Sources of Persistence in Cross-Country Income Disparities:

A Structural Analysis*

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Abstract

This study investigates the sources of cross-country income disparities in time series dynamics for both aggregate and sectoral levels. We first introduce a new approach for testing income disparity persistence. The method proposed by Pesaran, Pierse, and Lee (1993) is then used to decompose the persistence into components due to various shocks. By using the quarterly data of the US, UK, and Canada from 1961:1 to 1996:4, we find the persistence of aggregate income disparities is caused by the divergence in the non-agricultural sectors. In addition, macroeconomic shocks are quantitatively not as important as sector-specific shocks in driving the persistence.

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1. Introduction

One of the major empirical research topics in growth theory is the analysis of the convergence hypothesis implied by the neoclassical growth model. This hypothesis states that economies with similar structural parameters should converge in living standards to the same steady state levels and growth rates, provided that the economies exhibit diminishing returns to capital. Many empirical studies designed to test this hypothesis in a cross-sectional framework have found supportive evidence [e.g., Barro and Sala-i-Martin (1991,1992)].

However, the convergence hypothesis has been challenged by time series analyses of convergence. These studies interpret the lack of common unit roots in income levels across countries as an indication of non-convergence. If, on the contrary, the income difference between any two economies is a stationary process, the observed income disparity at any time tends to disappear in the long run. Based on this concept, studies such as Bernard and Durlauf (1995) and Quah (1992) find that there is no systematic convergence among a number of countries.

The purpose of this study is to further examine the sources of income-disparity persistence in the context of time series dynamics. Cross-sectional studies have explored the convergence issue by experimenting on various control variables that could explain the differences in microeconomic structures of economies. On the contrary, the time series approach devotes very little to understanding the effects of those variables on income convergence. This paper attempts to detect the economic forces that cause income differences to persist and the size of the long-run response of income disparity to various shocks.

While most of the time series studies on income convergence concentrate on aggregate cross-country comparison, this study uses disaggregated data to examine the sources of persistence in income disparities at industrial as well as aggregate levels. The sectoral analysis is of particular interest because firstly, income divergence at the aggregate level does not imply divergence in all sectors. There are cases in which income converges in some sectors but diverges in others.

Secondly, this disaggregated framework allows us to bring extra information from sectoral data to bear on the analysis at the aggregate level. The multivariate analysis proposed by Lee, Pesaran and Pierse (1992) and Pesaran, Pierse and Lee (1993), hereafter PPL, provides such a framework. By pooling sectoral data into a multivariate model, the persistence measure for the aggregate would embody information from disaggregated data. This helps us to solve the difficulties involved in determining the long-run properties of the time series within the relatively short time period in which data are available.

As to the sources of income disparities at both aggregate and sectoral levels, PPL method also provides a tool to decompose the total persistence of income disparities into components due to different shocks. This allows us to assess the relative importance of various economic shocks in explaining the persistence. The Keynesian theorists argue that policy actions on the demand side could affect economic growth. The Real-Business-Cycle (RBC) economists, in contrast, follow the idea that only *real* factors, such as technology or productivity changes, induce fluctuations in economic activity. To detect the sources of income persistence, we specify three types of demand shocks and two types of supply shocks. The shocks from the demand side are three nation-specific aggregate demand shocks: monetary policy, fiscal policy, and exchange rate shocks. One type of the supply shocks is a worldwide common aggregate supply shock, oil price shock, which is believed to affect the productivity of the economy. The residual shocks that cannot be identified by these four macroeconomic factors are considered as sector-specific technology or productivity shocks that are not generated by policy actions.

Quarterly time series data from the US, UK, and Canada for the period 1961:1-1996:4 are analyzed in this study. The results can be summarized as follows: Firstly, the persistence of cross-country aggregate income disparities is caused by the output divergence in the non-agricultural sectors for all three country-pairs. Secondly, much of the persistence can be attributed to the sector-specific supply shocks, which is consistent with the RBC paradigm. Shocks to oil prices, on the other hand, are common across borders and therefore contribute little to the persistence of cross-country income disparities. Finally, the aggregate demand shocks have only a minor contribution to the income disparities. Therefore, policy actions are not major causes of cross-country income disparities.

The remainder of this paper is organized as follows. Section 2 defines persistence in cross-country income differences and documents its existence at sectoral and aggregate levels for the three industrialized countries. The methodology and empirical results of income disparity persistence decomposition are set forth in Section 3. Section 4 is the conclusion.

2. Evidence of persistence in cross-country income disparities

In this paper, the persistence in cross-country income disparities is interpreted in the context of time series dynamics.[1] We first give a formal definition of persistence in income disparities. Unit root tests are then used to detect the persistence.

Consider countries *a* and *b*. Let Y_t^n denote country *n*'s log real per capita income at time *t*, for $n = a, b$. Let F_t be an increasing sequence of σ-algebras adapted to the stochastic process $\{Y_t^a - Y_t^b\}$, $F_t \supset F_{t\text{-}1}$.

Definition: *Incomes disparity across countries a and b,* $Y_t^a - Y_t^b$*, is persistent if*

$$\lim_{s\to\infty} \{\mathrm{E}[(Y_{t+s}^a - Y_{t+s}^b) \mid F_t] - \mathrm{E}[(Y_{t+s}^a - Y_{t+s}^b) \mid F_{t-1}]\} \neq 0 .$$

This definition states that any economic event at time *t* will affect our forecast of income difference into the far future. In other words, the disturbances of income difference would have a permanent effect. Under this definition, the non-persistence in the output gap between two countries implies that Y_t^a and Y_t^b may be completely identical, two straight lines, or two series sharing the same stochastic trend.

It is not hard to see that the display of persistence is equivalent to the presence of a unit root in $Y_t^a - Y_t^b$. Consider the following specification:

$$Y_t^a - Y_t^b = \mu + \rho\,(Y_{t-1}^a - Y_{t-1}^b) + \varepsilon_t, \tag{1}$$

where μ is a constant and ε_t is a zero-mean stationary process. Substituting recursively in equation (1) yields

$$Y_{t+s}^a - Y_{t+s}^b = \sum_{j=0}^{s-1} \rho^j \mu + \rho^s\,(Y_t^a - Y_t^b) + \sum_{j=0}^{s-1} \rho^j \varepsilon_{t+s-j}\,.$$

Hence,

$$\lim_{s\to\infty} \{\mathrm{E}[(Y_{t+s}^a - Y_{t+s}^b) \mid F_t] - \mathrm{E}[(Y_{t+s}^a - Y_{t+s}^b) \mid F_{t-1}]\} = \lim_{s\to\infty} \rho^s \varepsilon_t = \begin{cases} 0 & \text{if } |\rho| < 1, \\ \varepsilon_t & \text{if } \rho = 1. \end{cases}$$

If $|\rho| < 1$, then $Y_t^a - Y_t^b$ is a stationary process. If $\rho = 1$, then $Y_t^a - Y_t^b$ contains a unit root. Thus, there are persistent stochastic components in the income difference if $Y_t^a - Y_t^b$ is integrated of order one.[2] This allows us to apply unit root tests on cross-country income differences to analyze the existence of persistence. Failing to reject the null hypothesis of a unit root in the income difference would imply that persistence exists.

The spirit of our definition of persistence is parallel to the measurement of the income persistence usually seen in the literature, such as the one used by Campbell and Mankiw (1987). To see this, suppose that in equation (1), $\rho = 1$ and $\varepsilon_t = a(L)\,u_t$, where u_t is a white noise and $a(L)$ is an infinite-order lag polynomial. That is,

$$(1 - \mathrm{L})(Y_t^a - Y_t^b) = \mu + a(\mathrm{L})u_t. \tag{2}$$

The persistence condition in our definition can be stated alternatively as

$$\lim_{s\to\infty} \frac{\partial\ \{\mathrm{E}[(Y_{t+s}^a - Y_{t+s}^b) \mid F_t] - \mathrm{E}[(Y_{t+s}^a - Y_{t+s}^b) \mid F_{t-1}]\}}{\partial u_t} = a(1) \neq 0.$$

That is, $a(1)$ expresses the permanent effect of the shock u_t on the differential $Y_t^a - Y_t^b$. If the lag polynomial in (2) has a unit root, that is, if $a(1) = 0$, $Y_t^a - Y_t^b$ would be a trend stationary process. Thus the size of $a(1)$ is considered a measure both of the persistence of the shocks to $Y_t^a - Y_t^b$ and of the importance of the random walk component. This is in fact the measure popularized by Campbell and Mankiw (1987). The PPL method, which will be introduced in the next section, is a multivariate version of this persistence measure.

To examine whether income disparities persist at both sectoral and aggregate levels, we apply the Augmented Dickey-Fuller unit root test (ADF ρ-test) on the log real cross-country per capita income differentials. Restricted by the availability of disaggregated data, the empirical work focuses on the quarterly GDP data for the period 1961:1-1996:4 from three advanced industrialized countries: the United States, the United Kingdom, and Canada. For comparative purpose, GDP data in each country are grouped into six one-digit industrial sectors: agriculture, mining, manufacturing, construction, public utilities, and services.[3] All GDP data are converted to 1980 U.S. dollars.[4] A detailed account of the sources of the data is shown in the Appendix. All data are seasonally adjusted.

This paper analyzes sectoral per capita output instead of sectoral productivity due to a lack of data on labor hours and capital at the sectoral level. Data on numbers of sectoral workers are only available at the annual frequency and in a shorter period. In addition, the aggregation of sectoral productivity to national per capita income requires that the ratios of sectoral labor hours to population be time-invariant (see equation [3] in the next section). However, this assumption is not necessary to hold. Therefore, we follow previous sectoral studies such as PPL (1992, 1993) and analyze per capita sectoral output. The focus is on the disparities in outputs across countries. The per capita term serves to eliminate the population scale effect.[5]

The results of ADF ρ-tests are shown in Table 1. To show that the criteria for choosing the order of autoregression in the tests do not affect inferences, following Ng and Perron (1995), we use the Akaike Information Criterion (AIC), Schwartz's criterion, and a sequence of 5% *t*-tests on the coefficients of additional lags to choose the lag length for each series. The first half of Table 1 shows the test statistics of the level of the income disparity and the second half shows those of the first differences. The results show that first, for all three country-pairs, the disparities in the agricultural outputs show no persistence. A possible explanation for this result is that the effects of the most significant shocks to the agriculture sector, such as drought and flood, are usually very short. Another explanation is that, in the agriculture sector, the technology spillover effect, which causes convergence of factor productivity, dominates the comparative advantage effect, which leads to specialization and therefore yield a divergence over time.

[INSERT TABLE 1 ABOUT HERE]

On the other hand, all but one test statistics for the other sectoral output differences are insignificant at the 5% level. That is, the null hypothesis of a unit root cannot be rejected for the disparities in the non-agricultural outputs. These results indicate that the persistence in the aggregate income disparity is caused by the divergence in the non-agricultural outputs. Therefore, we will concentrate on the income disparities in the non-agricultural sectors in the following analysis.

3. Estimation and decomposition of persistence in cross-country income disparities

This section discusses the methodology and empirical results of the decomposition of income-disparity persistence. Section 3.1 lays out the econometric background of the method proposed by Pesaran, Pierse and Lee (1993) and Lee, Pesaran and Pierse (1992) (PPL), and its application in a cross-country multisectoral environment. Section 3.2 identifies various macroeconomic shocks to be used in the decomposition. The decomposition results and their implications are then discussed in Section 3.3.

3.1 Econometrics background

The PPL decomposition method was first introduced to study the sectoral output persistence within a country. In this paper, the method is extended to a cross-country income disparity investigation.

The advantages of employing the PPL method are twofold. First, as mentioned in Section 2, this multivariate persistence measure is an analogous calculation to the univariate measure of the stochastic variability of the random walk component of a unit root process. By pooling sectoral data into a multivariate model, the persistence at both sectoral and aggregate levels can be estimated systematically. The information contained in the relationships between sectoral disparities can be utilized to obtain a more reliable estimate of the persistence measure for the aggregate income disparity. Secondly, the PPL method allows us to assess the contribution of various macroeconomic factors to the persistence. If a robust pattern exists on the estimated measures, useful policy implications can be generated from the examination.

In what follows, we show how to apply the PPL methodology in a two-country environment with each country composed of comparable S sectors. Let $y^{n}_{i,t}$ denote the log real per capita output in country n's sector i, for $i = 1, 2, \ldots, S$ and $n = a, b$. Consider an $S\times 1$ vector of sectoral log output difference of interest: $x_t \equiv (y^{a}_{1,t} - y^{b}_{1,t}, y^{a}_{2,t} - y^{b}_{2,t}, \ldots, y^{a}_{S,t} - y^{b}_{S,t})'$.[5] The cross-country income differential, denoted as d_t, can be expressed in general as a linear function of the elements in x_t:

$$d_t = w' x_t. \tag{3}$$

When d_t represents the sectoral output differential in the ith industry, w is an $S\times 1$ vector with unity on its ith element and zeros elsewhere. Conversely, when d_t is the aggregate income differential, we set w to a unity vector in the empirical analysis. That is, by taking the first difference of (3), we use the sum of the sectoral output growth rates differences to measure the aggregate income growth rates difference.[6]

Suppose that x_t can be represented by a first-difference stationary process and no cointegration relation exists among the $I(1)$ elements in x_t. Consider the following multivariate equation:

$$\Delta x_t = \mu + B(\mathrm{L})\ \eta_t + A(\mathrm{L})\ \varepsilon_t, \tag{4}$$

where $A(\mathrm{L})$ and $B(\mathrm{L})$ are infinite-order polynomials in the lag operator L with $A(0) = I_S$ and μ is an $S\times1$ constant vector. The $k\times1$ vector η_t, with zero mean and covariance matrix Ω, includes innovations in macroeconomic variables specific to country a or b and those common to both countries. The elements of η_t, η_{it} ($i = 1, 2, \ldots, k$), are defined by the following system:

$$m_{it} = \beta_i' z_{it} + \eta_{it}, \qquad i = 1, 2, \ldots, k. \tag{5}$$

For the ith equation, m_{it} is a macroeconomic variable, z_{it} is a vector of predetermined variables, and β_i is a vector of coefficients. The residual shocks in ε_t, an $S\times1$ vector of white noise innovations with zero mean and covariance matrix Σ, are shocks that cannot be identified by the macroeconomic variables. To ensure that the parameters in (4) and (5) are identified, we assume that η_t and $\boldsymbol{\varepsilon}_t$ are uncorrelated.[7]

The first difference of the cross-country income disparity has the following representation:

$$\Delta d_t = w'\Delta x_{\mathrm{t}} = w'\mu + w'B(\mathrm{L})\ \eta_t + w'A(\mathrm{L})\ \varepsilon_t.$$

Let $f_{\Delta d}(0)$ be the spectral density function of Δd_t at zero frequency. The multi-factor persistence measure of the income disparity d_t, denoted as P, is defined as the square root of the spectral density scaled by the conditional variance of Δd_t:

$$P^2 = \frac{2\pi f_{\Delta d}(0)}{\mathrm{Var}(\Delta d_t \mid F_{t-1})} = \frac{w'B(\mathrm{I})\Omega B(\mathrm{I})'w + w'A(\mathrm{I})\Sigma A(\mathrm{I})'w}{w'B(0)\Omega B(0)'w + w'\Sigma w}.$$

Under the above assumptions, we can decompose P^2 as follows:

$$P^2 = \lambda P_m^2 + (1-\lambda)P_o^2,$$

where $P_m^2 = \frac{w' B(\mathrm{I})\Omega B(\mathrm{I})' w}{w' B(0)\Omega B(0)' w}$, $P_o^2 = \frac{w' A(\mathrm{I})\Sigma A(\mathrm{I})' w}{w' \Sigma w}$, and $\lambda = \frac{w' B(0)\Omega B(0)' w}{w' B(0)\Omega B(0)' w + w' \Sigma w}$.

The persistence measure P^2 is decomposed into two components: The first measure, P_m^2, is the degree of persistence due to the identified k macroeconomic shocks and the second one, P_o^2, is due to residual shocks. The parameter λ measures the contribution of the macro shocks to the total persistence.

The component P_m^2 can be further decomposed as follows:

$$P_m^2 = \sum_{i=1}^{k} \theta_i P_{m,i}^2,$$

where $P_{m,i}^2 = \frac{\sum_{j=1}^{k} w' b_i(\mathrm{I})\Omega_{ij} b_j(\mathrm{I})' w}{w' b_i(0)\Omega_{ii} b_i(0)' w}$ is the persistence measure due to a shock to the ith identified macroeconomic variable. The weight $\theta_i = \frac{w' b_i(0)\Omega_{ii} b_i(0)' w}{w' B(0)\Omega B(0)' w}$ tells the relative size of the contribution of this measure to P_m^2. The scalar Ω_{ij} denotes the (i, j) element of Ω and $b_i(\mathrm{L})$ denotes the ith column of the matrix $B(\mathrm{L})$.

3.2 Identifying macroeconomic shocks

This section identifies the vector of macroeconomic shocks η_t in equation (5). We consider five types of shocks. There are three country-specific aggregate demand shocks, including a monetary policy shock, a fiscal policy shock, and an exchange rate shock. The aggregate supply shock is a worldwide common shock, shocks to the oil prices. One may argue that this is not a complete list of all possible sources of macro shocks relevant to these three economies. However, they do represent the most important ones. Therefore, the residual shocks (ε_t), which cannot be identified by those aggregate macroeconomic factors, can be considered as sector-specific technology or productivity shocks on the supply side.

Not until recently did RBC economists start to consider the oil-price as an important source of permanent disturbance to productivity aside from technological changes. According to Stockman's (1988) argument, the shocks to oil prices are industry-specific but common across borders and should therefore contribute little to the cross-country income disparity persistence. However, if the coordination activities in industries required by a sudden change in oil-prices vary significantly across borders, the oil-price shocks will cause outputs to deviate permanently [Daniel (1997)]. Following Daniel (1997), we use the world petroleum price divided by the US producer price index to construct the real oil prices.

On the aggregate demand side, new classical economists believe that aggregate demand shocks are temporary because the price stickiness is short-lived in response to market pressures. The new Keynesian theory, however, has focused on the role of incomplete markets and other imperfections, which introduce a channel that demand-side innovations could have contributed to the long-run behavior of output.[8]

In the money market, although the debate about whether monetary policies have long-run influence on growth has never ceased, they have long been regarded as a cause of output fluctuations. For example, while the new classical economists advocate money neutrality, some endogenous growth models predict that an increase in the long-run growth rate of money supply decreases the long-run growth rate of output if this policy change has nontrivial effects on real rates of return. The role that monetary policy plays in international transmission has been documented in a large volume of literature. See Baxter and Stockman (1989) for an example. Real money stock is used as the measure of the monetary policy in this paper.

The relationship between fiscal policy and the paths of economic development has been emphasized by studies such as Barro (1990), Barro and Sala-i-Martin (1995), Easterly and Rebelo (1993), and Jones and Manuelli (1990). Barro and Sala-i-Martin point out that government consumption may include expenditures that entail distortions of private decisions. Jones and Manuelli present a model in which fiscal policies can have a permanent impact on growth.

Following Barro and Sala-i-Martin, we use the share of government expenditures in GDP as the fiscal policy variable.

Jones and Manuelli (1990) also offer a theoretical justification for the effect that foreign trade policies might have on growth. If trade policies artificially increase the price of capital goods and hence increase the rate of return on investment, growth could be spurred. Following PPL (1992), we examine the effect of trade conditions on income disparities via the changes in nominal exchange rates.[9]

Shocks are measured by the unexpected changes in the following variables: the real money growth rates difference ($\Delta\ln M_t^a$ - $\Delta\ln M_t^b$), difference in the government expenditure growth rates ($\Delta\ln G_t^a$ - $\Delta\ln G_t^b$), the growth rate of nominal exchange rates between the two countries ($\Delta\ln e_t$), and the growth rate of the real world oil price ($\Delta\ln P_t^{\text{oil}}$). A VAR(3) model is first considered as a fully unrestricted model. The likelihood ratio tests are then used to reduce the order of the VAR system. The test statistics are shown in the first half of Table 2. A VAR(1) model is chosen for the US-Canada pair, and a VAR(3) model for the US-UK and the UK-Canada pairs. Note that this step only determines the functional forms of the macro equations. The estimates of the persistence measures are computed by the joint estimation of these macro equations and equation (4), which will be discussed later.

[INSERT TABLE 2 ABOUT HERE]

When choosing the orders of the VAR systems, we also perform a series of Ljung-Box Q tests for each equation to test the null hypothesis of no serial correlation in the residuals. For these residuals to appropriately serve the roles as shocks, they should be white noise processes. The results are shown in the second half of Table 2. None of these tests has rejected the null hypothesis at the 5% significance level and, therefore, the specification is justified.

3.3 Estimation and decomposition of the persistence measures

Before estimating the model, we test the cointegrating relation among those $I(1)$ variables to ensure that the specification of equation (4) is valid. Johansen's (1988) Full Information Maximum Likelihood (FIML) tests are used to test the numbers of cointegrating relations. Both the Trace test and the Maximum Value test, as shown in Table 3, suggest that there is no cointegration relation among the variables. Therefore, the specification of equation (4) is justified.

[INSERT TABLE 3 ABOUT HERE]

To obtain estimates of the persistence measures, we need consistent estimates of $A(\mathrm{L})$, $B(\mathrm{L})$, and G in equation (4). For this purpose, we consider the following finite-order VARX system:

$$C(\mathrm{L})\, \Delta x_t = \alpha + D(\mathrm{L})\, \hat{\eta}_t + \varepsilon_t, \qquad (6)$$

where α is a constant vector; $\hat{\eta}_t$ is the estimate of macroeconomic shocks η_t obtained from Section 3.2; $C(\mathrm{L}) = \sum_{i=0}^{p} C_i \mathrm{L}^i$ with $C_0 = \mathrm{I}$; and $D(\mathrm{L}) = \sum_{i=0}^{q} D_i \mathrm{L}^i$. The estimated parameters needed to compute the persistence measures can be obtained from the following transformations: $A(\mathrm{I}) = (\mathrm{I} - C_1 - \ldots - C_p)^{-1}$, $B(\mathrm{I}) = (\mathrm{I} - C_1 - \ldots - C_p)^{-1} (D_0 + \ldots + D_q)$, and $B(0) = D_0$.

The whole system, including equations (5) and (6), is estimated by the Full Information Maximum Likelihood (FIML) method. The FIML estimators are computed via a double-length regression suggested by Pagan (1984, 1986) to avoid the generated-regressor (the shocks) problem.[10]

In a typical VAR specification, p and q are chosen sufficiently large to make serial correlation of the residuals unlikely. However, in a high dimension system like ours, this approach would consume many degrees of freedom.[11] Therefore, we set the maximum lag lengths p and q to three and perform a series of Wald tests on individual coefficients. A restricted model is obtained by excluding regressors that are insignificant at the 10% level. We then use the log-likelihood ratio test to test the restricted model against the unrestricted model. The test supports this more parsimonious model.

The sectoral and aggregate persistence measures are estimated based on this restricted model. The results are shown in Table 4. Note that the persistence measures P, P_m, and P_o are positive by definition. Therefore, the null hypothesis of a zero persistence measure is tested against the alternative of a positive one.

[INSERT TABLE 4 ABOUT HERE]

The results show that first of all, all the persistence measures are significantly different from zero at the 5% level. The significance of the overall persistence measure (P) is consistent with the unit root tests in Section 2.

Secondly, as to the size of the response, a one percent shock would lead to around a slightly less than one percent change in long-run aggregate income differentials for all three country-pairs. The responses in the sectors are mostly higher.

Finally, even though the significance of P_m's indicates that the macro shocks have significant effects on the persistence of the income disparities, their contribution to the total persistence measure is rather small because all the weights (λ's) are well below 0.5. This can also be seen from the fact that all the P_o's are very close to the overall measures (P). Therefore, most of the sources of the persistence in the income disparities are from sector-specific supply shocks other than the aggregate macro shocks that we identify here. Similar findings can be found in other sectoral output studies such as PPL (1992, 1993), which analyze the persistence of shocks to sectoral outputs within a country. This result provides some justification for the use of sectoral data in real business cycle analysis since the sector-specific shocks are more important than the aggregate shocks usually considered in the RBC models in driving the income-disparity persistence.[12]

4. Conclusion

A large volume of empirical time series literature has found that income fails to converge across different economies, as a contradiction to the prediction of neoclassical growth theory. Our research builds upon this literature and uses sectoral data from the US, UK, and Canada to examine the persistence of income disparities at industrial as well as aggregate levels. By analyzing the disaggregated data, we find income disparities among these three industrialized countries persist only at the non-agricultural sectors.

We further analyze the sources of persistence in income disparities by linking the persistence to several structural shocks. We find that even though the aggregate-demand shocks and the oil-price shock have significant effects on income disparities, their contribution is quantitatively not as important as the sector-specific residual shocks. This result suggests the importance of sectoral analyses in growth studies. Focusing only on the aggregate data may ignore the important roles of the sector-specific shocks.

References

Barro, Robert J. “Economic Growth in a Cross Section of Countries.” *Quarterly Journal of Economics* 106 (1990): 407-443.

Barro, Robert J. and Xavier Sala-i-Martin. “Convergence Across States and Regions.” *Brookings Papers on Economic Activity* 2 (1991): 107-158.

Barro, Robert J. and Xavier Sala-i-Martin. “Convergence.” *Journal of Political Economy* 100 (1992), 223-251.

Barro, Robert J. and Xavier Sala-i-Martin. *Economic Growth*. McGraw-Hill Publication, 1995.

Baxter, Marianne and Alan C. Stockman. “Business Cycles and the Exchange Rate Regime.” *Journal of Monetary Economics* 23 (1989): 377-400.

Bernard, Andrew B. and Steven N. Durlauf. “Convergence in International Output.” *Journal of Applied Econometrics* 10 (1995): 97-108.

Bernard, Andrew B. and Steven N. Durlauf. “Interpreting Tests of the Convergence Hypothesis.” *Journal of Econometrics* 71 (1996): 161-174.

Campbell, John Y. and N. Gregory Mankiw. “Are Output Fluctuations Transitory?” *Quarterly Journal of Economics* 102 (1987): 857-880.

Canova, Fabio, and Albert Marcet. “The Poor Stay Poor: Non-Convergence across Countries and Regions.” Discussion paper, No. 1265, Centre for Economic Policy Research, 1995.

Daniel, Betty C. “International Interdependence of National Growth Rates: A Structural Trends Analysis.” *Journal of Monetary Economics* 40 (1997): 73-96.

Dollar, David, and Edward M. Wolff. “Capital Intensity and TFP Convergence by Industry in Manufacturing, 1963-1985.” in W. Baumol, R.R. Nelson and E.N. Wolff (eds.), *Convergence of Productivity*, Oxford, 1994: 197-224.

Easterly, William, Michael Kremer, Lant Pritchett, and Lawrence H. Summers. “Good Policy or Good Luck? Country Growth Performance and Temporary Shocks.” *Journal of Monetary Economics* 32 (1993): 459-483.

Easterly, William, and Sergio Rebelo. “Fiscal Policy and Economic Growth.” *Journal of Monetary Economics* 32 (1993): 417-458.

GouriJroux, Christian, Alberto Holly, and Alain Monfort. “Likelihood Ratio Test, Wald Test, and Kuhn-Tucker Test in Linear Models with Inequality Constraints on the Regression Parameters.” *Econometrica* 50 (1982): 63-80.

Greenwald, Bruce C., and Joseph E. Stiglitz. “Financial Market Imperfections and Business Cycles.” *Quarterly Journal of Economics* 108 (1993): 77-114.

Johansen, Srren. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control* 12 (1988): 231-254.

Jones, Larry E., and Rodolfo Manuelli. "A Convex Model of Equilibrium Growth: Theory and Policy Implications." *Journal of Political Economy* 98 (1990): 1008-1038.

Lee, Kevin C., M. Hashem Pesaran and Richard G. Pierse. "Persistence of Shocks and Their Sources in a Multisectoral Model of UK Output Growth." *The Economic Journal* 102 (1992): 334-356.

Ng, Serena, and Pierre Perron. "Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of the Truncation Lag." *Journal of the American Statistical Association* 429 (1995): 268-280.

Pagan, Adrian R. "Econometric Issues in the Analysis of Regressions with Generated Regressors." *International Economic Review* 25 (1984): 221-247.

Pagan, Adrian R. "Two Stage and Related Estimators and Their Applications." *Review of Economic Studies* LIII (1986): 517-538.

Pesaran, M. Hashem, Richard G. Pierse, and Kevin C. Lee. "Persistence, Cointegration and Aggregation: A Disaggregated Analysis of Output Fluctuations in the U.S. Economy." *Journal of Econometrics* 56 (1993): 57-88.

Quah, Danny. "International Patterns of Growth: I. Persistence in Cross-Country Disparities." Working paper, MIT, 1992.

Stockman, Alan C. "Sectoral and National Aggregate Disturbances to Industrial Output in Seven European Countries." *Journal of Monetary Economics* 21 (1988): 387-409.

Summers, Robert, and Alan Heston. "The Penn World Table (Mark 5): An Expanded Set of International Comparison, 1950-1988." *Quarterly Journal of Economics* 425 (1991): 327-368.

Appendix: Data Sources

U.S. Data

Population:

Data from 1961:1 to 1992:2 are March, June, September, and December estimates of total population from CANSIM CD ROM. For data from 1992:3 to 1996:4, we collected the midyear estimates of total population from *International Financial Statistics* CD ROM (IFS), then used evenly weighted average values of two successive observations to estimate quarterly observations for population.

Price Deflator: GDP deflator from IFS.

Nominal Sectoral output:

Table 6.1, "National Income without Capital Consumption Adjustment by Industry," of the INFORUM Database at the University of Maryland.

Money: M1 from IFS.

Nominal Government Expenditure and GDP:

"Federal government purchases of goods and services" and "GDP" from CANSIM.

U.K. Data

Population:

The midyear estimates of total population were collected from IFS and evenly weighted average values of two successive observations were used to estimate quarterly observations for population.

Price Deflator: GDP deflator from IFS.

Real Sectoral output:

Real GDP by industry. These data were constructed by the sectoral and aggregate output indices (1990=100), the weights for sectors in 1990, and GDP at factor cost at 1990 prices. All the data are taken from the *Economic Trends, Annual Supplement*, 1997 edition.

Money: "Money plus Quasi Money" from IFS.

Nominal Government Expenditure and GDP:

"Government consumption and Investment" and "GDP" from IFS.

Exchange Rates: Pounds/Dollars exchange rates from IFS.

Canadian Data

Population: Quarterly population estimates from CANSIM.

Price Deflator: GDP deflator from CANSIM.

Real Sectoral output:

"Gross Domestic Product at Factor Cost by Industry, 1986 prices," from CANSIM.

Money: M1 from IFS.

Nominal Government Expenditure and GDP:

"Government current expenditure on goods and services and investment" and "GDP" from CANSIM.

Exchange Rates: Canadian Dollars/US Dollars exchange rates from IFS.

Real Oil Price Index

The nominal oil price index is the spot average of the world market crude petroleum price, US $/Barrel from IFS World Table. Dividing the nominal index by the US producer price from IFS yields the real oil price index.

TABLE 1. *Augmented Dickey-Fuller Unit Root Test Statistics*[a]

Cross-country log real per capita income difference: 1961:1 – 1996:4

	$y^{US}_{i,t}$ - $y^{CAN}_{i,t}$			$y^{US}_{i,t}$ - $y^{UK}_{i,t}$			$y^{UK}_{i,t}$ - $y^{CAN}_{i,t}$		
Lag Choice Criteria[b]	AIC	SCH	5%	AIC	SCH	5%	AIC	SCH	5%
<u>Level:</u>									
1. Agriculture	-24.97*	-24.97*	-24.97*	-22.37*	-22.37*	-22.37*	-29.08*	-34.23*	-34.23*
2. Mining	-4.136	-2.791	-4.136	-4.583	-4.583	-4.583	-6.800	-6.800	-6.800
3. Manufacturing	-12.60	-9.260	-12.60	-11.13	-11.13	-11.13	-9.033	-8.914	-9.033
4. Construction	-16.19	-11.62	-11.62	-5.664	-5.664	-5.664	-3.400	-3.400	-3.400
5. Public Utilities	-4.459	-4.459	-3.243	-14.95	-24.84*	-14.95	-4.283	-8.935	-4.283
6. Services	-1.714	-0.280	-0.280	-11.89	-11.89	-11.89	-0.588	-0.588	-0.588
Non-Agricultural Aggregate	-10.19	-10.19	-10.19	-4.492	-4.492	-4.492	-2.822	-4.541	-2.822
<u>First Difference:</u>									
1. Agriculture	-150.7*	-150.7*	-150.7*	-204.6*	-140.8*	634.9*	-647.0*	-647.0*	-647.0*
2. Mining	-119.9*	-119.9*	-119.9*	-185.7*	-185.7*	-185.7*	-306.0*	-306.0*	-306.0*
3. Manufacturing	-1125*	-148.0*	-262.0*	-115.7*	-144.4*	-144.4*	-296.2*	-126.8*	-296.2*
4. Construction	-49.34*	-81.11*	-49.34*	-157.8*	-157.8*	-157.8*	-134.9*	-134.9*	-134.9*
5. Public Utilities	-439.1*	-179.6*	-439.1*	-643.6*	-643.6*	-643.6*	-260.8*	-260.8*	-260.8*
6. Services	-77.53*	-157.9*	-157.9*	-163.4*	-163.4*	-163.4*	-154.2*	-154.2*	-154.2*
Non-Agricultural Aggregate	-151.8*	-151.8*	-13081*	-177.8*	-177.8*	-177.8*	-281.3*	-281.3*	-281.3*

a. The ADF ρ-test statistics are computed based on the OLS regressions that contain an intercept and a linear trend. The 5% significance level for the ADF tests is –21.158. An asterisk denotes significance at the 5% level.

b. "AIC" is the Akaike Information Criterion, "SCH" is Schwartz's criterion, and "5%" is the method using sequential testing for the significance of coefficients on additional lags at the 5% level. The lag lengths are assumed to have an upper bound 4 and a lower bound 0.

TABLE 2. *Macro Shocks Equations VAR Orders Selection: 1961:1 – 1996:4*

Likelihood Ratio Tests Statistics[a]

Null	Alternative	Degrees of freedom	US-CAN	US-UK[b]	UK-CAN
VAR(2)	VAR(3)	16	15.66	23.74**	27.36*
VAR(1)	VAR(3)	32	31.12	48.20*	66.36*
VAR(1)	VAR(2)	16	15.46	24.46**	39.00*

Residuals Ljung-Box Q Tests Statistics[c]

		US-CAN VAR(1)	US-UK VAR(3)	UK-CAN VAR(3)
Monetary Shocks:	$Q(1)$	0.029	0.646	0.504
	$Q(2)$	0.669	0.663	0.672
	$Q(3)$	1.244	0.668	0.720
	$Q(4)$	5.796	5.350	1.118
Fiscal Shocks:	$Q(1)$	0.014	0.173	0.023
	$Q(2)$	0.035	0.348	0.050
	$Q(3)$	0.743	0.634	0.111
	$Q(4)$	1.024	1.426	0.222
Exchange Rate Shocks:	$Q(1)$	0.001	0.066	0.018
	$Q(2)$	0.146	0.434	0.178
	$Q(3)$	6.492	0.779	0.397
	$Q(4)$	6.742	0.795	0.443
Oil Shocks:	$Q(1)$	0.001	0.011	0.007
	$Q(2)$	3.324	0.071	0.028
	$Q(3)$	3.346	0.206	0.166
	$Q(4)$	3.481	0.511	0.992

a. An asterisk denotes significance at the 5% level. A double asterisk denotes significance at the 10% level.

b. Since two of the test statistics are only marginally rejected at the 10% level, we also try VAR(1) and VAR(2) models for this case. However, the lower order models yield serial correlated fiscal policy shocks. Therefore, a VAR(3) model is adopted.

c. This half shows the Ljung-Box Q-test statistics for the residuals from the selected VAR models. $Q(p)$ is the test statistic for the null of no serial correlation in the estimated residuals against serial correlation of order p. The Q statistic is chi-square distributed with p degrees of freedom. The 5% critical values for p = 1, 2, 3, and 4 are 3.84, 5.99, 7.81, and 9.49, respectively.

TABLE 3: *Johansen's FIML Test Statistics of the Cointegration Rank: 1961:1 – 1996:4*

# of Coint. Vectors	Trace Test Statistics			Maximum Value Test Statistics			5% Critical Value	
	US-Can	US-UK	UK-Can	US-Can	US-UK	UK-Can	Trace	Max.
h=0	70.77	63.02	72.91	35.32	24.01	33.12	82.55	36.86
h=1	35.45	39.01	39.80	16.88	16.20	18.24	58.96	30.92
h=2	18.57	22.81	21.55	10.52	12.94	13.39	39.10	24.48
h=3	8.047	9.868	8.159	4.631	7.510	7.689	23.45	18.25
h=4	3.416	2.358	0.470	3.416	2.358	0.470	11.63	11.63

This table presents tests of the number of cointegrating vectors in the system of five sectoral per capita income differences. The autoregression includes a constant term, a time trend, and four lags. The Trace test examines the null hypothesis of at most r cointegrating vectors against the general alternative that $h = 5$. The Maximum Value test tests the null hypothesis $h = r$ against the alternative that $h = r+1$.

TABLE 4: *Persistence Measure Decompositions on Cross-Country Income Difference: 1961:1 – 1996:4*

		P	P_m	P_o	λ
US-CAN	Mining	1.275	3.266	1.063	0.052[a]
		(0.152)	(1.338)	(0.124)	(0.036)
	Manufacturing	0.898	0.974	0.890	0.087
		(0.067)	(0.282)	(0.065)	(0.044)
	Construction	1.393	2.447	1.270	0.075
		(0.143)	(0.573)	(0.124)	(0.042)
	Utilities	0.821	0.841	0.818	0.132
		(0.060)	(0.236)	(0.057)	(0.049)
	Services	1.186	2.252	1.149	0.023[b]
		(0.121)	(0.880)	(0.115)	(0.024)
	Non-agricultural Aggregate	0.921	1.130	0.896	0.098
		(0.101)	(0.377)	(0.091)	(0.029)
US-UK	Mining	0.767	0.767	0.767	0.132
		(0.044)	(0.044)	(0.044)	(0.049)
	Manufacturing	1.006	1.039	1.004	0.056[a]
		(0.027)	(0.429)	(0.011)	(0.037)
	Construction	1.064	1.643	1.011	0.066
		(0.044)	(0.500)	(0.020)	(0.040)
	Utilities	1.032	1.580	1.004	0.039[b]
		(0.027)	(0.537)	(0.016)	(0.032)
	Services	0.957	1.131	0.948	0.047[a]
		(0.028)	(0.329)	(0.018)	(0.034)
	Non-agricultural Aggregate	0.827	0.832	0.826	0.157
		(0.038)	(0.063)	(0.038)	(0.048)
UK-CAN	Mining	0.747	0.747	0.747	0.154
		(0.045)	(0.104)	(0.043)	(0.053)
	Manufacturing	1.003	1.009	1.002	0.171
		(0.029)	(0.168)	(0.005)	(0.053)
	Construction	1.214	1.413	1.206	0.034[b]
		(0.140)	(0.620)	(0.136)	(0.030)
	Utilities	0.998	1.038	0.992	0.128
		(0.081)	(0.115)	(0.083)	(0.049)
	Services	1.645	1.758	1.626	0.137
		(0.275)	(0.346)	(0.276)	(0.048)
	Non-agricultural Aggregate	0.800	0.776	0.808	0.260
		(0.057)	(0.070)	(0.056)	(0.056)

$P^2 = \lambda P_m^2 + (1-\lambda)P_o^2$, where P is the total persistence measure, P_m is the measure due to the macroeconomic shocks, P_o is that due to sector-specific or residual shocks, and λ measures the contribution of the macro shocks to total persistence. A superscript "a" denotes insignificance at the 5% level, but significance at the 10% level. A superscript "b" denotes insignificance at the 10% level. The numbers in parentheses are FIML asymptotic standard errors. The null hypothesis of a zero persistence measure is tested against the alternative of a positive one. The Wald statistic for this one-sided test has a distribution of $\frac{1}{2}\chi^2(0) + \frac{1}{2}\chi^2(1)$. See GouriJroux et al. (1982).

Endnotes

1. Canova and Marcet (1995) discuss the persistence of cross-country income inequality in a cross-sectional analysis.
2. According to the definition of income convergence in Bernard and Durlauf (1995), convergence requires equalities in both linear deterministic and stochastic trends between Y_t^a and Y_t^b, whereas non-persistence in income difference only requires equality in stochastic trends. In other words, convergence requires μ in equation (1) to be zero, while non-persistence does not. Note that the type of convergence used here is convergence in mean square.
3. The agriculture sector includes agriculture, forestry, fishing and hunting. The mining sector includes mining and quarrying. The services sector includes transportation, communication, wholesale trade, retail trade, finance, insurance, real estate, services, and government.
4. Following Dollar and Wolff (1994), Summers and Heston (1991), and Bernard and Durlauf (1995), we use the Purchasing Power Parities index calculated by the United Nations to convert all the income data to a common currency.
5. The persistence in per capita sectoral output disparity may be equivalent to that in the productivity disparity under some circumstances. Note that the log per capita sectoral output disparity between countries *a* and *b* in sector *i*, y_i^a - y_i^b, is constructed as log($\tilde{y}_i^a$ / N^a) – log($\tilde{y}_i^b$ /N^b), where $\tilde{y}$ is sectoral output and *N* is total population in a country. This is equal to [log($\tilde{y}_i^a$ /L_i^a) – log($\tilde{y}_i^b$ /L_i^b)] – [log(L_i^a /N^a) – log(L_i^b /N^b)], where L_i is labor hours in sector *i*. Therefore, as long as the labor share difference [log(L_i^a /N^a) – log(L_i^b /N^b)] is stationary, no persistence in productivity disparity is equivalent to no persistence in per capita output disparity. However, since the data are not available, we are not very comfortable to make this stationarity assumption in the paper.

6. We use the sum of log sectoral outputs to approximate the logarithm of the sum of sectoral outputs in each country. The correlation coefficients between these two measures are 0.928, 0.954, and 0.994 for the US, the UK, and Canada, respectively.
7. Without this assumption, the joint estimation of (4) and (5) will result in biased estimates. For more details, see Section 3.3 in Pesaran et al. (1993).
8. For instance, the credit-rationing model by Greenwald and Stiglitz (1993) suggests that Federal Reserve policies have permanent influences by increasing the probabilities of loans.
9. An alternative measure of trade conditions is the terms of trade: see, for example, Easterly et al. (1993). The estimation results from these two measures are very similar. Therefore, we only report the results from the exchange rate measure to conserve space.
10. The computations of the FIML estimators as well as the corresponding asymptotic covariance matrix are conducted using GAUSS. The programs are available from the authors upon request.
11. This is also the reason that we work on a two-country framework. Ideally, we should employ a VARX model including industrial outputs of all three countries. With the relatively small sample size, however, it is not feasible.
12. The results of the decomposition of the persistence measure due to macro shocks, P_m^2, into measures due to each individual shock are not reported to conserve spaces. Since the macro shocks only have minor contributions to the persistence, these results do not add significant contributions to this paper. The results are available from the authors upon request.