrating vectors cannot be rejected in the systems for Japan and Sweden, indicating that there are no long run relationships between the three variables for these countries.

The apparent absence of a long run relationship between the three variables for Japan and Sweden may be due to differences in the data for these countries. For example, as Figure 6 shows, the fertility rate for Sweden has followed a distinct fluctuating "roller coaster" pattern over the period that is quite different from the marked decline in fertility since the early 1960s in the UK, USA and Australia. Similarly, in Japan, apart from a dramatic drop in the birth rate in 1966, fertility did not start to decline until the middle of the 1970s (see Figure 5).[12] Inequality in Sweden and Japan, as measured by the Gini series used here, has also not risen over the period to the extent that it has in the other three countries. However, the Gini series for these countries, particularly for Japan, are also from

[11] The results were obtained using CATS in RATS, version 2 (Dennis et al, 2005).
[12] We are grateful to the referees for pointing out that the drop in the birth rate in 1966 in Japan was the result of cultural beliefs relating to the "Year of the Fire Horse"(Azumi (1968) cited in Caudill (1973)). To test the influence

comparatively lower quality, and therefore less reliable, sources (UNU-WIDER, 2005). As the focus of this study is on the estimation of both long run and short run relationships in a VECM, no further estimations were conducted for Japan and Sweden.

The long run β coefficients on the individual variables in the ECTs for the UK, Australia and the USA are given in Table 2. The cointegrating vectors are all normalised on the coefficient for labour productivity (Y/L) to facilitate comparisons between countries, as this is the only variable that is significantly different from zero in the vectors for all three countries. Table 2 also gives the α or speed-of-adjustment coefficients on the long run ECT in the error correction model (ECM) for each variable in the system. The coefficients on the lagged differenced variables that represent the short run effects on each variable are shown in Table 3. In addition, Table 4 provides a brief summary of the short and long run effects for each country.

The stability of the estimated coefficients in the VECMs for the UK, Australia and USA were investigated by recursive estimation over the full period for each country. The hypothesis that the full sample estimate of the cointegrating vector is within the cointegration space for each subsample was accepted at the 5% significance level in all cases. This indicates that the long run coefficients in the cointegrating relationships for the UK, USA and Australia have remained constant over the period of estimation (Dennis et al, 2005).

The results reported in Table 2 for the UK and Australia show that these countries share a stable long run relationship between fertility and productivity in which inequality is not significant. The coefficient (α) on the long run relationship is also significant in the ECMs for Y/L and TFR for the UK and Australia, indicating that both fertility and productivity adjust to deviations from equilibrium in the long run relationship between them. However, the coefficient

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of this event, the TFR series for Japan was smoothed by linear interpolation and the data for 1965-1967 imputed. Reon fertility is much larger in the ECT for Australia, implying that an increase (decrease) in productivity is associated with a much larger decrease (increase) in fertility for long run equilibrium in Australia than in the UK. Both variables show a much larger, or faster, rate of adjustment to any disequilibrium in the long run relationship in the UK than in Australia.

The relationships between inequality and productivity and fertility in the short run for the UK and Australia are more complex (see Table 3). The short run coefficients for inequality are significant in the ECMs for productivity in the UK and for both productivity and fertility in Australia, indicating a role for inequality in affecting productivity and fertility over time horizons of one to two years. Increases in inequality (i.e. increases in GINI) lead to lower productivity growth in the UK and both lower productivity and higher fertility in Australia in the short run, although inequality is not significant in the long run relationship between productivity and fertility for either country. However, there is no evidence of effects of either productivity or fertility on inequality in Australia, in the short run or the long run. The coefficients on both the long run ECT and the short run differences of productivity and fertility are not significant in the ECM for inequality. This implies that inequality in Australia is weakly exogenous in the Granger causality sense for productivity and fertility in the short run, and for the parameters of the long run relationship between them. In the UK, inequality does not respond to deviations from the long run relationship between productivity and fertility, but is influenced by fertility with a one year lag.

The results of the estimation of the VECM for the USA are quite different. The long run coefficients in Table 2 show a stable relationship between labour productivity and the Gini coefficient in which fertility is not significant. However, the coefficient on the ECT (α) is

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estimation using the smoothed series made no significant difference to the results.

significant for both fertility and Gini but not for productivity. This indicates that labour productivity is weakly exogenous in the Granger causality sense for the parameters of the long run relationship. Thus both inequality and fertility will adjust to any deviation from the long run equilibrium between inequality and productivity, but productivity itself does not adjust. In the short run, however, productivity in the USA is influenced by both fertility and inequality. Productivity in the USA also has a short run influence on inequality but fertility shows no short run influences other than its own lags.

5. CONCLUSION

There is evidence of a long run relationship between fertility and productivity for Australia and the UK to which both variables adjust , and a relationship between productivity and inequality in the USA in the long run that also influences fertility. Productivity is affected by both fertility and inequality in the short run in all three countries. These results are consistent with much, but not all, of the theoretical and empirical evidence cited in Section 2, including the differences found between countries in the relationship between productivity and inequality. They highlight the complexities of the relationships involved, and the potential policy implications of these complexities for individual countries.

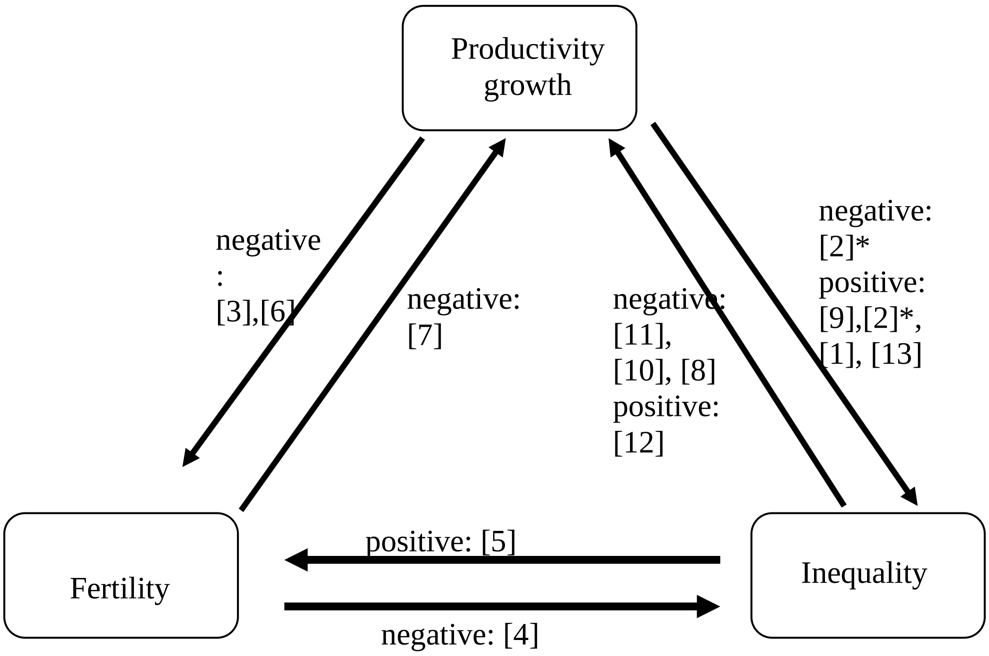
The long run relationship between fertility and productivity found for the UK and Australia has implications for the public policy response to the costs of population ageing in these countries. In particular, policies to boost fertility may not alleviate the costs of population ageing, even once the higher birth rate cohorts enter the workforce, because the higher employment to population ratio may be offset by lower labour productivity in the long run. One cannot, however, push this conclusion too far based on these results. Some pro-fertility policies may positively affect labour productivity in ways that are unrelated to their primary objective of raising the fertility rate. For example, child care subsidies may encourage human capital formation which would be positive for labour productivity.

For the USA, the results suggest that while policies to promote fertility or reduce inequality will not affect productivity in the long run, increasing productivity will reduce both inequality and fertility in the long run. This suggests a dilemma for those who would want to reduce inequality and raise fertility at the same time as promoting productivity growth.

In the short run, the results indicate that higher inequality leads to lower productivity growth in all three countries. To the extent that the relationship between inequality and productivity is negative, the results fit with the emerging views on the link between inequality and productivity cited in Section 2. However, this effect was not found in the results for any country in the long run. Perhaps inequality in the UK, Australia and the USA has not been sufficiently large for longer run effects to occur. The positive relationship between inequality and fertility found for Australia also fits with the evidence cited in Section 2, although only in the short run results. Again, perhaps in a high income country like Australia the effect is not strong enough to persist in the long run. As Figures 2-4 show, income inequality in the UK, Australia and the USA has trended upwards over the last two decades, at least in terms of the income measures used here. If this trend is seen as undesirable per se, the case for arresting it is not weakened by these results insofar as reducing inequality could boost productivity in the short run and at least do no harm to productivity or fertility in the long run.

The results found here raise important questions about the characteristics of individual countries or groups of countries that may influence both the size and nature of the relationships between productivity, fertility and inequality. The data in Figures 2 - 6 show the potential for correlation between the variables for different countries, for example, between fertility in the UK, Australia and USA, which suggests that these countries may be subject to common shocks such as the availability of the oral contraceptive pill. Further research is needed to identify potential common shocks and estimate their impact on the relationships for these countries. The timing of the effects is also clearly important. As the literature reviewed in Section 2 shows, the links between the three variables are based on long term considerations, such as the effects on labour productivity as population growth reduces capital endowment per worker. The analysis in this study aims to focus on the distinction between short and long run effects through the use of a VECM. However, very long term influences such as these, which may occur only when corresponding birth cohorts enter the workforce, may not be discernible here. Hence more research is needed for individual countries to check on country specific differences in the relationships over longer time periods, particularly with regard to the role of inequality.

Figure 1. Examples from the theoretical and empirical literature on the relationship between inequality, fertility, and productivity growth



* negative for low income countries and positive for high income countries, but overall the effect was found to be weak

[1] Aghion et al. (1999)
[2] Barro (2000)
[3] Becker and Barro (1988)
[4] Deaton and Paxton (1997)
[5] De la Croix and Dopke (2003)
[6] Galor and Weil (1996)
[7] Galor and Zang (1997)
[8] Hayes et al. (1994)
[9] Kuznets (1963)
[10] Perotti (1996)
[11] Persson and Tablellini (1994)
[12] Stiglitz (1969)
[13] Violante (1996)

Figure 2: TFR, GINI and Labour Productivity (all in log form) for the UK

(1961 = 100)

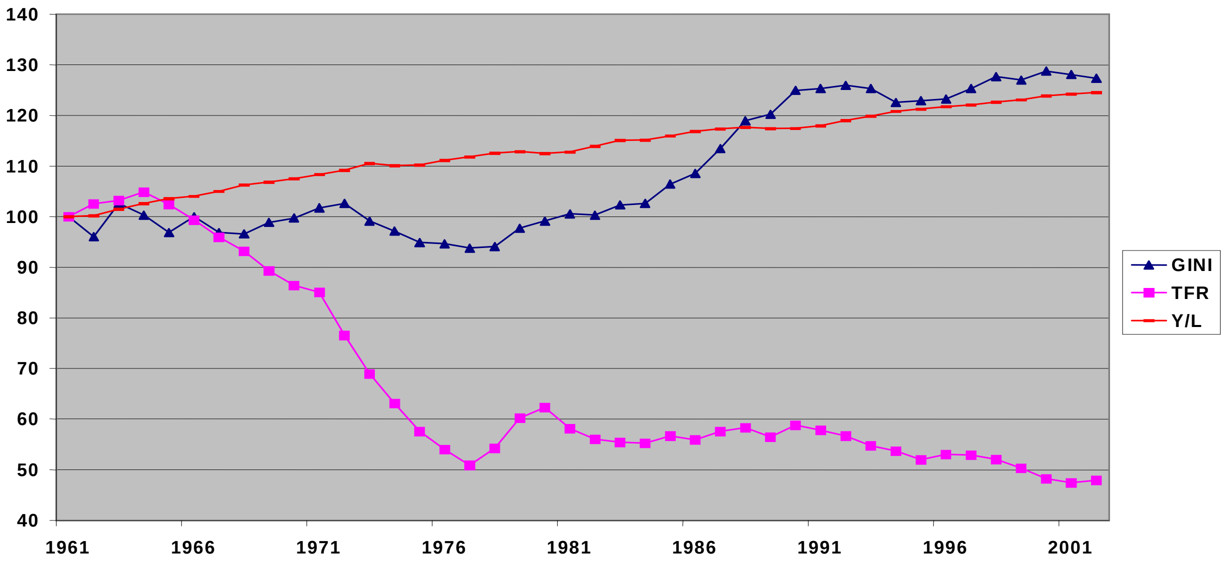


Figure 3: TFR, GINI and Labour Productivity (all in log form) for Australia

(1951 = 100)

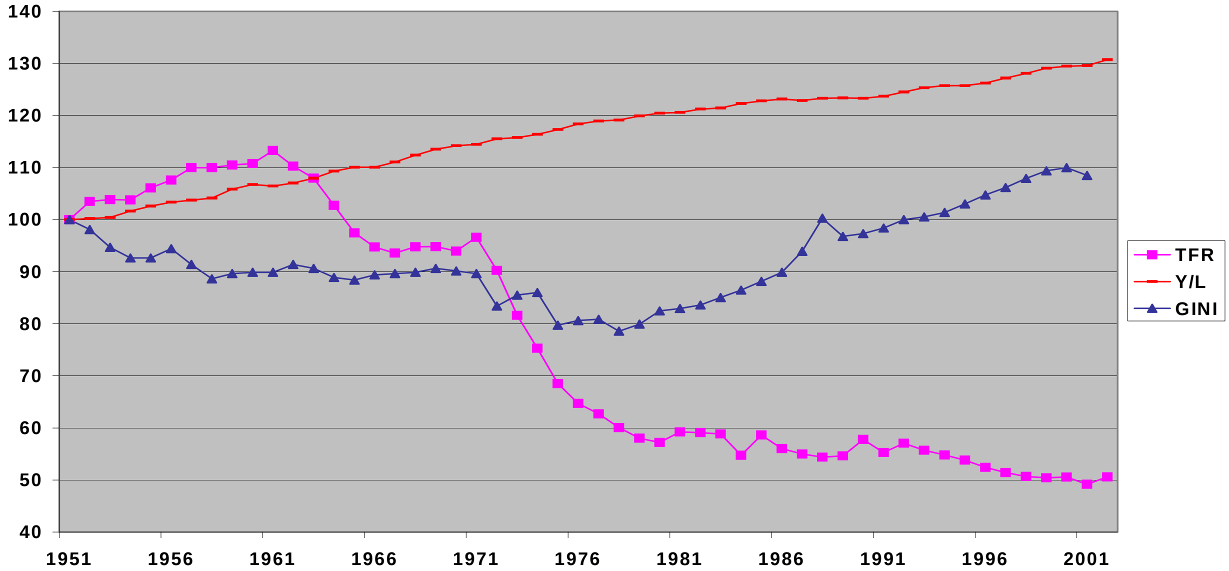


Figure 4: TFR, GINI and Labour Productivity (all in log form) for the USA

(1960 = 100)

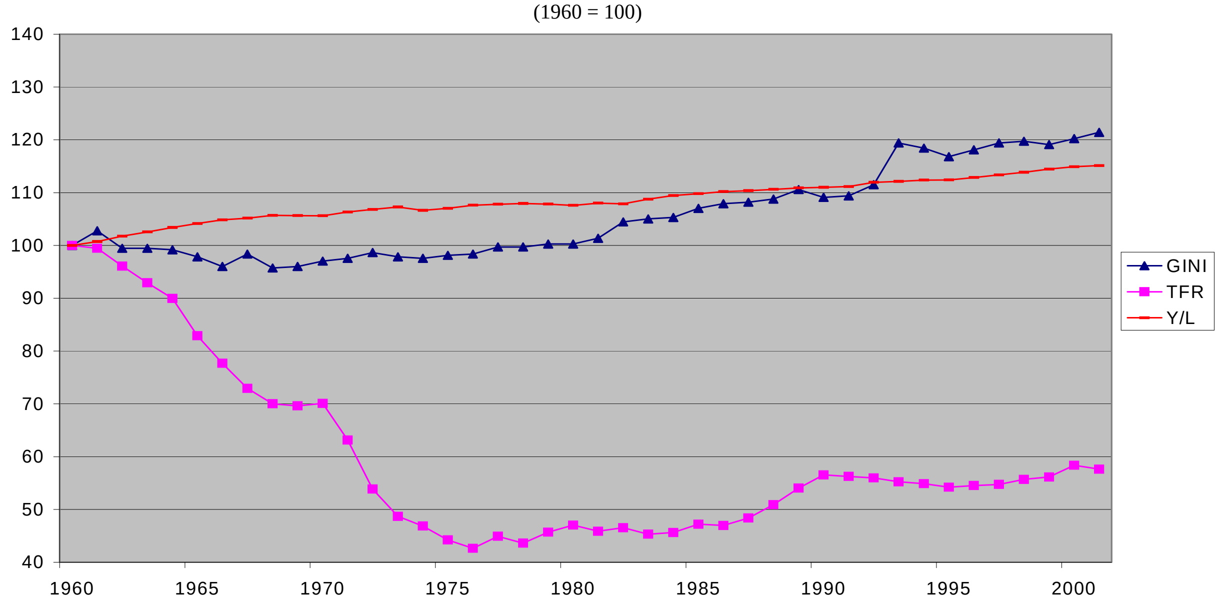


Figure 5: TFR, GINI and Labour Productivity (all in log form) for Japan

(1960 = 100)

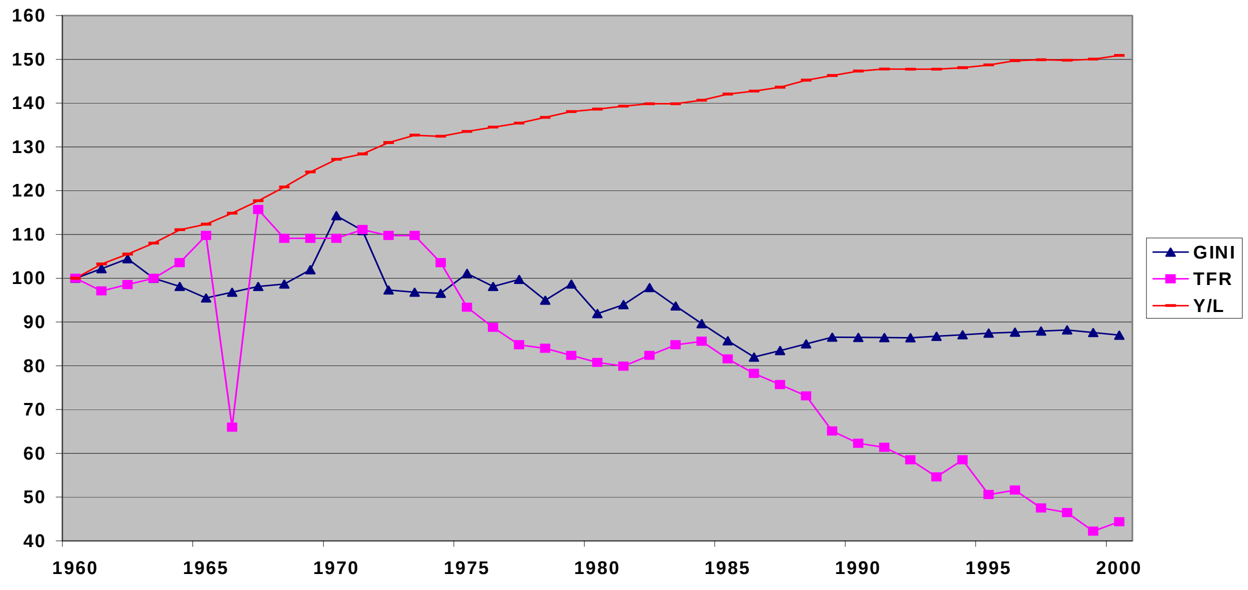


Figure 6: TFR, GINI and Labour Productivity (all in log form) for Sweden

(1960 = 100)

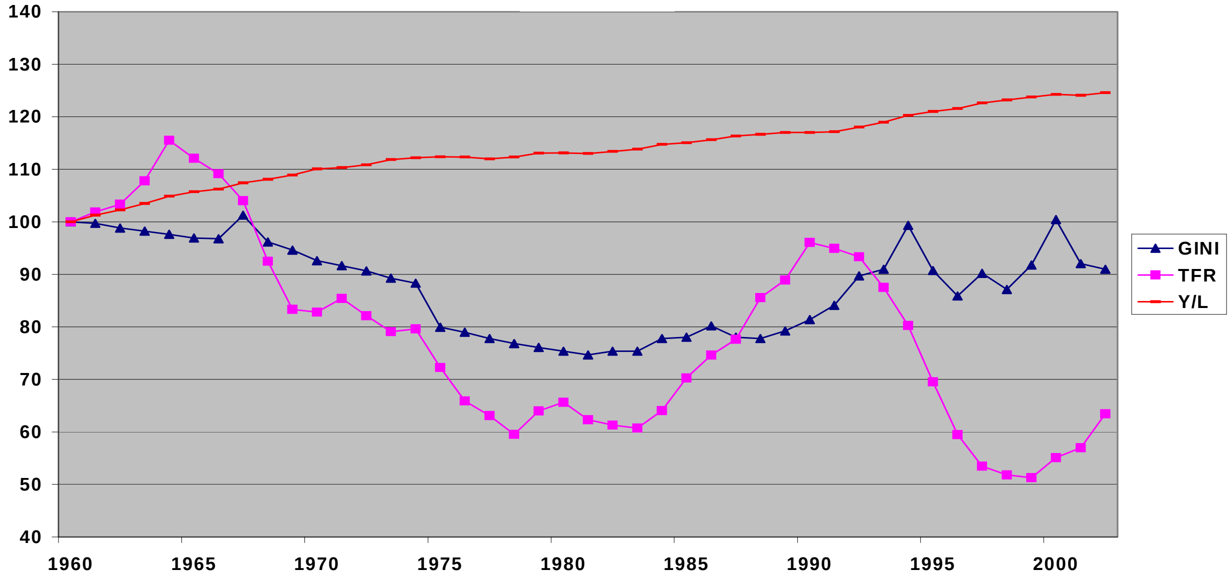


Table 1: Rank Test for determination of number of cointegrating vectors

	Null	Eigenvalues	Trace Statistic[1]	*p*-value
UK	r = 0	0.591	43.630*	0.041
	r = 1	0.343	19.582	0.253
	r = 2	0.239	9.519	0.154
Australia	r = 0	0.603	53.845*	0.000
	r = 1	0.344	3.268	0.997
	r = 2	0.197	4.404	0.367
USA	r = 0	0.480	43.691*	0.040
	r = 1	0.382	21.904	0.145
	r = 2	0.294	9.852	0.136
Japan	r = 0	0.430	27.665	0.646
	r = 1	0.218	9.200	0.947
	r = 2	0.185	5.018	0.601
Sweden	r = 0	0.407	34.396	0.275
	r = 1	0.283	17.034	0.420
	r = 2	0.183	7.450	0.309

[1] Uses the small sample correction of the trace test derived in Johansen (2000, 2002).
* Denotes significance at 5%.

Table 2: Long run coefficients of the VECMs

	Y/L	TFR	GINI
UK			
β coefficients of the error-correction term (ECT)[1]	1.000	0.230* (6.212)	– 0.082 (-1.621)
Equations of the system:			
Dependent variable[2]	dY/L_t	$dTFR_t$	$dGINI_t$
Coefficient on the ECT (α)	– 0.437* (-2.356)	– 0.825* (-2.450)	0.433 (1.365)
$\bar{R}^2$	0.592	0.616	0.584
LM test for autocorrelation of the system: p-value = 0.163			
Doornik-Hansen test for normality of the system: p-value = 0.769			
Australia			
	Y/L	TFR	GINI
β coefficients of the error-correction term (ECT)[1]	1.000	1.447* (8.860)	– 0.044 (-0.108)
Equations of the system:			
Dependent variable[2]	dY/L_t	$dTFR_t$	$dGINI_t$
Coefficient on the ECT (α)	0.044* (7.548)	– 0.039* (-3.339)	– 0.003 (-0.214)
$\bar{R}^2$	0.426	0.548	0.274
LM test for autocorrelation of the system: p-value = 0.900			
Doornik-Hansen test for normality of the system: p-value = 0.052			
USA			
	Y/L	TFR	GINI
β coefficients of the error-correction term (ECT)[1]	1.000	– 0.060 (-0.904)	1.553* (3.824)
Equations of the system:			
Dependent variable[2]	dY/L_t	$dTFR_t$	$dGINI_t$
Coefficient on the ECT (α)	0.070 (0.930)	– 0.452* (-2.745)	– 0.296* (-4.340)
$\bar{R}^2$	0.473	0.688	0.588
LM test for autocorrelation of the system: p-value = 0.654			
Doornik-Hansen test for normality of the system: p-value = 0.550			

[1] Coefficients are normalised on Y/L and written in the form: ECT = Y/L + β_2 TFR + β_3 GINI
[2] Prefix "d" indicates first difference of each variable.
* Denotes significance at 5%. *t*-values are given in brackets below each coefficient.

Table 3: Short run coefficients of the VECMs

Dependent Variable[1]	dY/L_{t-1}	dY/L_{t-2}	dY/L_{t-3}	$dTRF_{t-1}$	$dTFR_{t-2}$	$dTFR_{t-3}$	$dGINI_{t-1}$	$dGINI_{t-2}$	$dGINI_{t-3}$
	Short-run coefficients[2]								
UK									
dY/L_t	0.552*	-0.059	0.201	-0.307*	0.099	0.037	0.102	0.025	-0.154*
	(2.773)	(-0.392)	(1.219)	(-3.413)	(0.920)	(0.368)	(1.057)	(0.286)	(-2.216)
$dTFR_t$	0.416	0.407	0.274	0.563*	-0.177	-0.142	0.123	0.076	-0.009
	(1.217)	(1.476)	(0.914)	(3.446)	(-0.905)	(-0.780)	(0.706)	(0.485)	(-0.071)
$dGINI_t$	-0.193	-0.311	0.032	0.525*	0.095	-0.178	-0.135	0.031	0.340*
	(-0.533)	(-1.196)	(0.112)	(3.404)	(0.516)	(-1.036)	(-0.821)	(0.211)	(2.850)
Australia									
dY/L_t	0.137	-0.555*		0.138*	-0.179*		-0.124*	-0.128*	
	(1.115)	(-4.327)		(2.020)	(-2.719)		(-2.036)	(-2.122)	
$dTFR_t$	0.560*	0.284		0.231	0.321*		0.246*	0.157	
	(2.301)	(1.124)		(1.709)	(2.474)		(2.042)	(1.315)	
$dGINI_t$	-0.081	0.248		-0.214	0.278		0.134	-0.091	
	(-0.280)	(0.826)		(-0.336)	(1.807)		(0.937)	(-0.639)	
USA									
dY/L_t	0.052	0.096		-0.121	0.227*		0.028	-0.214*	
	(0.309)	(0.536)		(-1.444)	(2.829)		(0.228)	(-1.784)	
$dTFR_t$	0.548	0.430		0.554*	-0.242		-0.012	0.167	
	(1.498)	(1.090)		(3.010)	(-1.375)		(-0.046)	(0.636)	
$dGINI_t$	0.492*	-0.076		-0.017	-0.109		-0.037	-0.227*	
	(3.253)	(-0.467)		(-0.222)	(-1.506)		(-0.327)	(-2.084)	

[1] Prefix "d" indicates first difference of each variable.
[2] Lag lengths of 4 lags for UK and 3 lags for Australia and USA were determined by LR tests of paired comparisons of different lag lengths in the original VAR system.
* Denotes significance at 5%. *t*-values are given in brackets below each coefficient.

Table 4: Summary of long run and short run effects in the VECMs for the UK, Australia and USA

		VARIABLES		
		Y/L	TFR	GINI
UK	Long run influences	TFR (-ve)	Y/L (-ve)	None
	Short run influences[1]	TFR (-ve) GINI (-ve)	Own lags only	TFR (+ve)
Australia	Long run influences	TFR (-ve)	Y/L (-ve)	None
	Short run influences[1]	TFR (t-1:+ve; t-2:-ve) GINI (-ve)	Y/L (+ve) GINI (+ve)	None
USA	Long run influences	None	Diseqm. in ECT between Y/L and GINI (-ve)	Y/L (-ve)
	Short run influences[1]	TFR (+ve) GINI (-ve)	Own lags only	Own lags only

[1]Own lags of a variable are not included here if other variables are significant.

DATA APPENDIX

UK (1961-2002)

TFR: Office for National Statistics, Total Fertility Rate (UK); *GINI*: UNU/WIDER World Income Inequality Database, series from the IFS Inequality Spreadsheet derived from the Family Expenditure Survey and the Family Resources Survey; *Y/L*: OECD Economic Outlook Statistics and Projections, Labour productivity of the total economy (United Kingdom).

USA (1960 – 2001)

TFR: Population Reference Bureau, US Total Fertility Rate, (All Races); *GINI*: UNU/WIDER World Income Inequality Database, series from the US Census Bureau derived from the Current Population Survey; *Y/L*: OECD Economic Outlook Statistics and Projections, Labour productivity of the total economy (United States).

Australia (1951 – 2001)

TFR: Australian Bureau of Statistics (ABS), Cat. no. 3105.0.65.001, Australian Historical Population Statistics, Table 39; *GINI*: series from Leigh (2005), p.S65, Table 1, derived from taxation statistics; *Y/L*: Real GDP from ABS, Cat. no. 5206, hours worked from ABS Cat. no. 5204, OECD Economic Outlook Statistics and Projections, Labour productivity of the total economy (Australia).

Japan (1960-2000)

TFR: National Institute of Population and Social Security Research, Population Statistics of Japan, Table 4.3; *GINI*: UNU/WIDER World Income Inequality Database, series from the Japanese Statistics Bureau derived from the Family Income and Expenditure Survey and the Survey of People’s Living Conditions; *Y/L*: OECD Economic Outlook Statistics and Projections, Labour productivity of the total economy (Japan).

Sweden 1960 – 2002)

TFR: Council of Europe, Demographic year book, Sweden, Table 3; *GINI*: UNU/WIDER World Income Inequality Database, series from the Sweden CSO derived from the Income Distribution Survey; *Y/L*: OECD Economic Outlook Statistics and Projections, Labour productivity of the total economy (Sweden).

APPENDIX: Testing the stability of the model parameters

Figures A1 to A6 show the results of tests of the constancy of the β coefficients of the cointegrating vectors for the UK, Australia and the USA. They are obtained by a recursive estimation procedure that tests the difference between $\beta^{(n)}$ and $\beta^{(T)}$, where $\beta^{(T)}$ is the full sample estimate of the cointegrating vector, and $\beta^{(n)}$ is obtained by successively estimating the model using increasing subsamples from ($t = n$) to ($t = T$), where ($t = 1, . . . n$) provides the base sample for the recursive estimation. In order to test parameter constancy across the whole period, all of the models were estimated using both forward and backwards recursion, that is, using the first half of the sample as the base to recursively test the stability of the parameters in the second half of the period, and vice versa. The test statistic, Q_T, is calculated as described in Dennis et al (2005, p.163,), and is derived from Hansen and Johansen (1999).

In Figures A1 to A6, the test statistic labelled "*X(t)*" represents the estimated cointegrating relations as a function of the short-run dynamics and deterministic components, whereas the test statistic labelled "*R1(t)*" is corrected for the short-run effects and represents the "clean" cointegrating relation which is actually tested for stationarity to determine the cointegrating rank and provides the estimated β coefficients shown in Table 2. All the test statistics in the Figures are indexed so that the 5% critical value is equal to 1.00 for ease of comparison. In all the Figures, the test statistics are well below the 5% critical value for the whole period, indicating that the long run coefficients of the cointegrating relationships for the UK, USA and Australia have remained constant over the period of estimation.

Figure A1: Test of Beta Constancy for UK

5% C.V. = 1.00 (2.63 = Index)

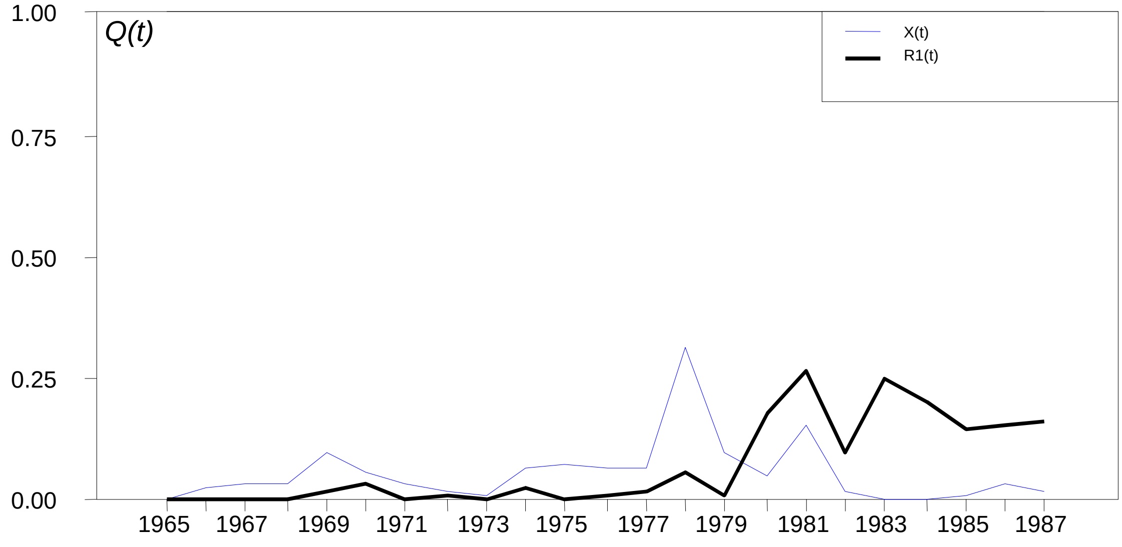


Figure A2: Test of Beta Constancy for UK

5% C.V. = 1.00 (2.63 = Index)

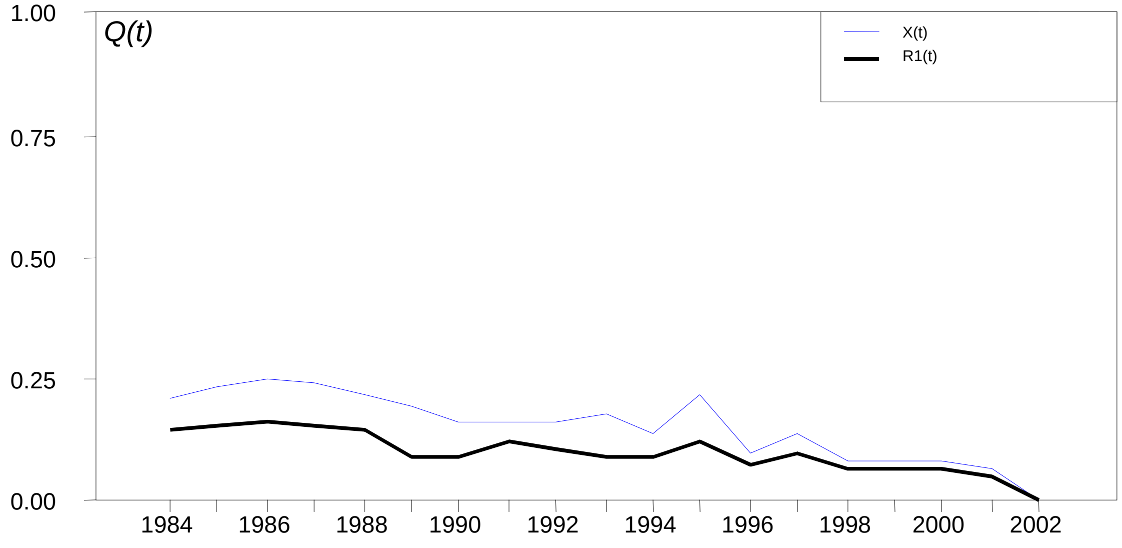


Figure A3: Test of Beta Constancy for Australia

5% C.V. = 1.00 (2.4 = Index)

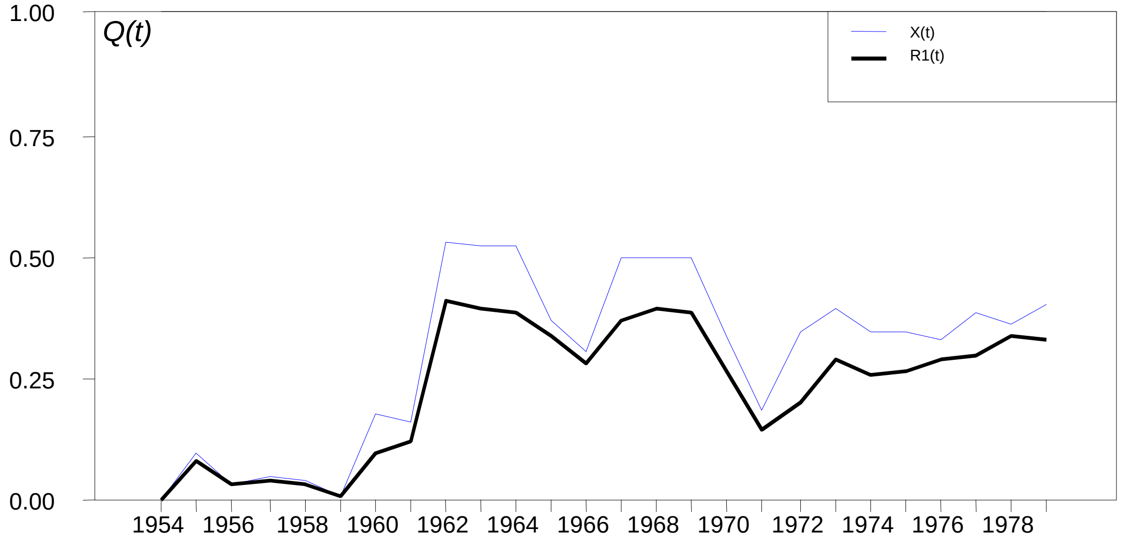


Figure A4: Test of Beta Constancy for Australia

5% C.V. = 1.00 (2.4 = Index)

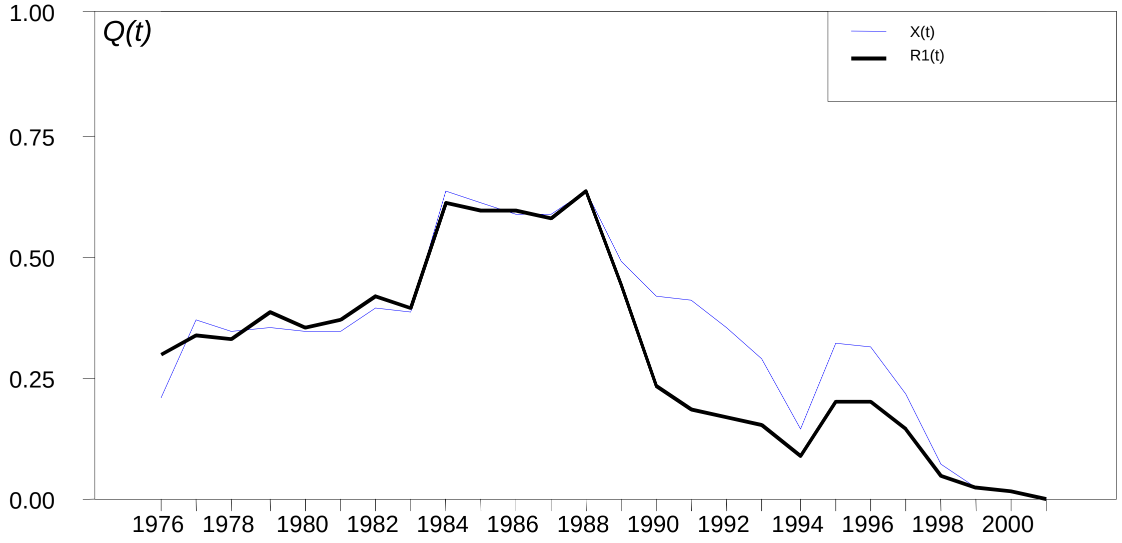


Figure A5: Test of Beta Constancy for USA

5% C.V = 1.00 (2.63 = Index)

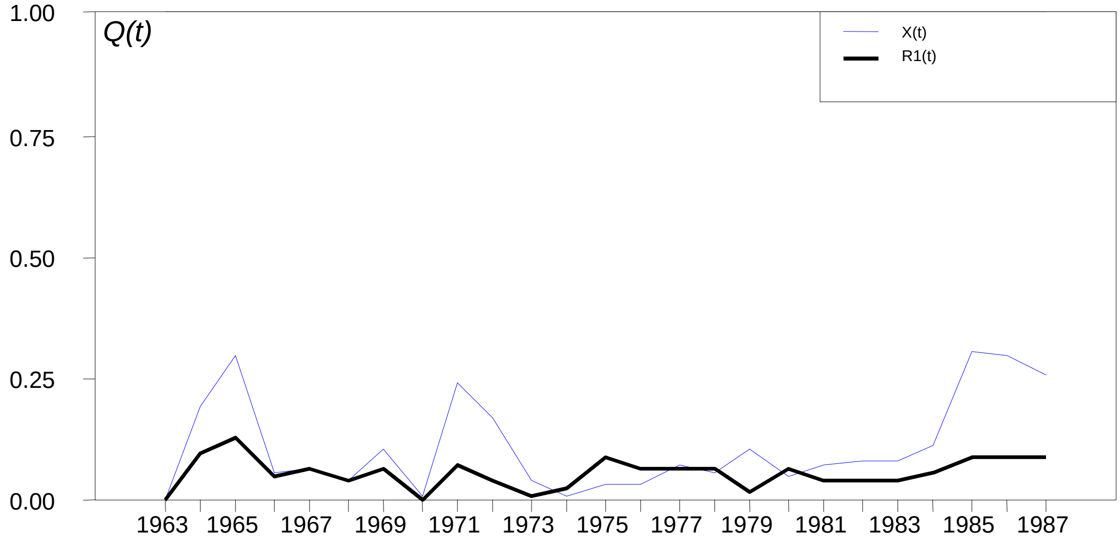
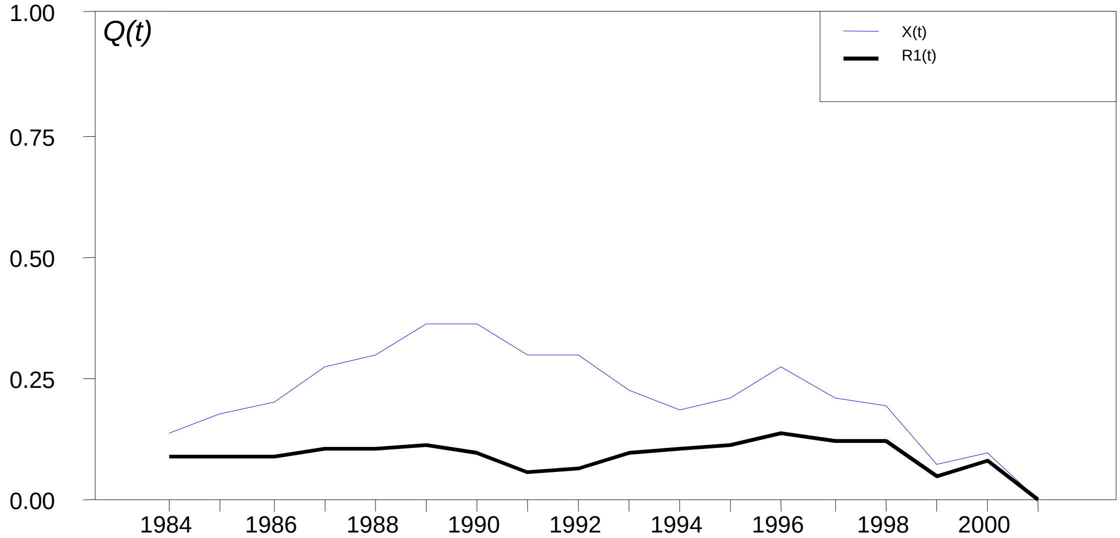


Figure A6: Test of Beta Constancy for USA

5% C.V. = 1.00 (2.63 = Index)



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