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Prudence Serju

Estimating potential output for Jamaica: a structural VAR approach

1. INTRODUCTION

The output gap is the difference between actual output and its 'potential' level, where potential output is the level of output that is consistent with a stable rate of inflation given the productive stock of capital (Claus, 1999). The gap is therefore an important indicator of demand pressures in the economy. As such, the dynamics of the output gap are important to monetary policy as they convey important information about potential inflation, as well as the capacity for sustained growth.

However, potential output and consequently the output gap are not directly observable,[1] and therefore have to be estimated or inferred. Currently the Bank of Jamaica's macroeconomic model uses an estimate of potential output derived from a Kalman

[1] This is largely a result of the absence of timely information on the capital stock.

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filter.[2] However, forecasting potential output, estimated by the Kalman filter, out of sample poses challenges to obtaining model and theoretically consistent results. Against this background, this paper examines an alternate multivariate method that can be used to complement the current estimates of potential output.

A variety of techniques have been developed to estimate potential output and the output gap. A common method used is the production function approach where potential output is derived as the level of output at which all factors of production are fully utilised. The advantage of this structural approach is its ability to identify all sources of output growth.[3] However, given the uncertainty surrounding an appropriate production function and deriving correct measures of total factor productivity, which is unobservable, this method is somewhat limited.

Consequently, researchers tend to rely more on statistical or pure time series methods which decompose output into its trend and cyclical components. In this context, potential output is identified as the permanent (stochastic trend) component of output while the output gap is represented by the transitory (cyclical) component. Examples of this approach include the Hodrick and Prescott (1997) HP filter and the Baxter and King (1995) band-pass filter. These univariate filters also have a disadvantage arising from the instability of the estimates near the end of the sample period.

Multivariate filters were constructed to estimate potential output as an alternative to the univariate filters. Using the semi-structural approach Conway and Hunt (1997) augment the stochastic-trend estimation of the HP filter with information from a Phillips curve and Okun's Law relationships, along with a survey measure of capacity utilisation. They found that the semi-structural multivariate filter provided a more reliable measure of inflationary pressure than the HP filter.

Accordingly, this paper uses a more robust multivariate approach, a structural vector autoregressive (SVAR) model with long run restrictions as proposed by Blanchard and Quah (1989) to estimate potential output and the output gap for Jamaica.[4] The advantage is that the time series analysis is based on economic theory.

[2] See Allen and Robinson (2004).

[3] Namely labour, capital and technology.

[4] This method does not impose restrictions on the short-run dynamics of the permanent component of output, but incorporates a process for permanent shock that is more general then a random walk.

The estimate is then compared to those derived from the linear trend method, HP and BP filters, as well as the Kalman filter. The paper also estimates a series of Phillips curve equations using the output gaps constructed by each of the four methods in an attempt to evaluate inflationary pressures in the economies.

The estimate of potential output from the various models, with the exception of the linear trend model suggest that the measure of output gap give relatively consistent indication of the magnitude of slack in the economy. In relation to the gap's ability to predict inflationary pressures, the gap derived from the HP and BP filters has insufficient information for predicting inflation with any level of accuracy, while that of the linear trend and SVAR models can be used to estimate inflation with a reasonable degree of accuracy.

The rest of the paper is organized as follows. Section 2 examines four techniques used to estimate potential output and the output gap. The methods include linear time trend, HP and BP filters and a SVAR model. Section 3 outlines the SVAR model for Jamaica, while section 4 presents the empirical results. This section also examines the predictive power of the output gap with respect to inflation. The conclusion is presented in the final section.

2. METHODS FOR ESTIMATING POTENTIAL OUTPUT AND THE OUTPUT GAP

2.1 Linear trend method

Potential output in its simplest form can be computed using deterministic trends, in particular a linear time trend. This approach has been widely used in a number of empirical studies as it is relatively easy to calculate and understand. Using this method potential output is calculated from the following linear equation:

$$Y_t^* = \alpha + \beta\tau \tag{1}$$

where Y^* represents potential output, α is the intercept, β is the coefficient for the slope and τ is a time trend.

Although this method is relatively easy to calculate, the derivation of potential output is not grounded in economic theory. Movements in potential output are associated with growth in productivity, i.e. labour, capital and technology (total factor productivity). Additionally, labour productivity is related to changes in the population, labour force participation and skilled versus un-skilled workers. Critics have shown that there is no realistic explanation to prove that the factors affecting productivity are constant over time, particularly if the country has undergone structural reforms. The Jamaican economy has undergone many natural disasters, as well as experienced a considerable loss of skilled workers due to emigration over the last 10 years. These factors will affect overall productivity. In this context, a more rigorous methodology is required to ascertain statistical significant estimates of potential output for Jamaica.

2.2 The Hodrick-Prescott & band-pass filters

The Hodrick-Prescott (HP) filter can be used to calculate potential output from the actual GDP outturn. This technique minimises a combination of the size of the actual output fluctuations around its trend and the rate of change in the trend output for the whole sample (Gounder and Morling, 2000). Using the HP filter, potential GDP is defined as the series of values that minimises the following problem:

$$\sum_{t=1}^{T}[(Y_t - Y_t^*)^2 + \lambda\sum_{t=2}^{T-1}(Y_{t+1}^* - Y_t^*) - (Y_t^* - Y_{t-1}^*)]^2 \qquad (2)$$

where Y_t is observed GDP in period t, and Y_t^* is potential GDP in time t, which are expressed as logarithms. $(Y_t - Y^*_t)$ is the output gap. λ is a weighting factor that determines the degree of smoothness of the trend. The weighting factor is set to 1600 and 100 when using quarterly and annual data, respectively, which removes cycles with frequency shorter than eight years from the data. Based on the above problem the HP filter selects the potential GDP sequence that minimises the squared difference between actual and potential GDP subject to the restriction that potential GDP does not fluctuate unduly.

Other than been easy and relatively quick[5] to apply, the HP filter makes the output gap stationary over a wide range of smoothing values and it allows the trend to change over time. However, the HP filter has some weaknesses, the most important

[5] The HP filter is available as a ready-made procedure in the econometric programme Eviews.

being that the estimate of potential GDP does not take into account other economic trends. As previously noted, potential output is the maximum output an economy can sustain without a rise in inflation. The HP filter does not distinguish between an expansionary stage, which relates to periods of fast acceleration in inflation and one where inflation is increasing very reasonably. Baxter and King (1995) found that estimates using the HP filter display instability near the end of the sample period. Further Harvey and Jaegar (1993) and Cogley and Nason (1995) found that the HP filter with integrated data can induce spurious cyclicality. Also Guay and St-Amant (1996) found that the HP filter does not accurately decompose time series into their trend and cyclical component when the data display the typical spectral shape discovered by Granger (1966).[6] This technique also disregards structural breaks and regime shifts, as well as the ambiguity surrounding the arbitrary choice of the smoothing parameter.[7]

The band-pass (BP) filter of Baxter and King (1995)[8] uses moving averages that isolate the periodic components of an economic time series that lie in a specific band of frequencies. Baxter and King's (1995) business cycle filter, referred to as a linear filter, eliminates very slow moving (trend) components and very high frequency (irregular) components while retaining intermediate (business cycle) components. This method does not require judgments about trend breaks; however, it requires analysts to make assumptions about how the filters are structured, including the values of one or more parameters. The filters are two-sided symmetric linear filters that apply a set of weights $a_i, i = 0, \pm 1, \pm 2, \ldots$ to a time series y_t.

The 'ideal' band-pass filter is a moving average of infinite order and its estimation requires a data set of infinite length (Koustas, 2003). Approximations of the ideal filter are obtained by truncating the moving average process and choosing the filter weights in a manner that optimizes a set of objectives. For quarterly time series, Baxter and King (1995) suggest the use of the 'Burns and Mitchell' band-pass filter that allows frequency components between 6 and 32 quarters, with a lag length of 12. As a

[6] The typical Granger shape, i.e. the spectrum's peak is located at zero frequency and most of its variance is located in the low frequencies, is characteristic of nearly all macroeconomic time series.

[7] See Harvey and Jaeger (1993) for more shortcomings of the HP filter.

[8] See Baxter and King (1995) for a detailed working of the BP filters.

result of this lag length, three years of data would be lost at the beginning and end of the sample period.

2.3 Structural vector autoregression

Potential output can also be estimated from a structural vector autoregression (SVAR) model. The SVAR model combines economic theory with statistical techniques to differentiate between permanent and temporary movements in output. The innovations in the SVAR are decomposed to recover structural shocks. Using an identification rule the structural shocks are separated into demand and supply shocks. The effects of demand shocks on output are classified as temporary while the aggregate supply shocks are considered to be permanent. In this context, potential output is calculated by aggregating a chain of supply shocks while the output gap is formed from a combination of the demand shocks on output. The advantage of this method is that the model has a stronger reliance on theory but it allows the data to determine the short-run dynamics.

3. SVAR MODEL FOR JAMAICA'S GDP

The non-stationary characteristics of Jamaica's real GDP, designated as 'y_t' permits its decomposition into permanent and transitory components. In this context, the structural VAR methodology with long run restrictions that was proposed by Blanchard and Quah (1989) is used in the identification of the permanent and transitory components of real GDP.

Using a three variable VAR, with real GDP (y_t), unemployment (e_t) and capacity utilization ($capu_t$) and following Claus (1999) the model is as presented in equation (3). Capacity utilization is included as it represents data that is closely related to the concept of potential output.

$$
\begin{aligned}
\Delta y_t &= \sum_{k=0}^{\infty} s_{11}(k)\nu_{1t-k} + \sum_{k=0}^{\infty} s_{12}(k)\nu_{2t-k} + \sum_{k=0}^{\infty} s_{13}(k)\nu_{3t-k} \\
e_t &= \sum_{k=0}^{\infty} s_{21}(k)\nu_{1t-k} + \sum_{k=0}^{\infty} s_{22}(k)\nu_{2t-k} + \sum_{k=0}^{\infty} s_{23}(k)\nu_{3t-k} \qquad (3) \\
capu_t &= \sum_{k=0}^{\infty} s_{31}(k)\nu_{1t-1} + \sum_{k=0}^{\infty} s_{32}(k)\nu_{2t-k} + \sum_{k=0}^{\infty} s_{33}(k)\nu_{3t-k}
\end{aligned}
$$

or:

$$\begin{bmatrix} \Delta y_t \\ e_t \\ capu_t \end{bmatrix} = \begin{bmatrix} S_{11}(L) & S_{12}(L) & S_{13}(L) \\ S_{21}(L) & S_{22}(L) & S_{23}(L) \\ S_{31}(L) & S_{32}(L) & S_{33}(L) \end{bmatrix} \begin{bmatrix} \nu_{1t} \\ \nu_{2t} \\ \nu_{3t} \end{bmatrix} \quad (4)$$

where $S_{ij}(L)$ are polynomials in the lag operator, v_{1t}, v_{2t} and v_{3t} are uncorrelated white noise disturbances, and the individual coefficients are denoted as $s_{ij}(k)$.

Equation (4) can be written as:

$$x_t = S(L)\ \nu_t \quad (5)$$

where $x_t = [\Delta y_t\ e_t\ capu_t]'$ and $\nu_t = [\nu_{1t}\ \nu_{2t}\ \nu_{3t}]'$. The shocks ν_t are normalised, such that var(ν_{1t}) = var(ν_{2t}) = var(ν_{3t}) = 1 and:

$$E(\nu_t \nu_t') = \begin{bmatrix} \mathrm{var}(\nu_{1t}) & \mathrm{cov}(\nu_{1t},\nu_{2t}) & \mathrm{cov}(\nu_{1t},\nu_{3t}) \\ \mathrm{cov}(\nu_{2t},\nu_{1t}) & \mathrm{var}(\nu_{2t}) & \mathrm{cov}(\nu_{2t},\nu_{3t}) \\ \mathrm{cov}(\nu_{3t},\nu_{1t}) & \mathrm{cov}(\nu_{3t},\nu_{2t}) & \mathrm{var}(\nu_{3t}) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = 1 \quad (6)$$

ν_{1t} represents an aggregate supply shock, while ν_{2t} and ν_{3t} are aggregate demand shocks. The coefficients of $S_{11}(L)$ denote the impulse response of an aggregate supply shock on the change in output.

The following assumption is made to facilitate the decomposition of output into its permanent and transitory components. Consistent with the natural rate hypothesis, demand side shocks have no long-run effect on output, while supply side productivity shocks are assumed to have a permanent effect. In this context, potential output is related to productivity shocks. Against this background, the cumulated effects of ν_{2t} and ν_{3t} on Δy_t are equal to zero, i.e.:

$$\sum_{k=0}^{\infty} s_{12}(k)\nu_{2t-k} + \sum_{k=0}^{\infty} s_{13}(k)\nu_{3t-k} = 0 \quad (7)$$

The structural shocks, ν_t are unobserved. To retrieve the supply side and demand side shocks the estimation process is as follows. We first estimate an unrestricted VAR of the form:

$$\begin{bmatrix} \Delta y_t \\ e_t \\ capu_t \end{bmatrix} = \begin{bmatrix} \Phi_{11}(L) & \Phi_{12}(L) & \Phi_{13}(L) \\ \Phi_{21}(L) & \Phi_{22}(L) & \Phi_{23}(L) \\ \Phi_{31}(L) & \Phi_{32}(L) & \Phi_{33}(L) \end{bmatrix} \begin{bmatrix} \Delta y_{t-1} \\ e_{t-1} \\ capu_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \quad (8)$$

or:

$$x_t = \Phi\ (L)\ x_{t\text{-}1} + \varepsilon_t \tag{9}$$

The estimated unrestricted model can be inverted to the Wold moving average representation:

$$\begin{bmatrix} \Delta y_t \\ e_t \\ capu_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \tag{10}$$

or:

$$x_t = C(L)\ \varepsilon_t$$

with:

$$C(L) = (I - \Phi(L)\ L)^{-1} \tag{11}$$

The variance-covariance matrix of the vector of reduced-form innovations, Σ, is given by:

$$\mathrm{E}(\varepsilon_t \varepsilon_t') = \begin{bmatrix} \mathrm{var}(\varepsilon_{1t}) & \mathrm{cov}(\varepsilon_{1t},\varepsilon_{2t}) & \mathrm{cov}(\varepsilon_{1t},\varepsilon_{3t}) \\ \mathrm{cov}(\varepsilon_{2t},\varepsilon_{1t}) & \mathrm{var}(\varepsilon_{2t}) & \mathrm{cov}(\varepsilon_{2t},\varepsilon_{3t}) \\ \mathrm{cov}(\varepsilon_{3t},\varepsilon_{1t}) & \mathrm{cov}(\varepsilon_{3t},\varepsilon_{2t}) & \mathrm{var}(\varepsilon_{3t}) \end{bmatrix}$$

$$= \begin{bmatrix} s_{11}(0)^2 + s_{12}(0)^2 + s_{13}(0)^2 & s_{11}(0)s_{21}(0) + s_{12}(0)s_{22}(0) & s_{11}(0)s_{31}(0) + s_{13}(0)s_{33}(0) \\ s_{11}(0)s_{21}(0) + s_{12}(0)s_{22}(0) & s_{21}(0)^2 + s_{22}(0)^2 + s_{23}(0)^2 & s_{22}(0)s_{32}(0) + s_{23}(0)s_{33}(0) \\ s_{11}(0)s_{31}(0) + s_{13}(0)s_{33}(0) & s_{22}(0)s_{32}(0) + s_{23}(0)s_{33}(0) & s_{31}(0)^2 + s_{32}(0)^2 + s_{33}(0)^2 \end{bmatrix} \tag{12}$$

$$= \Sigma$$

Applying the assumption that the innovations in ε_t are a linear combination of the structural shocks in v_t, the structural shocks can be related to the disturbances of the reduced-form model as follows:

$$\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} = \begin{bmatrix} s_{11}(0) & s_{12}(0) & s_{13}(0) \\ s_{21}(0) & s_{22}(0) & s_{23}(0) \\ s_{31}(0) & s_{32}(0) & s_{33}(0) \end{bmatrix} \begin{bmatrix} v_{1t} \\ v_{2t} \\ v_{3t} \end{bmatrix} \tag{13}$$

or:

$$\varepsilon_t = S(0)v_t \tag{14}$$

with:

$$E(\varepsilon_t \varepsilon_t^{'}) = S(0)E(\nu_t \nu_t^{'})S^{'}(0) = \Sigma \qquad (15)$$

To recover the structural shocks from the reduced form innovations ε_t, the identification of $S(0)$, the matrix of the contemporaneous effect of the structural disturbances ν_t on x_t will be required. The identification of the nine coefficients of $S(0)$ can be accomplished through equations (12), (4), (10) and (13) with the restriction that demand shocks have only temporary effects on output.[9]

The six equations in the nine unknowns derived from equation (12) are as follows:

$$\mathrm{var}(\varepsilon_{1t}) = s_{11}(0)^2 + s_{12}(0)^2 + s_{13}(0)^2 \qquad (16a)$$

$$\mathrm{var}(\varepsilon_{2t}) = s_{21}(0)^2 + s_{22}(0)^2 + s_{23}(0)^2 \qquad (16b)$$

$$\mathrm{var}(\varepsilon_{3t}) = s_{31}(0)^2 + s_{32}(0)^2 + s_{33}(0)^2 \qquad (16c)$$

$$\mathrm{var}(\varepsilon_{1t},\varepsilon_{2t}) = s_{11}(0)\, s_{21}(0) + s_{12}(0)\, s_{22}(0) \qquad (16d)$$

$$\mathrm{var}(\varepsilon_{1t},\varepsilon_{3t}) = s_{11}(0)\, s_{31}(0) + s_{13}(0)\, s_{33}(0) \qquad (16e)$$

$$\mathrm{var}(\varepsilon_{2t},\varepsilon_{3t}) = s_{22}(0)\, s_{32}(0) + s_{23}(0)\, s_{33}(0) \qquad (16f)$$

Equations (4), (10) and (13) imply:

$$\begin{bmatrix} S_{11}(L) & S_{12}(L) & S_{13}(L) \\ S_{21}(L) & S_{22}(L) & S_{23}(L) \\ S_{31}(L) & S_{32}(L) & S_{33}(L) \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} s_{11}(0) & s_{12}(0) & s_{13}(0) \\ s_{21}(0) & s_{22}(0) & s_{23}(0) \\ s_{31}(0) & s_{32}(0) & s_{33}(0) \end{bmatrix} \qquad (17)$$

or:

$$S(L) = C(L)\, S(0) \qquad (18)$$

After imposing the restrictions that demand shocks have only temporary effects on output and that the cumulative effects of demand shocks on output equals zero, the $S(L)$ matrix becomes a lower triangular matrix, which provides the following three equations.

$$C_{11}(L)\, s_{12}(0) + C_{12}(L)\, s_{22}(0) + C_{13}(L)\, s_{32}(0) = 0 \qquad (19a)$$

$$C_{11}(L)\, s_{13}(0) + C_{12}(L)\, s_{23}(0) + C_{13}(L)\, s_{33}(0) = 0 \qquad (19b)$$

[9] That is, the cumulated effects of demand shocks on output are equal to zero.

$$C_{21}(L)\, s_{13}\,(0) + C_{22}\,(L)\, s_{23}\,(0) + C_{23}\,(L)\, s_{33}\,(0) = 0 \qquad (19c)$$

From equation (19a) the growth in output can be written as a linear combination of the current and past structural shocks as follows:

$$\Delta y_t = S_{11}\,(L)\; v_{1t} + S_{12}\,(L)\; v_{2t} + S_{13}\,(L)\; v_{3t} \qquad (20)$$

or:

$$\Delta y_t = s_{11}\,(0)\; v_{1t} + s_{11}{*}(L)\; v_{1t} + S_{12}\,(L)\; v_{2t} + S_{13}\,(L)\; v_{3t} \qquad (21)$$

where $s_{11}{*}(L)$ is the transitory effect of the permanent shocks to output, which is represented by $S_{11}\,(L) = s_{11}\,(0) + s_{11}{*}(L)$. The transitory component reflects factors linked with the adjustment in the supply side of the economy following a permanent shock to output, such as habit formation, learning and adjustment costs for capital and labour.

Against this background, the change in output that is attributed to potential output is given by:

$$\Delta y^p{}_t = S_{11}\,(L)\; v_{1t} = s_{11}\,(0)\; v_{1t} + s_{11}{*}(L)\; v_{1t} \qquad (22)$$

Accordingly, the cyclical portion of output that is due to demand side shocks is defined by the output gap and is given by:

$$gap_t = S_{12}\,(L)\; v_{2t} + S_{13}\,(L)\; v_{3t} \qquad (23)$$

4. DATA AND ESTIMATION

The model uses quarterly data from 1981:01 to 2004:04 and includes real Gross Domestic Product (GDP), unemployment rate and a measure of capacity utilization.[10] All variables are in logs and seasonally adjusted. The variables used are consistent with that used by Blanchard and Quah (1989).

Except for a measure of capacity utilisation, which was obtained from the Jamaica Public Service Company, all the variables were acquired from the Statistical Institute of Jamaica (STATIN). For the GDP series, initial work had been done for the period 1996 to 2004. For the purpose of this paper, the annual GDP series was collected from STATIN for the period 1981 to 1995 and the series extended using the Denton Least Square Approach. Table A, Appendix, gives the results of the unit root tests. The

[10] Electricity sales is used as a proxy for capacity utilization.

Augmented Dickey Fuller (ADF) test corroborates the generally accepted notion that GDP is a difference stationary process.

The three-variable VAR model is estimated with GDP in log difference, unemployment as log deviations from a deterministic trend while capacity utilisation was found to be trend stationary. The Akaike Information Criterion indicated an appropriate lag structure of 4 lags to remove the presence of serial correlation from the residuals.

5. EMPIRICAL RESULTS

5.1 Actual output vs. potential output

Estimates of potential GDP from the SVAR and actual GDP are shown in figure 1. The plots of potential output versus actual GDP from the trend, BP and HP filter models are shown in figures A, B and C in the appendix.

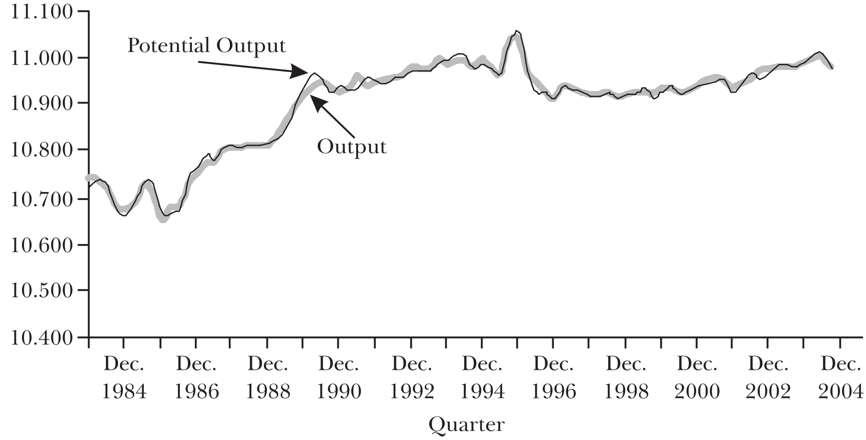
Given that the dynamics of potential output from the SVAR reflects the impact of productivity shocks, the graph shows that there was considerable productivity improvement between June 1986 and March 1990. Thereafter the growth in productivity, though sustained for most of the period was marginal. Notably, the fall in potential output in the mid 1990s was sharper than the decline in actual output, which could have been attributed to the financial sector crisis. One year lagged estimate of total factor productivity (solow residual) is plotted against the potential output in figure 1A. The graph show a strong correlation and the a priori expectation that changes in total factor productivity leads and drives the changes in potential output.

5.2 Linear, HP and SVAR

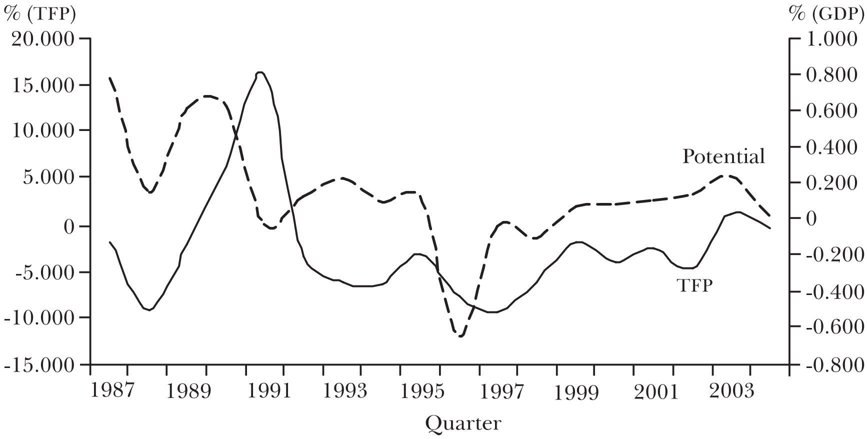
The four measures of the output gap were constructed for Jamaica using the techniques described in section 2. The results are shown in Figure 2.

The result from the linear trend shows two distinct period of excess supply during the sample period, namely September 1983 to March 1989 and December 1996 to December 2004. On average, the HP and BP gaps show similar periods of excess supply. Of note, the result for the BP filter was similar in nature to that of the HP filter. For the SVAR, the result, on average, shows a much shorter period of excess supply in the first period.

FIGURE 1. ACTUAL OUTPUT VS. SVAR POTENTIAL OUTPUT, 1983-2004 (log, Jamaica 1996 dollar million)

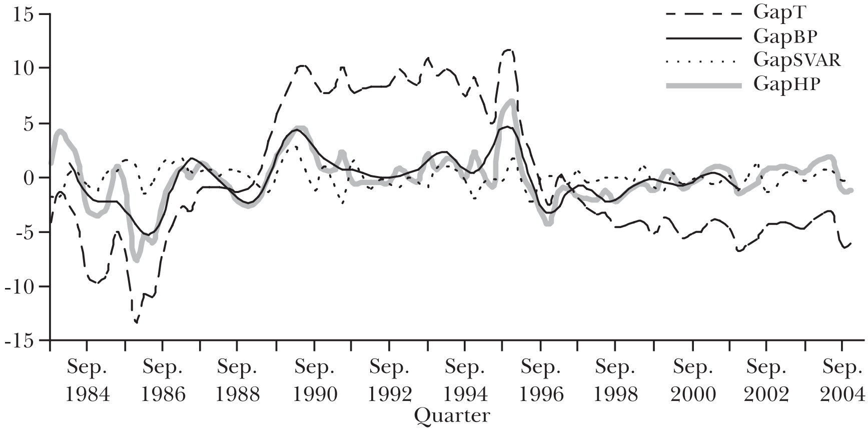


Changes: Total Factor Productivity vs. SVAR Potential GDP, 1987-2004



Notably, the trend model indicates a deeper recession in the two periods of excess supply. Between June 1989 and September 1996 the linear trend technique depicts a continuous period of excess demand. The HP and BP models, on average showed prolonged periods of excess demand, which are however, significantly less in magnitude than that of the trend model. However, the result from the SVAR model shows shorter periods of excess demand over this sample period. The feasibility of the sustained period of excess demand indicated by the trend model seems unlikely and hence the robustness of this methodology appears questionable. Notably, the results from the SVAR and HP filter are

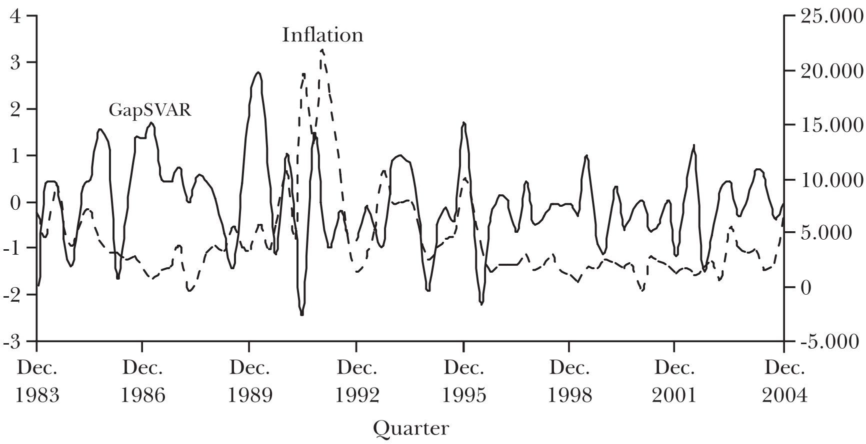
FIGURE 2. OUTPUT GAPs, 1983:03-2004:04 (log difference* 100)



somewhat similar. Although not depicting consistent periods of excess demand or supply, they show on average shorter periods relative to the result from the trend model and BP filter. Noteworthy, at the end of the sample period the output gap derived from the linear trend and HP filter is more negative that the gap defined by the SVAR model.

Since liberalization, the period of demand as indicated by the SVAR is consistent with periods of high inflation (see Figure 3). Prior to liberalization, prices were controlled and hence inflation during this period would not be adequately explained by excess demand. Notably, during the latter part of the sample, which was

FIGURE 3. SVAR OUTPUT GAP VS. INFLATION, 1983-2004 (log difference*100)



characterized by single digit inflation, the economy was generally below capacity.

Allen and Robinson (2004) suggested that the transmission of excess demand pressures to inflation is directly through the impact on costs and indirectly through the exchange rate, as the gap is filled by imports. The latter would be more the case in the early 1990's, the period immediately following liberalization, where excess demand preceded and coincided with exchange rate driven inflation. Bullock et al. (1990) suggest that the exchange rate movement during this period reflected fiscal and hence consequently monetary expansion. Such expansionary policy would have driven the excess demand during that period (see Figure 3).[11]

5.3 Output gap and inflation

The accuracy of the four output gap measures in predicting inflation was tested via a Phillip's curve model. Following Allen and Robinson (2004), inflation is modelled as a forward-looking open economy Phillip's curve equation as follows;

$$\pi_t = \beta_1 E_t \pi_{t+1} + \beta_1 (L) gap_t + \beta_2 (L) \Delta ler_t \tag{24}$$

where 'π' is inflation rate, $E_t\ \pi_{t+1}$ represents expected inflation, 'β_1' represents the coefficient for each of the output gaps used in the equation, '*ler*' is the Jamaican exchange rate *vis-à-vis* the US dollar and L the lag operator. Equation (24) conveys that inflation dynamics are influenced by inflation expectations, some measure of excess demand and imported inflation. Equation (24) is estimated using a generalized method of moments (GMM) with 'π_{t+1}' serving as a proxy for expected inflation and along with current values of the output gap and first differences of the exchange rate as the instruments.

The estimated results from the foreword-looking Phillips curve test are shown in table 1. The in-sample forecast graphs are contained in figures D, E, F and G in the appendix.

With the exception of the result for the HP and BP models, the coefficient on the output gap for the linear trend and SVAR techniques are positive and significant at the 5 per cent level. The results suggest that the gap derived from the HP and BP models have statistically insufficient information for explaining inflation

[11] Part of the movement in the exchange rate was also due to low investor confidence in the economy.

TABLE 1. RESULTS OF PHILLIPS CURVE EQUATION: DEPENDENT VARIABLE: INFLATION: ESTIMATION PERIOD 1984:01 - 2002:04

	Linear Gap	*HP Gap*	*BP Gap*	*SVAR Gap*
Lead Inflation	0.6353	0.7454	0.6839	0.792
	(0.0530)*	(0.0566)*	(0.0656)*	(0.0435)*
Output Gap			-0.0264	
			(0.1366)	
Output Gap (-1)	0.1250	-0.2353		0.471
	(0.0375)*	(0.1999)		(0.1696)*
Dler			0.0103	
			(0.0034)*	
Dler (-1)	0.0106	0.0076		0.0057
	(0.0016)*	(0.0028)*		(0.0016)*
Summary Statistics				
Durbin Watson	2.083	2.196	2.197	2.026

NOTE: Standard Errors in parenthesis. * denotes significance at the 5 per cent level.

with any reasonable level of accuracy. The coefficient on the SVAR models had the largest explanatory power.

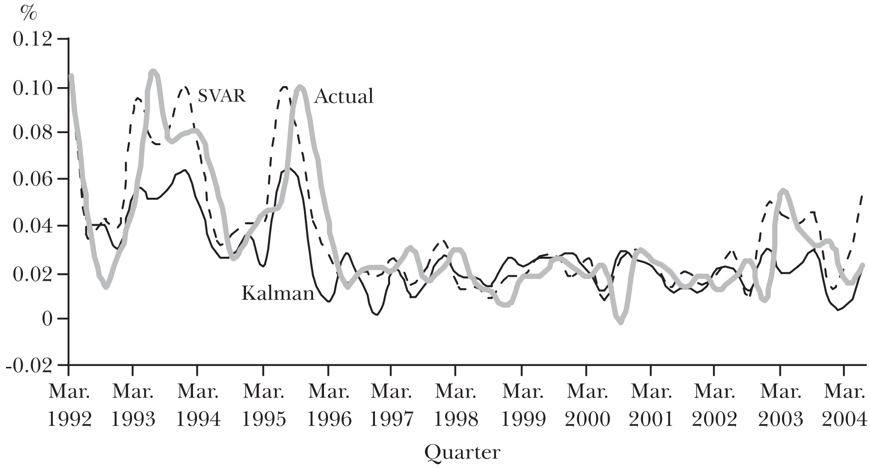
Table B (Appendix) provides a comparison of the forecasting accuracy of the four models under consideration. Based on these statistics, the linear trend and SVAR models have the greatest predictive power for out-sample forecasts, which is reflected in their THEIL U and Janus statistics.

5.3.1 SVAR vs. Kalman filter estimate of inflation

With respect to the forecasting of inflation using output gaps, the results from the SVAR is compared with the Kalman filter estimates that is currently used by the Bank in its macro model.[12] Table C in the appendix contains the forecast evaluation statistics while figure 4 below shows a graph of the estimates. Based on the forecast evaluation statistics, the SVAR model has the greater predictive power. This is supported by figure 4, which shows that the SVAR model captures more closely the magnitude of the peaks and troughs of inflation over the sample period.

[12] Sample period March 1992 to June 2004.

FIGURE 4. INSAMPLE FORECAST OF INFLATION: SVAR VS. KALMAN FILTER, 1992-2004



6. CONCLUSION

Having an understanding of the dynamics of potential output and the output gap can be helpful to the monetary authorities as these factors can play a critical role in inflation. Against this background this paper reviewed four methods that are used to estimate potential output and hence the output gap, namely HP and BP filters, linear time trend and the SVAR model. Based on the results the best model for estimating the output gap is the SVAR, which has relatively good predictive power and is most consistent with economic theory when compared to the other models.

A comparison of the forecasting capability of the results derived from the SVAR and Kalman filter shows the SVAR as the better model for estimating inflation. Of note, the SVAR measure of potential output is expected to complement the Bank's Kalman filter measure as well as aid in sectoral estimates of capacity utilization in assessing capacity constraints.

The SVAR potential output showed two periods of sustained productivity and a period of considerable improvement. Productivity in the latter period was driven primarily by developments in the mining sector as well as a general thrust by some companies to be more capital intensive.

The result from the SVAR model showed shorter periods of excess demand during the sample period relative to the other models. Of note, the trend model depicted a persistent period of excess demand between June 1989 and September 1996, whichl seems unlikely. Since liberalization, the periods of excess demand as indicated by the SVAR is consistent with periods of high inflation. During the latter part of the sample, which was characterized by single digit inflation, the economy was generally below capacity.

Additionally, the output gap derived from the HP and BP filters has insufficient information for predicating inflation with any level of accuracy. However, the output gap from the linear trend and SVAR models can be used to estimate inflation with some suitable level of accuracy.

The main policy implication from this research is the relative importance of the output gap or capacity constraint to inflation in Jamaica. Monetary policy cannot affect long run growth, however, it is capable of affecting short run demand and hence the output gap. The results also show that output level is not deviating significantly from potential output. In that regard, there is a constraint to how much faster the economy will be able to grow. The inability of potential output to grow or accelerate faster since the 1990's may reflect the level of disinvestment in manufacturing, primarily in the garment sector, the reduction in acreages in agriculture due to weak competitiveness. The financial sector crisis of the mid 1990's could have also contributed.

Appendix

FIGURE A. ACTUAL OUTPUT VS. TREND POTENTIAL OUTPUT, 1983-2004 (log, Jamaica 1996 dollar million)

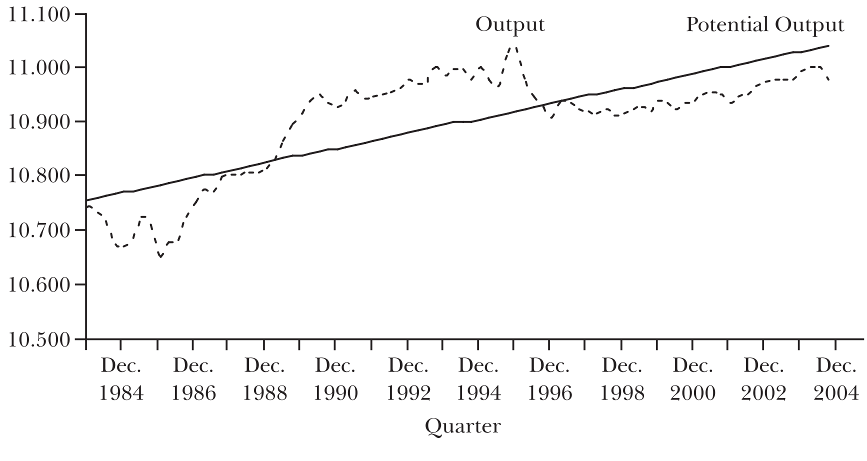


TABLE A. AUGMENTED DICKEY-FULLER TEST

	T Statistics			*T Statistics*		
Variables	*Levels*	*Trend First Difference*	*Lag*	*Levels*	*Trend First Difference*	*Lag*
RGDP	-1.47	-4.44	4	-1.55	-4.37	4
Unemployment	-2.25	-3.54	3	-1.93	-3.56	3
Capacity Utilisation	-3.55		1		-3.59	1
5% Critical Value	-3.46				-2.89	
1% Critical Value	-4.06				-3.50	

FIGURE B. ACTUAL OUTPUT VS. HP POTENTIAL OUTPUT, 1983-2004 (log, Jamaica 1996 dollar million)

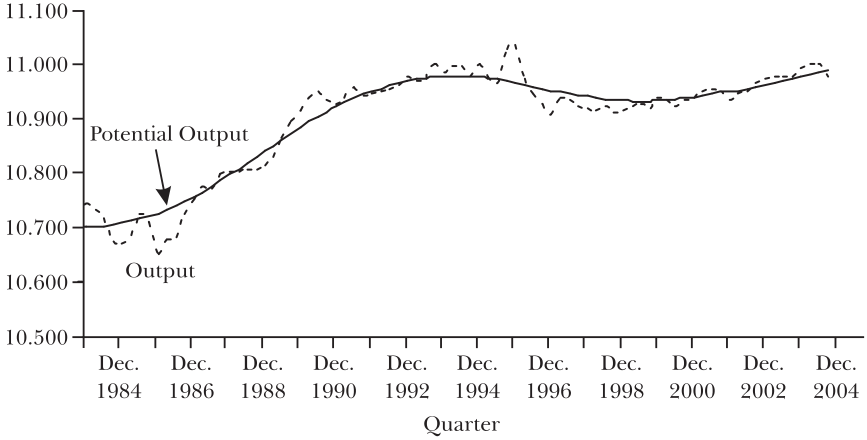


TABLE B. MODEL FORECAST EVALUATIONS: OUT-SAMPLE FORECAST SAMPLE, 2002:1-2004:4

Model	*MSE*	*RMSE*	*MAE*	*THEIL U*	*Janus*
SVAR	0.0004	0.0203	0.0161	0.2918	0.4473
TREND	0.0003	0.0183	0.0155	0.2848	0.3969
HP Filter	0.0004	0.0209	0.0165	0.2996	0.4671
BP Filter	0.0002	0.0140	0.0101	0.3077	

FIGURE C. ACTUAL OUTPUT VS. BP POTENTIAL OUTPUT, 1984-2001 (log, Jamaica 1996 dollar million)

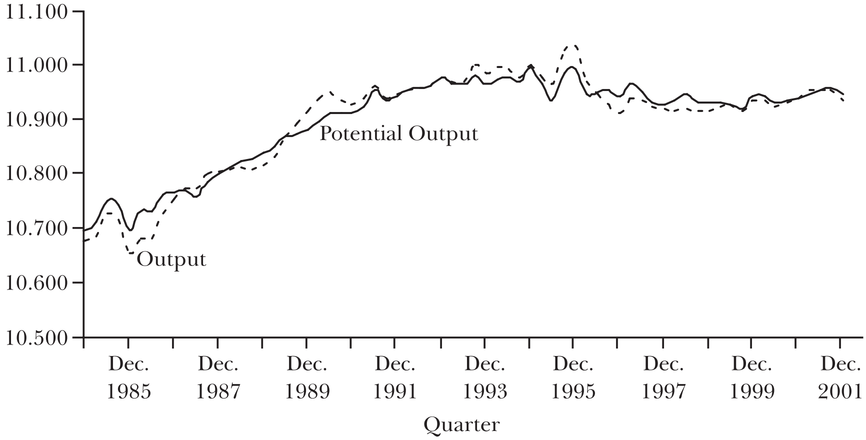


TABLE C. MODEL FORECAST EVALUATIONS: IN-SAMPLE FORECAST - SAMPLE 1992:1 2004:2

Model	*MSE*	*RMSE*	*MAE*	*THEIL U*
SVAR	0.0009	0.0296	0.0183	0.2254
Kalman	0.0009	0.0306	0.0197	0.2705

FIGURE D. INSAMPLE FORECAST OF INFLATION: SVAR MODEL, 1984-2002

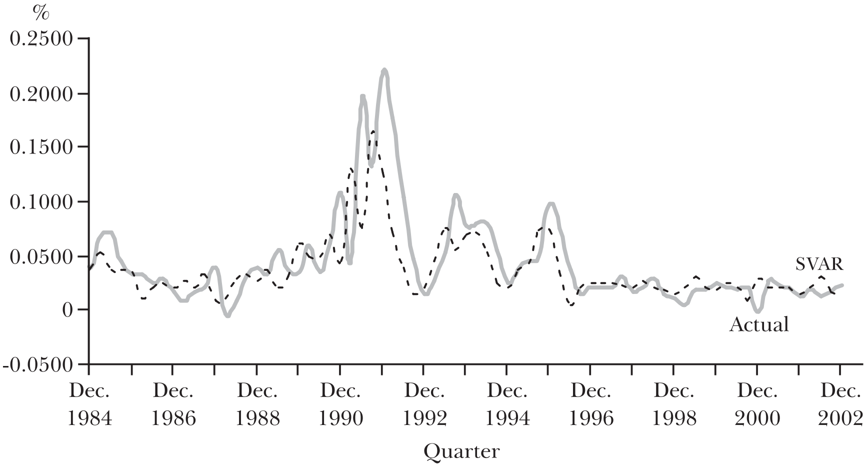


FIGURE E. INSAMPLE FORECAST OF INFLATION: TREND MODEL, 1984-2002

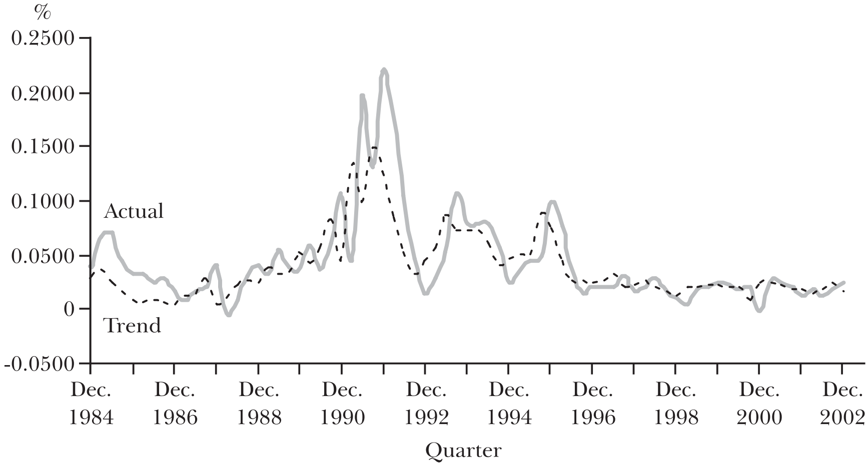


FIGURE F. INSAMPLE FORECAST OF INFLATION: HP FILTER, 1984-2002

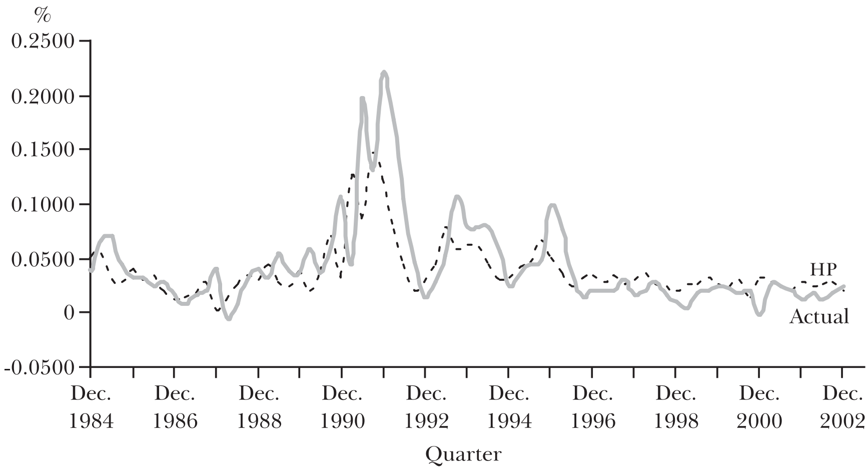
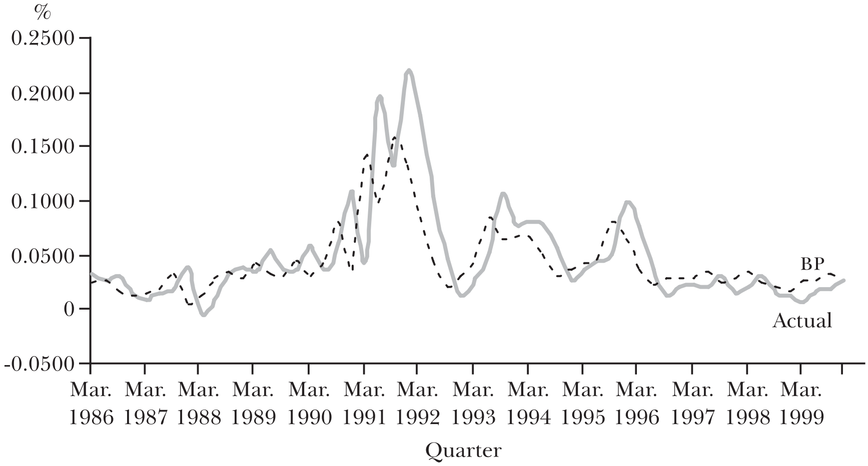


FIGURE G. INSAMPLE FORECAST OF INFLATION: BP FILTER, 1986-2000



BIBLIOGRAPHY

Allen, C., and W. Robinson (2004), *Monetary Policy Rules and the Transmission Mechanism in Jamaica,* Research and Economic Programming Division, Bank of Jamaica.

Baxter, M., and R. G. King (1995), *Measuring Business Cycles: Appropriate Band-Pass Filters for Economic Time Series,* NBER (Working Paper, nº 5022).

Blanchard, O., and D. Quah (1989), "The Dynamics Effects of Aggregate Supply and Demand Disturbances", *American Economic Review*, vol. 79, pp. 655-73.

Bullock, C., J. Robinson and E. Shaw (1990), *Towards a Liberalized Foreign Exchange System for Jamaica: An Assessment of the Issues, Precedents and Prospects,* Research and Economic Programming Division, Bank of Jamaica.

Butler, L. (1996), *A Semi-Structural Method to Estimate Potential Output: Combining Economic Theory with a Time-Series Filter,* Bank of Canada (Technical Report, nº 76).

Claus, I. (1999), *Estimating Potential Output for New Zealand: A Structural VAR Approach,* Reserve Bank of New Zealand (Discussion Paper Series 2000/03).

Cogley, T., and J. Nason (1995), "Effects of the Hodrick-Prescott Filter on Trend and Difference Stationary Time Series: Implication for Business Cycle Research", *Journal of Economic Dynamics and Control*, vol. 19, pp. 253-78.

Conway, P., and B. Hunt (1997), *Estimating Potential Output: A Semi-Structural Approach,* Reserve Bank of New Zealand (Discussion Paper G97/9).

Gounder, K., and S. Morling (2000), *Measures of Potential Output in Fiji,* Economics Department, Reserve Bank of Fiji (Working Paper 2000/6).

Granger, C. W. J. (1966), "The Typical Spectral Shape of an Economic Variable", *Econometrica,* vol. 34, pp. 150-61.

Guay, A., and P. St-Amant (1996), *Do meechnaical Filters Provide a Good Approximation of Business Cycles?,* Bank of Canada (Technical Report, nº 78).

Harvey, A., and A. Jaegar (1993), "Detrending, Stylised Facts and the Business Cycle", *Journal of Applied Econometrics*, vol. 8, pp. 231-47.

Hodrick, R., and E. C. Prescott (1997), "Post-War US Business Cycles: An Empirical Investigation", *Journal of Money, Credit and Banking*, vol. 29, February, pp. 1-16.

Koustas, Z. (2003), *Stylized Facts of the Canadian Business Cycle,* Department of Economics, Brock University.

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Regional integration and elasticities of export demand in Barbados

1. INTRODUCTION

Proponents of trade liberalization argue that exports are an important component of growth in generating foreign exchange necessary to finance imports and maintain healthy international reserves. What drives exports has subsequently been an interesting question drawing a multitude of contributions. Among the empirical studies there is Algieri (2004); Cosar (2002); Senhadji and Montenegro (1999); Duffy, Wohlgenant and Richardson (1990) and Marquez and McNeilly (1988). These studies have emphasized the importance of export demand elasticities. According to Senhadji and Montenegro (1999) demand elasticity is defined as a measure of the sensitivity of demand against the changes in price and income. The higher the income elasticity of demand, the more powerful are exports as an engine of growth. The higher the price elasticity, the more competitive is the international market for exports of the particular country, and thus a

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real devaluation will be more successful in promoting export revenue.

Following Algieri (2004); Cosar (2002) and Senhadji and Montenegro (1999) among others, this paper estimates the price and income elasticities for Barbados' goods exports to its trading partners. The price and income elasticities of exports are relevant in a country's balance of payments management (including exchange rate, subsidy and tariff policies), monetary and fiscal policies, the international transmission in changes in economic activity, prices and the employment effects of changes in own or partner countries' trade restraints and the severity of external balance constraints on domestic policy choices (Goldstein and Khan, 1985).

Senhadji and Montenegro (1999) examined the export demand elasticities for 75 developing and industrial nations for the period 1960-1993. The study used the Phillip's Fully Modified time series estimator that account for the non-stationarity in the data as well as the potential endogeneity among the explanatory variables and the autocorrelation of the error term. The paper considered Dominican Republic, Jamaica, Haiti and, Trinidad and Tobago in the Caribbean. Jamaica did not yield meaningful results. The exports of Dominican Republic, Haiti and, Trinidad and Tobago were price and income inelastic[1] in the short run. In the long run exports remained price inelastic and became highly responsive to income. The long run income elasticity for Dominican Republic, Haiti and, Trinidad and Tobago were 1.34, 1.24 and 1.41 respectively. Senhadji and Montenegro (1999) did not include Barbados in their export demand elasticity analysis. This paper seeks to fill in that void.

In their export elasticities study, Senhadji and Montenegro (1999) used time series techniques which overlooks the cross sectional variation of the data. To incorporate the cross sectional variation, this paper uses panel data techniques (the system general method of moments estimator) that accounts for endogeneity issues, country-specific time-invariant factors, unit root effects and omitted variable biases in the choice of instruments (refer to Blundell and Bond, 1998 for a detailed account of the system general methods of moments technique).

The empirical studies on export elasticities have been focused on large economies. For instance, Algieri (2004) worked on Russia;

[1] Inelastic means the modulus of the coefficient is less than one and elastic means the modulus is greater than one.

Duffy et al. (1990) studied United States cotton exports and Cosar (2002) studied Turkish exports. This paper serves to highlight the difficulties of exporting from a small open economy with a fixed exchange rate.

The existing literature on Barbados exports has concentrated on the country's export performance. Using descriptive statistics, Campbell (1993) investigated the performance of non-sugar exports in Barbados for the period 1967-1991. Another example is Worrell (1992) who examined the post-war economic performance of Barbados and the success of the export-oriented strategy. None of the studies worked on export elasticities, making this study the first of this type in Barbados.

The paper uses the imperfect substitutes model to formulate the model for estimation. The imperfect substitutes model was developed by Goldstein and Khan (1985). It has been commonly employed in the studies on export elasticities in both developed and developing countries (see for example Algieri, 2004; Cosar, 2002). A system general method of moments approach (SYS GMM) is undertaken on a sample of 35 goods export markets of Barbados using the data from the Central Bank of Barbados, International Monetary Fund (IMF) and the World Development Indicators. The estimates indicate that income elasticity is positive and very elastic corroborating with theory. As for the price elasticity the result is negative as theory predicts but very inelastic. The inelasticity of the real exchange rate coefficient (the price elasticity) is not surprising given that Barbados has preferential trade agreements with the United Kingdom (Initially under the Lomé convention and now the Cotonou Agreement), the United States (under the Caribbean Basin Initiative), Canada (under the Canadian Programs for Commonwealth Caribbean Trade, Investment and Industrial Cooperation) and the Caribbean countries (under the Caribbean Community and Common Market). Thus, it can be inferred that Barbadian exports are unlikely to be price competitive, a finding of interest for developing policy responses.

Regional income and price slopes were investigated. Results showed that the Caribbean income and price slope dummies are highly significant. This shows that in small open economies, such as Barbados in addition to income responsiveness, regional integration is more important to trading than price competitiveness.

The paper is organized as follows: Section 2 discusses the export structure and performance of Barbadian goods to motivate the research. The shares of the main trading partners in total exports are also presented in this section and viable export commodities are identified. Section 3 relates the theoretical foundation that is the basis for the empirical analysis in section 4. Section 4 presents the export demand model and the associated price and income elasticity estimates. Finally, section 5 concludes.

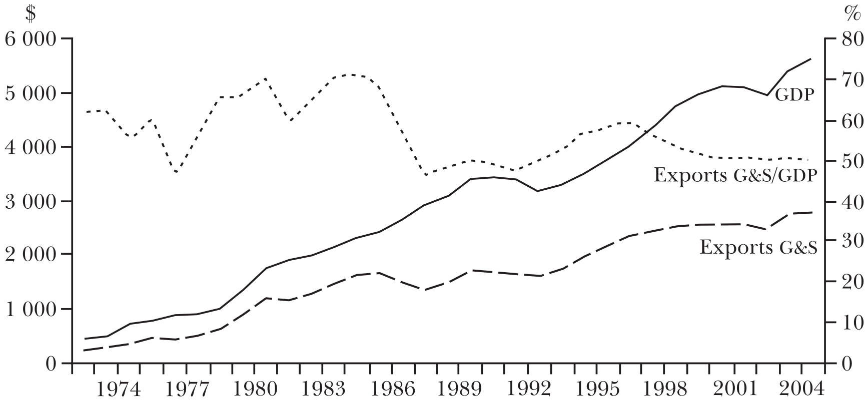
2. EXPORT PERFORMANCE IN BARBADOS

The economic growth process of Barbados has historically been influenced by the direction of trade in tourism services and exports of goods.

Figure 1 shows the gross domestic product (GDP) and exports of good and services for Barbados for the period 1972-2004. Both graphs have been increasing but at a diverging trend. Not surprising, the ratio of exports of goods and services to GDP has been falling as depicted in figure 1. The ratio of exports of goods and services to GDP has been impressive from 1978 to 1985, a period of intensified import substitution protection (Whitehall, 1986). From 1978-1985 the proportion of exports of goods and services to GDP was at least 65 percent, the highest for the entire period of analysis. In 1986 the ratio fell to about 57 percent and further to 46 percent in 1987. Thereafter the ratio slightly set on an increasing trend to a peak of about 60 percent in 1996 and then returned on a falling trend recording a proportion of about 50 percent in 2004. It is important to extract whether aggregated components of exports aligns with this, identify export constraints and opportunities to escape the low-level export trap.

It is a fact that the tourism industry of Barbados has been dominating exports (Howard, 2006: 101). However, there is need

FIGURE 1. GDP AND EXPORTS OF GOODS AND SERVICES, 1972-2004 (millions of $)



for diversification to avoid dependency on one export item. An interesting point to note is that Barbados embarked on an export diversification policy after 1985 following the fall in sugar industry and the strong performance of service exports (Howard, 2006:105). In light of this, the study critically examines the trend in export of goods to identify the possible goods Barbados can concentrate on to boost growth. Using a sample of 35 exporting countries[2] of Barbados and the period 1997-2004 for which detailed data was available, tables 1 and 2 were constructed to show the general statistical overview of the components of Barbados' exports and the direction of exports respectively.

TABLE 1. COMPOSITION OF BARBADIAN EXPORTS (%)

Category	*1997*	*1999*	*2001*	*2003*	*2005*
Tobacco, beverages	14.3	17.3	17.3	16.0	13.3
Chemicals N.E.S	17.0	16.3	18.6	24.3	23.1
Clothing	1.6	1.3	0.9	0.5	0.3
Crude Materials	0.6	0.3	0.1	0.0	0.3
Electronic Components	6.1	2.9	3.2	3.6	3.9
Food	21.8	8.8	6.1	7.6	8.8
Furniture and Parts	0.2	0.1	0.1	0.2	0.1
Machinery	0.6	0.3	1.7	0.4	3.5
Manufactured Goods	18.1	23.4	18.6	12.0	16.6
Miscellaneous Manufacture	2.8	0.5	0.1	0.1	0.5
Oils, fats, waxes	2.8	3.2	3.2	3.3	1.8
Other Commodities	0.6	3.7	3.7	5.0	8.7
Sugar	9.3	17.3	21.2	21.7	13.5
All Other	4.1	4.6	5.1	5.4	5.7
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

SOURCE: Central Bank of Barbados.

In 2001, the Barbadian goods exports were dominated by sugar directed towards the limited export markets. Sugar was mainly exported to the United Kingdom under the non-reciprocal preferential trade arrangement. As table 1 shows sugar exports rose from about 9 percent of total exports in 1997 to about

[2] The 35 major countries Barbados export to considered are Anguilla, Antigua & Barbuda, Aruba, Australia, Bahamas, Belize, Bermuda, Brazil, Canada, Costa Rica, Dominica, Dominican Republic, France, Germany, Grenada, Guyana, Haiti, Hong Kong, Jamaica, Japan, Mexico, Montserrat, Netherland Antilles, Panama, Puerto Rico, Singapore, Spain, St. Kitts & Nevis, St. Lucia, St. Vincent, Suriname, Trinidad & Tobago, United Kingdom, United States of America and Venezuela.

TABLE 2. DIRECTION OF EXPORTS (percent of total)

Country	*1997*	*1999*	*2001*	*2003*	*2005*
Antigua & Barbuda	3.7	5.1	3.5	4.1	4.0
Canada	1.5	0.5	2.3	1.9	2.6
Dominica	2.8	3.2	2.4	2.8	2.5
Grenada	3.2	4.1	4.5	4.8	4.7
Guyana	4.3	4.4	4.2	4.6	3.9
St. Kitts & Nevis	2.5	3.6	3.0	3.0	3.2
Jamaica	9.9	11.0	11.5	8.9	12.8
St. Lucia	7.1	7.7	7.6	6.4	7.7
St. Vincent	4.6	5.5	5.2	9.9	5.3
Suriname	1.6	3.1	2.6	2.7	2.2
Trinidad & Tobago	11.3	11.7	9.2	8.3	9.4
United Kingdom	28.5	23.8	25.3	21.7	19.5
United States	12.3	8.9	9.8	11.4	10.6
Other	6.7	7.5	8.9	9.5	11.7
Total	*100.0*	*100.0*	*100.0*	*100.0*	*100.0*

SOURCE: Central Bank of Barbados.

17 percent in 1999. In 2001 the proportion of sugar exports to total goods exports rose to about 21 percent. The ratio stagnated at about 22 percent in 2003 contributing the greatest proportion of exports in that year. Later sugar exports fell to about 14 percent in 2005. The fall of sugar exports is highly attributed to the closing down of domestic sugar production factories, reduction in acreage planted and the World Trade Organization's (WTO) pressure on United Kingdom to change the preferential treatment. Consequently, sugar export proceeds were out done by chemicals component from 2003. Whereas sugar exports were falling, chemicals exports were significantly rising. The chemicals component rose to about 24 percent in 2003 from about 19 percent in 2001. In 2004 chemicals continued to be the main foreign currency earner, accounting for 23 percent goods exports in 2005. Over the period of analysis (1997-2005), chemicals to total exports ratio have been on a dramatic increase making chemicals the current highest earner of foreign currency and a promising export component to the economic growth of Barbados.

Beverages and tobacco seem to be doing relatively well on the export market. In 1997, beverages and tobacco amounted to about 14 percent of total exports (refer to table 1). In 1999 the ratio of beverages and tobacco rose to about 17 percent in both 1999 and 2001. In 2003 the ratio slightly fell to 16 percent and further dropped to about 13 percent in 2005. Sugar and beverages and tobacco contributed almost similar proportions of exports in 2005. However, beverages and tobacco only fell by about 3 percent from 2003 to 2005 whereas sugar fell by about 8 percent from 2003 to 2005. Considering these ratios, it can be deduced that beverages and tobacco are more favourable than sugar exports suggesting resources can be shifted from sugar to beverages and tobacco.

Manufactured goods increased from 18 percent in 1997 to about 23 percent in 1999. After 1999, manufactured goods ratio was declining due to strong competition from low cost countries. In 2001, 2003 and 2005 manufacturing goods contributed about 19 percent, 12 percent and 17 percent respectively. As evidenced from figure 1, the clothing exports are on a declining trend from year to year since Barbados could not keep up with countries which have a large cheap pool of unskilled labour. Subsequently, the ratio of clothing exports to total exports has been contributing less than 2 percent of total exports which further declined to 0.3 percent in 2005. Certainly, the clothing exports do not seem to be a viable export commodity. Electronic components fell from about 6 percent in 1997 to about 3 percent in 1999. The fall was associated with increased competition from low cost domiciles. Thereafter, the proportion of electronic components exported slightly rose to 3.3 percent, 3.6 percent and 3.9 percent in 2001, 2003 and 2005 respectively.

Clothing, crude materials, furniture and parts and miscellaneous manufacture are the most insignificant export products of the 13 products reported in table 1. Other commodities are on a consistently rising trend. The ratio was 0.7 percent in 1997. The ratio rose to 3.7 percent in 1999 and 2001. Later other commodities rose to 5 percent of total exports and finally to 8.7 percent in 2005.

Table 2 presents the percentages of the direction of exports for the 13 highest export markets of Barbados out of the 35 countries listed in footnote 2. The major export market is the United Kingdom followed by Jamaica, United States and Trinidad and Tobago. The proportion of export market to United Kingdom has been falling due to the decline in sugar exports. Despite the fall in sugar exports, United Kingdom remains one of the most important export markets of Barbados. Exports to Jamaica have been favourable. In 1997, Jamaica constituted of about 10 percent of Barbadian exports. The exports to Jamaica as a ratio of total exports rose to 11 percent in 1999 and further to about 12 percent. Thereafter, the Jamaican exports fell to 9 percent and rose again to about 13 percent in 2005.

Focusing on the goods exports, it is essential to model the demand for Barbadian exports by its export markets and examine the magnitudes of its export demand elasticities for policy making. The next section relates the theoretical framework for export demand, the building block of our empirical analysis.

3. THEORETICAL FRAMEWORK

The theoretical foundation of our empirical analysis is the imperfect substitutes model (developed by Goldstein and Khan, 1985), in which the basic assumption is that neither imports nor exports are perfect substitutes for domestic products. This assumption is realistic and can be confirmed by a counterfactual thought experiment. If domestic and foreign goods were perfect substitutes, a given country would be either an exporter or an importer. However, the world market is characterized by the presence of bilateral trade and the coexistence between imports and domestic production; hence, the hypothesis of perfect substitution can be rejected.

The main features of the imperfect substitutes model can be summarized as follows. In accordance with conventional demand theory, the consumer maximizes utility subject to a budget constraint. The resulting demand functions for imports and exports represent the quantity demanded as a function of the level of (money) income in the importing region, the imported good's own price, and the price of domestic substitutes. In the model, the possibility of inferior goods and of domestic complements for imports are usually excluded; thus, income elasticities and cross-price elasticities of demand are assumed to be positive, while the own-price elasticity of demand is assumed to be negative. Typically, the additional assumption is made that the consumer has no money illusion, that is a doubling of money income and all prices leaves demand constant. Moreover, the model only focuses on current income for import (export) demand, and no distinction is made between secular or cyclical income movements or between transitory and permanent income.

We will now derive the export demand function for Barbados. Suppose that Barbados, the exporting country, has only one trading partner, the rest of the world. Hence, Barbados' export demand (x_t) coincides with the import demand of the rest of the world (m_t^*). We assume that there is a representative agent in the rest of the world, who lives forever and maximizes his/her utility by choosing how much to consume of his/her domestic endowment (w_t^*) and of the imported good (m_t^*). We assumed further that there is no production sector because production often involves the combining of intermediate inputs yet the model makes no distinction between intermediate and final products. The optimization problem is written as follows.

$$\underset{\{w_t^*, m_t^*\}_{t=0}^{\infty}}{Max} U_t = \underset{\{w_t^*, m_t^*\}_{t=0}^{\infty}}{Max} E_t \cdot \{\sum_{t=0}^{\infty} (1+\delta)^{-1} \cdot u(w_t^*, m_t^*)\}$$

subject to the budget constraint:

$$b_{t+1}^* = (1+r) \cdot b_t^* + (s_t^* - w_t^*) - p_t \cdot m_t^* \quad (1)$$

and a transversality condition, which excludes Ponzi-games, i.e. the fact that a consumer can freely consume all lifetime resources, by borrowing forever without paying of the debt.

$$\lim_{T \to \infty} \frac{b_{T+1}^*}{\prod_{t=0}^{T} (1+r)^{-1}} = 0 \quad (2)$$

The starred variables represent the rest of the world, the importing country, while the non-starred variables refer to Barbados. $E\{\ \}$ is the expectation operator at time t; δ is the consumer's rate of time preferences, i.e. the subjective discount rate, which measures the individual's impatience to consume; agents are free to borrow and lend at the same world interest rate r, that is the yield on capital; b_{t+1}^* denotes the next period stock of Barbados bonds held by the rest of the world if positive and the next period stock of foreign bonds held by Barbados if negative; p_t is the price of the Barbadian good in terms of foreign commodity; s_t^* is the stochastic endowment which follows an autoregressive of order one process of the form:

$$s_t^* = \mu \cdot s_{t-1}^* + (1-\mu) \cdot \bar{s}^* + \varepsilon_t^*; \ 0 \le \mu \le 1 \text{ and } \varepsilon_t^* \approx (0, \sigma^2) \quad (3)$$

with an unconditional mean $\bar{s}^*$ and an unconditional variance $\sigma^2 / (1-\mu^2)$. ε_t^* is an independent and identically distributed shock to the stochastic endowment with zero mean and variance σ^2. μ governs the degree of persistence of the endowment shock.

Now consider the case in which the individual utility function is of the addilog type, such as:

$$u_t(w_t^*, m_t^*) = \frac{A_t \cdot (w_t^*)^{1-\alpha}}{1-\alpha} + \frac{B_t \cdot (m_t^*)^{1-\beta}}{1-\beta} \qquad (4)$$

$$A_t = e^{a+\upsilon_t}$$

$$B_t = e^{b+\delta_t}$$

where A_t and B_t are exponential stationary random shocks, which cause variations in the preferences of the representative agent, υ_t and δ_t are stationary shocks, α and β are called curvature parameters and their inverse can be interpreted as long-run intertemporal elasticities of substitution between the domestic and imported good. Solving the optimization problem and substituting the values for A_t and B_t we will have the following first order conditions:

$$w_t^* = \lambda_t^{-1/\alpha} \cdot \left(e^{\alpha+\upsilon_t}\right)^{1/\alpha}$$
$$m_t^* = \lambda_t^{-1/\beta} \cdot \left(e^{\beta+\delta_t}\right)^{1/\beta} \cdot p_t^{-1/\beta} \qquad (5)$$

After taking log of the above equations and performing simple algebraic manipulation we get:

$$\ln m_t^* = \ln x_t = \frac{\alpha}{\beta}\ln w_t^* - \frac{1}{\beta}\ln p_t + c + \omega_t \qquad (6)$$

where $c = \frac{1}{\beta}(b-a)$ and $\omega_t = \frac{1}{\beta}(\delta_t - \upsilon_t)$. This is the standard export port demand function of the economic imperfect substitute model.

We generalize the rest of the world assumption to include each export market of Barbados. That is, equation (6) is transformed into panel data form. Using i to denote each of the major exporting countries' of Barbados, t to represent time, R_{it} the real effective exchange rate is used for variable p_t and I_{it} the foreign income replaces $w*$. Thus, the relevant export demand function for estimation is:

$$\ln X_{it} = \varphi_0 + \varphi_1 \ln I_{it} + \varphi_2 R_{it} + \varepsilon_{it} \qquad (7)$$

GDP volume (2000=100) has been used to proxy foreign income I_{it}. The real effective exchange rate is calculated as:

$$R_{it} = \frac{P_d}{e_i P_i}$$

where e_i is the nominal exchange rate with country i (number of Barbados dollars per unit of foreign currency). P_i is the consumer price of country i and P_d is the price of domestic goods. X_{it} is real exports deflated by Barbados' consumer price index. The figures for exports have been obtained from the Central Bank of Barbados. Exchange rates; GDP volume (2000=100) domestic; foreign consumer prices and Barbados' consumer price index are from the International Monetary Fund (IMF) and the World Development Indicators.

4. EMPIRICAL ANALYSIS

4.1 Econometric methodology

The data constitutes of 35 export markets of Barbados over a period of 12 years from 1994-2005. It is a yearly unbalanced panel data. The countries are the largest exporting markets of Barbados and were also selected based on the availability of data. Marquez and McNeilly (1988) revealed that the existing elasticity estimates are subject to biases arising from the omission of relevant variables, aggregation across countries and commodities and simultaneity. This study uses an econometric methodology that eliminates many of the restrictions cited by Marquez and McNeilly (1988). Given the form of the data, the usual ordinary least squares (OLS) and within-groups methods for panel data are unlikely to be appropriate in the analysis. Specifically, omitted variable bias is likely to affect the OLS coefficient estimates, due to the presence of unobserved country-specific influences η_i. This concern can be addressed using the within-groups estimation technique. However, the within-groups estimate is affected by endogeneity. The dynamic model considered is of the form:

$$x_{it} = \gamma_0 x_{it-1} + \gamma_1 Z_{it} + h_t + \eta_i + \varepsilon_{it} \tag{8}$$

where Z_{it} contains current or lagged values of explanatory variables (that is $\ln I_{it}$ and R_{it}) and x_{it} is the $\ln X_{it}$. h_t captures aggregate time effects, η_i captures country-specific effects and ε_{it} are serially uncorrelated errors. x_{it-1} and Z_{it} are assumed to be correlated with the individual effects, η_i. This representation confirms that the export demand model in equation (8) is in fact a dynamic model for the level of x_{it}, when $|\gamma_0| \prec 1$.

It is well known that the OLS and the within-groups technique provide biased estimates of the coefficient γ_0 on the lagged dependent variable described in equation (8). The bias in the OLS is typically upwards due to the correlation between individual effects and the lagged dependent variable. The within–groups estimate for the lagged dependent variable tend to be biased downwards such that a candidate model should have the coefficient of the lagged dependent variable falling between the estimate of the OLS and the within-groups (see for example Bond, 2002 for discussion). Moreover, the coefficients of the other explanatory variables may also be biased as a consequence of their correlation with the lagged dependent variable.

The first difference general method of moments (DIFF GMM) has been used to account for the omitted variable bias and the endogeneity issue (see Arellano and Bond, 1991). The differencing of the model eliminates the unobserved time-invariant effects, η_i and appropriate instruments can then control for endogeneity and measurement error. This method implies taking first differences of equation (8):

$$x_{it} - x_{it-1} = \gamma_0 (x_{it-1} - x_{it-2}) + \gamma_1 (Z_{it} - Z_{it-1}) + (h_t - h_{t-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \qquad (9)$$

Using sufficiently lagged values of x_{it} and Z_{it} as instruments for the first differences $(x_{it-1} - x_{it-2})$ and $(Z_{it} - Z_{it-1})$ in equation (9). However, the differencing procedure may discard much of the information in the data since the largest share of the variation in export demand statistics is cross sectional.

This study consequently focuses on the system GMM estimator by Arellano and Bover (1995) and Blundell and Bond (1998). The estimator is suitable for short time periods with large cross-sectional individuals. The system estimator can be seen as an extension of the first difference estimator that provides a way of retaining some of the information in the equations in levels. Provided the additional instruments used are valid, the system GMM estimator tends to have better finite sample properties unlike the first difference GMM estimator, since it exploits the available time series information efficiently. This is likely to be particularly important when considering variables that are highly persistent (refer to Blundell and Bond, 1998).

In short, the system GMM is computed by combining moment conditions for the equations in first differences —equation (9)—

using suitably lagged level variables as instruments, with additional moment conditions for the equation in levels —equation (8)— where the instruments are suitably lagged values of $(x_{it-1} - x_{it-2})$ and $(Z_{it} - Z_{it-1})$, provided the first-differences are uncorrelated with country-specific effects η_i. Therefore, the instrument matrix is also made up of two separate parts: one part with lagged level variables as instruments for the first differences and the other part with lagged variables (in first-differences) as instruments for the equation in levels. For a discussion of this estimator in the context of empirical application, see Bond (2002).

The validity of the instruments used for the first-differenced equation depends principally on the absence of serial correlation in the disturbances ε_{it}. In that case, the first differenced residuals are expected to show negative first order serial correlation but does not display second order serial correlation. Tests for first and second order autocorrelation are reported as m_1 and m_2 in table 3. First order serial correlation appears to be present in the first difference equation (column 3). This finding further endorses the advantage of undertaking the SYS GMM approach which rectifies any first order serial correlation.

A crucial assumption of the SYS GMM estimator is that the first-differences of x_{it} and Z_{it} should not be correlated with the individual effects η_i in order for the first differences to be valid instruments in the levels equation. This assumption is known to be valid if the x_{it} and Z_{it} series have constant means over time for each country, after removing common time trends. The instruments set chosen in this paper are small due to the limited size of our sample. The Sargan test for overidentifying restrictions did not reject the validity of our instrument sets considered. The instrument used on the first-differenced equation is the sixth lag of real exchange rate R_{t-6}. The SYS GMM estimator's instrument consists of the same instrument for the first difference equation R_{t-6} and an additional instrument of Δx_{t-6} for the equation in levels. Δ represent first difference.

4.2 Results

Table 3 presents the estimates of income and price elasticities.

The table shows the results of discarded estimation methods compared to our preferred model. Column 1 shows the OLS results with a significant lagged dependent variable of 0.89 elasticity and the real exchange rate of -0.01. However, OLS estimation method does not incorporate the cross sectional variation of our

TABLE 3

Variable	*OLS* (1)	*Fixed Effects* (2)	*DIFF GMM* (3)	*SYS GMM* (4)
x_{t-1}	0.89***	0.16**	0.19	0.41*
	(0.02)	(0.07)	(0.14)	(0.22)
I_t	0.05	1.14	12.11***	9.61***
	(0.63)	(0.75)	(3.67)	(5.23)
R_t	-0.01*	-0.01***	0.0002	-0.01**
	(0.00)	(0.00)	(0.00)	(0.00)
m_1	-1.57	0.89	-2.04	-2.03
	[0.12]	[0.00]	[0.04]	[0.04]
m_2	-0.19	0.37	-0.21	-0.19
	[0.85]	[0.40]	[0.83]	[0.85]
Sargan Test			0.69	0.18
Diff-Sargan				0.103

NOTES: The dependent variable is $\Delta x_t = x_t - x_{t-1}$ where $t-1$ is one year period; x_t is the logarithm of exports; I_t logarithm of foreign income and R_t is the real exchange rate. Sample: 35 countries, 282 observations, 1994-2005. Year dummies included, robust standard errors in curved brackets ( ) and *p*-values in square brackets [ ]; * , **, *** indicates the coefficient is significant at 10, 5 and 1 percent significance level respectively; m_1 and m_2 are tests of first order and second order serial correlation respectively with null hypothesis of no serial correlation of each order; the instrument for the DIFF GMM is R_{t-6} ; and, the instruments for the SYS GMM are: R_{t-6} for the first difference equation and Δx_{t-6} for the equation in levels.

data. The within groups (column 2) estimate of lagged dependent variable is 0.16 elasticity. As theory predicts, the OLS coefficient of the lagged dependent variable is biased upwards (upper bound) whereas the within groups estimate is biased downwards (lower bound). The next tested model is the first difference GMM (DIFF GMM) in column 3 which shows a positive coefficient of the lagged dependent variable (that is 0.19) which is within the upper and lower bounds, a necessary condition required for the candidate model. Blundell and Bond (1998) argue the first difference estimation suffer from omitted variable bias.

The most preferred model is the system GMM (SYS GMM). The coefficient of the lagged dependent is 0.41 which lies between the OLS and within group estimates. Besides the lagged dependent variable, the coefficients of the independent variables are the income and price elasticity of the Barbadian exports. The coefficients show the sensitivity of Barbadian exports to changes in relative prices and foreign income.

In line with literature, the income elasticity enters the SYS GMM equation with the expected sign. The elasticity of income with respect to exports is 9.61 and is significant at 10 percent. That means growth in Barbados' partner countries will translate into growth of at least the same magnitude of Barbados' exports. More precisely, growth in trading partner countries' lead to about 10 times higher growth in Barbados. Thus, trade remains an important engine of growth in Barbados. The finding suggests the country should capitalize on this fact in reviving exports of goods. This fact provides knowledge to diversification opportunities of Barbados. Statistics in section 2 indicates that chemicals, manufactured goods and beverages and tobacco are the most viable export commodities and the United States, Jamaica, and Trinidad and Tobago are the most critical markets.[3]

An interesting finding is that the goods exports of Barbados are price inelastic. The price elasticity is negative as theory predicts meaning that given Barbados' fixed exchange rate, an increase in the trading partner's consumer prices relative to Barbados' prices makes Barbados's goods more competitive. The elasticity of the real exchange rate is -0.001 which is negligible though highly significant. The reason can be traced to the fact that the demand for Barbados' exports of goods is not influenced by changes in consumer prices. One could suggest this is due to the non-competitive exports under the preferential trade treatment to the United Kingdom, the United States, Canada and to the Caribbean countries. The other possibility of negligible price elasticity could be Barbados' subsidies on many commodities such that consumer prices do not really adjust to match demand and supply.

To test whether these elasticities differ significantly across geographical regions, the 35 countries in the sample were classified into five regions — Caribbean ($carib$), Europe ($euro$), North America (NA), Central and South America (CSA) and Asia and Australasia ($asia$). A dummy was created ($D=1$) for each region. We then interacted each regional dummy with foreign income such that for instance $D*I_{carib}$ represent incomes for Caribbean countries and zero otherwise. The results incorporating regional income slopes are reported in column 3, table 4 (SYS GMM2).

Four regional dummies are considered in the regression, excluding Asia to avoid multicollinearity. The results show that only

[3] Please note that the UK market imports mostly sugar from Barbados and since it is the most affected from the erosion of the preferential treatment, the UK was excluded from the list of critical markets.

TABLE 4

Variable	SYS GMM (1)	SYS GMM2 (2)	SYS GMM2 (3)
x_{t-1}	0.41* (0.22)	0.15 (0.14)	0.22 (0.15)
I_t	9.61*** (5.23)	12.6*** (3.14)	10.5*** (0.75)
R_t	-0.01** (0.00)	0.002 (0.002)	-0.03 (0.03)
$D*I_{carib}$		0.56** (0.26)	
$D*I_{euro}$		-0.30 (0.45)	
$D*I_{NA}$		-0.78 (1.55)	
$D*I_{CSA}$		0.03 (0.06)	
$D*R_{carib}$			0.06** (0.03)
$D*R_{euro}$			-8.34 (6.67)
$D*R_{NA}$			-0.45 (3.26)
$D*R_{CSA}$			0.03 (0.03)
m_1	-2.03 [0.04]	-1.67 [0.10]	-1.29 [0.20]
m_2	-0.19 [0.85]	-0.13 [0.90]	-0.81 [0.42]
Sargan Test	0.18	0.80	0.62

NOTES: The dependent variable is $\Delta x_t = x_t - x_{t-1}$ where $t-1$ is one year period; x_t is the logarithm of exports; I_t logarithm of foreign income and R_t is the real exchange rate; D represented regional dummy. Sample: 35 countries, 282 observations, 1994-2005. Year dummies included, robust standard errors in curved brackets ( ) and *p*-values in square brackets [ ]; * , **, *** indicates the coefficient is significant at 10, 5 and 1 percent significance level respectively; m_1 and m_2 are tests of first order and second order serial correlation respectively with null hypothesis of no serial correlation of each order; same instruments are used for the 3 equations: R_{t-6} for the difference part and Δx_{t-6} for the levels equation.

the Caribbean income dummy ($D*I_{carib}$) is significant suggesting the elasticity of Caribbean income is 13.16 (=12.6+0.56) and for other regions income elasticity remains 12.6. Thus, the Caribbean income elasticity is larger than for all other regions.

Similarly, interacting regional dummies with the real exchange rates results in the regression shown in column 3, table 4. Once more, only the Caribbean cross price dummy $D*R_{carib}$ is significant equal to 0.06. Since the coefficient of R_t is not significantly different from zero. That means the Caribbean price elasticity is equal to 0.06. For other regions the price elasticity is zero. The positive value of the price elasticity of the Caribbean is not surprising given that about 74 percent of the Caribbean countries are in the Caricom,[4] which is a captive market.

To sum up, the demand for Barbadian exports is significantly linked to the movements in its trading partners' incomes, which becomes a crucial determinant of economic performance in Barbados. Moreover, the Barbadian exports are more responsive to incomes in the Caribbean than other regions implying regional integration is crucial for trading (exporting). Thus the imperfect substitutes' model is not sufficient in explaining Barbados' exports, instead an augmented substitutes model (with regional integration) is suitable.

5. CONCLUSION

Using the system general method of moments estimator, this paper provides estimates for the income elasticities, price elasticities and regional integration effects of the exports for Barbados' goods to 35 of its exporting countries. These elasticities have significantly been useful in designing both internal and external policies. Despite the importance of these elasticities, their estimates have significantly differed from country to country.

With respect to Barbados goods exports, this paper found a coefficient of 9.61 for current income elasticity. Current price elasticity showed a coefficient of -0.001. A closer look at regional slope dummies showed that the Caribbean region has significantly higher income and price elasticities than other regions

[4] Caricom stands for Caribbean Common Market. The Caricom member states are Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, St Lucia, St Vincent and Grenadines, Suriname, and Trinidad and Tobago.

indicating that an augmented imperfect substitutes' model is suitable for explaining Barbados' tradable goods exports. Even though these results are obtained only from a small set of exporting countries, they nevertheless enable us to draw some policy implications for Barbados' exports. The results convey an important message that, in addition to the tourism export services, Barbados has opportunities to exploit the sensitivity to foreign incomes of its goods exports in determining the amount of goods to export. However, the exports are not price sensitive due to Barbados' commodity subsidies and its preferential trade agreements with the United Kingdom, the United States, Canada and the Caribbean countries.

The sensitivity of exports to the incomes in the foreign markets implies that exports can be volatile. Hence, another look is needed at the issue of the lack of price-competitiveness. One approach is to devalue the dollar but it is not a politically sound strategy since Barbados has had a fixed exchange rate for about 35 years. A more feasible approach might be to increase total productivity levels in manufacturing with the notion that this would lead to cost savings thereby leading to lower prices for the manufactured goods and improved quality. This can be achieved by making capital goods duty free for exporting firms, so that the cost of acquiring technology is made as cheap as possible;[5] encouraging the use of up to date operations management methodologies, by providing training grants; and lowering the cost to businesses of entering the export market.

REFERENCES

Algieri, B. (2004), "Price and Income Elasticities of Russian Exports", *European Journal of Comparative Economics,* vol. 1, nº 2, pp. 175-93.

Arellano, M., and O. Bover (1995), "Another Look at the Instrumental Variable Estimation of Error-Components Models", *Journal of Econometrics,* vol. 68, pp. 29-51.

Arellano, M., and S. R. Bond (1991), "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations", *Review of Economic Studies,* vol. 58, pp. 277-97.

[5] It is assumed that the government loss in revenue from duties will be recovered by taxing higher profits obtained.

Blundell, R., and S. Bond (1998), "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models", *Journal of Econometrics,* vol. 87, pp. 115-43.

Bond, S. (2002), "Dynamic Panel Data Models: A Guide to Microdata Methods and Practice", *Portuguese Economic Journal,* vol. 1, 141-62

Campbell, T. (1993), *Non-Sugar Exports in Barbados after Independence,* Central Bank of Barbados (Working Papers, nº 1993).

Central Bank of Barbados (2006), unpublished data.

Cosar, E. E. (2002), "Price and Income Elasticities of Turkish Export Demand: A Panel Data Application", *Central Bank of Turkey Review,* vol. 2, pp. 19-53.

Duffy, P. A., M. K. Wohlgenant and J. W. Richardson (1990), "The Elasticity of Export Demand for US Cotton", *American Journal of Agricultural Economics,* vol. 72, nº 2, pp. 468-74.

Goldstein, M., and M. S. Khan (1985), "Income and Price Elasticities in Foreign Trade", in R. W. Jones and P. Kenen (eds.), *Handbook of International Economics,* vol. II, chp. 20, North Holland, Amsterdam, pp. 1041-105.

Howard, M. (2006), *The Economic Development of Barbados*, University of the West Indies Press, Jamaica, Barbados, and Trinidad and Tobago.

International Monetary Fund (2006), *International Financial Statistics*, October (CD-ROM).

Marquez, J., and C. McNeilly (1988), "Income and Price Elasticities for Developing Countries", *Review of Economics and Statistics,* vol. 70, nº 2, pp. 306-14.

Munoz, S. (2006), *Zimbabwe's Exports Performance: The Impact of the Parallel Market and Governance Factors,* IMF (Working Paper, nº 06/28).

Senhadji, A. S., and C. E. Montenegro (1999), "Time Series Analysis of Export Demand Equations: A Cross-Country Analysis", *IMF Staff Papers,* vol. 46, nº 3, pp. 259-73.

Whitehall, P. (1986), "Profit Variation in the Manufacturing Sector of Barbados", *Social and Economic Studies,* vol. 35, nº 4, pp. 67-91.

Worrell, D. (1992), *Export Diversification,* Central Bank of Barbados (Working Papers, nº 1992).

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The Laffer curve of macroeconomic volatility and growth: can it be explained by the different nature of crises?

1. INTRODUCTION

The relation between macroeconomic volatility and growth has long been the focus of intense scrutiny. From the view held in the 1980s that the impact of volatility on growth was at most minor, great strides have been made in the literature. The most important contribution is probably that of Ramey and Ramey (1995), who find a strong negative relation between volatility and growth.

Such negative relation has generally been confirmed in subsequent studies (Martin and Rogers, 2000; Fatás, 2002; Aizenman and Pinto, 2005; and Hnatkovska and Loayza, 2005) but there are a few – albeit partial – exceptions. First, Imbs (2002) reports a positive relation between growth and volatility across sectors although he confirms that the relation across countries is negative.

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Second, Rancière, Tornell, and Westermann (2003) show how credit market imperfections in financially open economies could lead to higher growth while increasing volatility. Third, Kose, Prasad and Terrones (2005) conclude that higher trade openness brings benefits in terms of higher growth even though it exposes an economy to more volatility arising from external shocks.

There are many reasons to believe that macroeconomic volatility may lead to lower economic growth: A very general one is the fact that volatility tends to be associated with uncertainty. Economic uncertainty may reduce growth through several channels. First, it should induce agents to postpone decisions, the more so the riskier the decisions are (because of risk aversion). Second, investment irreversibilities could make firms invest suboptimally in the face of uncertainty. Servén (1998) confirms empirically the negative link between volatility and investment. A more specific argument is related to the existence of financial constraints, which are bound to increase with macroeconomic volatility, particularly during sharp recessions (Martin and Rogers, 1997; Talvi and Végh 2000).

There are also some arguments in favour of a positive relation between volatility and growth. A general one is that more volatility should lead to higher returns and, thereby, higher growth. For this general argument to hold, however, it would be necessary for countries to have risk-sharing mechanisms so that risky projects can be carried out without any major problems. Another argument comes from the higher likelihood of firms' innovating during high-growth periods (even if they are followed by contraction periods), which should bring more growth. A more specific argument is the existence of a precautionary motive for savings: more volatility should encourage more savings which – if kept in the domestic economy – would raise investment and, thereby, growth.

Given the above arguments for and against a negative relationship between volatility and growth, one possibility is that the relation is not linear, i.e. that it positive for a certain level of volatility while negative for a higher level. This is what we test in this paper as well as the underlying reasons for such non-linearity. Our results confirm that the relation between volatility and growth looks like a Laffer curve: a certain degree of volatility is more growth-enhancing than very low one. However, when volatility becomes very large, it does appear to hamper growth.

When exploring the underlying reasons for a Laffer curve depicting the relation between volatility and growth, we focus on the role of crises. This is because of their importance in explaining large swings in economic growth. While the consensus view is that crises - being associated with high volatility - are very detrimental for growth (Hnatkovska and Loayza, 2005), they could also serve as a catalyst for change and, thereby, enhance long term growth. In this vein, Rancière et al. (2003) show theoretically and empirically that countries having experienced occasional crises and with a negative skewness of credit growth experience faster income growth on average.[1] One possible explanation for this differing views lies on the different nature of crises. While Hnatkovska and Loayza (2005) study cases of extremely negative volatility independently of their source, Rancière et al. (2003) focus on experiences of sharp reductions in credit growth, generally identified as banking crises. In this study, we test the impact of three main types of financial crises (currency, banking and sovereign crises) on the degree of macroeconomic volatility. We conclude that only sovereign crises are clearly associated with higher volatility. Banking crises, on the other hand, tend to place countries in a lowers level of volatility, which are, in turn, associated with higher growth. However, this latter result is less robust to different model specifications than that for sovereign crises.

The paper is structured as follows. After this brief introduction, Section 2 describes the data used and the empirical strategy followed. Section 3 reports our results and Section 4 concludes.

2. DATA ISSUES AND EMPIRICAL STRATEGY

We have data for a maximum of 114 countries from 1978 to 2002 which gives us 25 years of data. The list of countries is presented in Table A.1 of the Appendix. Most of our data have been obtained from the World Bank's World Development Indicators (WDI). However, we have pooled data from a variety of other sources. Summary statistics for the variables we use in the paper are shown in Table A.2 of the Appendix.

[1] However, Aghion et al. (2005) show the opposite theoretically and empirically, namely that tighter credit leads to both higher aggregate volatility and lower mean growth for a given total investment rate.

Data on GDP per capita come from the World Bank's WDI. The same source has been used for the rate of enrolment in secondary school, life expectancy, domestic credit to the private sector, gross fixed capital formation, inflation (measured as both the GDP deflator and the consumer price index), and trade openness (measured as the sum of exports and imports over GDP).

The frequency of banking crises is based on lists of crisis events from several sources, but mainly Caprio and Klingebiel (2003), cross-checked with Domaç and Martínez-Peria (2000) and IMF staff reports. Caprio and Klingebiel use common macroeconomic indicators to date both systemic and non-systemic banking crises and these are, in turn, complemented with interviews with financial experts of each country considered. The frequency of currency crises is based on the dataset in Bubula and Otker-Robe (2003). These authors use a definition of "de facto" currency crises, by which a crisis occurs when the index (constructed as the average of the change in the exchange rate vis-à-vis the USD and domestic interest rate) experience a change of over 3 times the standard deviation of the sample. Finally, data for sovereign debt crisis episodes are obtained from various reports available from Standard & Poor's.

Empirical strategy

In order to empirically determine what the shape of the relation between volatility and growth is and what factors might be behind it, we conduct two different types of exercises.

In the first one, we develop a new approach to unveil the shape of such relation. To this effect, we run the following regression:

$$\gamma_{c(t,T)} = \beta \cdot y_{ct} + \delta \cdot z_{c(t,T)} + Q_{c(t,T)} + \varepsilon_{c(t,T)}$$

where $\gamma_{c(t,T)}$ corresponds to the average per capita GDP growth rate of country c between time t and T; y_{ct} is the logarithm of per capita GDP level at time t; $z_{c(t,T)}$ is a set of controls based used in the growth literature and suggested by Levine and Renelt (1992). These include the logarithm of enrolment in secondary schooling at time t and the average population growth between time t and T. We move away from imposing a linear (or, at most, quadratic) relationship in the relationship between volatility and growth as it has generally been done in the literature and divide up the countries in our sample into four quartiles according to the volatility of their per capita GDP growth. We include the dummies for a country being in each quartile as a $Q_{c(t,T)}$ and these are our coefficients of interest. Obviously, in order to avoid multicollinearity, we omit the dummy for the first quartile so that each coefficient corresponds to the effect on growth of being in a given quartile relative to the first quartile.

In the second exercise, we investigate what are the determinants of a country ending up in a different level of macroeconomic volatility (namely in a different quartile). To this effect, we define a categorical variable which takes the value from 1 to 4, depending on the quartile where the observation is placed. Thus, for instance, an observation with a very low level of volatility, which would be in the first quartile of the volatility distribution, would take a value of 1. On the other hand, countries with a higher degree of volatility would be in the fourth quartile and the categorical variable would, therefore, take the value of 4. Next we regress the following equation:

$$q_{c(t,T)} = \beta_i \cdot F_{ic(t,T)} + \varphi \cdot w_{c(t,T)} + \eta_{c(t,T)}$$

where $q_{c(t,T)}$ is to the categorical variable defined earlier, and $F_{ic(t,T)}$ corresponds to the number of crises of type *i* that occurred in country *c* between time *t* and *T*. We consider three types of crises: currency crises (those brought about by a big depreciation in country *c*'s currency); banking crises (those associated with a crisis in country *c*'s banking system) and; sovereign crises (those where country *c* defaults on or restructures its sovereign debt). The coefficients β_i are those of interest to us in this exercise as they reveal which types of crisis place countries in higher or lower quartiles of the GDP per capita growth rate volatility distribution. In this regression, we also need to control for other potential determinants of the volatility of per capita GDP growth ($w_{c(t,T)}$), namely the variability of inflation and of terms-of-trade between time *t* and *T,* as well as the level of trade integration and financial development taken at time *t*. We assume the error term ($\eta_{c(t,T)}$) is well-behaved. The categorical nature of the dependent variable causes us to estimate the previous equation using an ordered logit. Therefore, the coefficients we estimate in these regressions can be interpreted as the predicted change in the quartile that a change in the corresponding dependent variable would imply. Thus, for instance an estimated coefficient of 0.25 for the frequency of sovereign crises would mean that, if a given country were to experience 4 additional sovereign crises over the period considered, this would cause this country to move up one quartile in the distribution of per capita GDP growth rate volatility.

For each of these two exercises, we perform two types of regressions: *i)* a cross-section one between 1978 and 2002; *ii)* a panel of rolling regressions which encompasses two windows, 1978-1998 and 1982-2002, with a maximum of 302 observations. We only consider these two relatively long periods since the relationships that we are investigating (especially the one between volatility and growth) are a long run ones.

Finally, it is important to point out that both estimation procedures are subject to potentially important endogeneity problems between the independent and the dependent variables. We deal with this problem in the panel estimation by shortening the period over which we calculate the dependent variable (the average standard deviation of per capita GDP growth in the first case and the quartile the country belongs to in the second) so that it does not fully overlap with the periods use to compute the variables in the right hand side of the equation.

3. RESULTS

The non-linear relation between economic volatility and growth

We begin by confirming Ramey and Ramey's result of a negative relationship between volatility and growth in our cross-section, after controlling for the usual determinants of economic growth. The result is maintained for our sample and time span (Column 1, Table 1 below). Furthermore, the estimated coefficients for the control variables (the initial level of per capita GDP, population growth and the fraction of population enrolled in secondary schooling)[2] are significant with the expected sign.

[2] We also use life expectancy as a proxy of human capital. Results do not change.

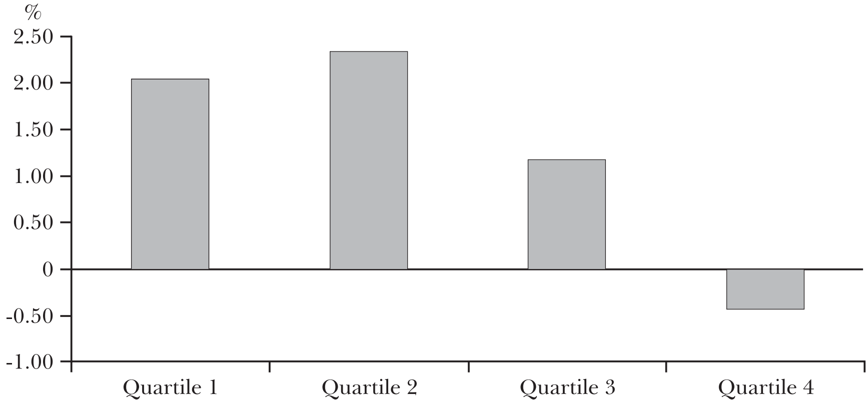
Although we have confirmed the negative slope of the volatility coefficient, we have assumed linearity in the relation between volatility and growth. We now move to testing whether this is the case. To this end, we divide our sample into four quartiles according to GDP growth volatility and compute the average GDP growth for each of them As it can be seen, the second quartile has higher average growth than the first (Graph I below). Average growth is substantially reduced for the observations in the third quartile and it even becomes negative for those in the fourth. We,

TABLE 1. RELATIONSHIP BETWEEN VOLATILITY AND GROWTH (CROSS-SECTION)

Regressions	*1*	*2*	*3*	*4*
Std. deviation GDP growth	-0.478[b]			
	(0.136)			
Quartile 2		0.00776[a]	0.00647[a]	0.00875[b]
		(0.00403)	(0.00409)	(0.00398)
Quartile 3		-0.002	-0.0022	-0.00148[b]
		(0.00458)	(0.00514)	(0.0047)
Quartile 4		-0.014[b]	-0.0146[a]	-0.0109
		(0.00647)	(0.00744)	(0.00677)
Log(GDP)	-0.00503[b]	-0.00362	-0.00461[a]	-0.00579[a]
	(0.00247)	(0.00263)	(0.00259)	(0.00294)
Log(secondary schooling)	0.00756[b]	0.00732	0.00603[a]	0.00725[b]
	(0.00311)	(0.00329)	(0.00334)	(0.00328)
Avg. population growth	-0.00389[a]	-0.00532	-0.00666[b]	-0.0055[b]
	(0.00221)	(0.00251)	(0.00271)	(0.00254)
Log(investment rate)			0.0136[b]	
			(0.00564)	
Domestic credit to the private sector				0.000202[b]
				(0.0000857)
Constant	0.0561[b]	0.0307[a]	0.00261	0.0393[b]
	(0.0183)	(0.0187)	(0.0226)	(0.0188)
Number of observations	102	102	91	97
R^2	0.3792	0.3644	0.3976	0.4061
p-values for the *F*-tests				
H_0: Quartile 2 = Quartile 3		0.0740	0.1295	0.0559
H_0: Quartile 2 = Quartile 4		0.0023	0.0083	0.0077
H_0: Quartile 3 = Quartile 4		0.0913	0.1141	0.1903

NOTE: Heteroskedasticity-robust standard errors.
[a] Significant at the 10% level. [b] Significant at the 5% level.

GRAPH I. AVERAGE PER CAPITA GDP GROWTH BY VOLATILITY QUARTILE



then, introduce the top three quartiles of the volatility distribution, instead of volatility as such, in the previous cross-section and test for the relation between each of them and economic growth.[3]

Our results show that a moderate level of volatility – i.e. the second quartile of the distribution – is associated with higher growth in a statistically significant way (Column 2, Table 1). On the other hand, very high volatility – i.e. the fourth quartile of the distribution – is accompanied by much lower growth and that this result is significant at close to 1% level. Finally, the observations in the third quartile are not distinguishable from those in the first quartile in terms on their impact on growth.

The different impact of the second and fourth quartile is confirmed when testing for the equality of their coefficients. Such equality is rejected at a 5% significance level for the coefficients of quartiles 2 and 4, but also of quartiles 2 and 3 and 3 and 4 (see tests below Column 2, Table 1). These findings point to a non-linear relation between volatility and growth, which has the shape of a Laffer curve.

To check the robustness of the results, we introduce additional potential determinants of economic growth, as controls. We introduce them separately because of their high correlation with each other and with our previous regressors which may lead to collinearity problems. As it turns out, an important determinant of a country's growth rate – although subject to endogeneity

[3] Since we have a constant in the regression, we need to exclude the first quartile.

problems - is the accumulation of physical capital which is found significant in increasing per capita GDP growth (Column 3, Table 1). The non-linear shape of the relation between volatility and growth is basically confirmed although the positive sign of the second quartile is only significant at the 11% level. The second growth determinant introduced is the development of the financial system, measured as the level of credit granted by the banking system to the private sector. This is found significant (Column 4, Table 1) and the non-linear shape of the relation between volatility and growth is maintained although this time we obtain a significantly negative sign for countries in the third quartile although the coefficient for the fourth quartile is not significant at any standard significance level. Finally, the *F*-tests of equality of the quartile coefficients confirm the shape of a Laffer curve. Also in the two robustness tests, we reject the hypothesis that the coefficients of the second and fourth quartiles are the same. In the last regression, when financial development is taken into account, we also reject the equality of the coefficients of the second and fourth quartiles, as well as between the second and the third.

Finally, as an additional robustness test, we re-run the four equations above using panel data. Again, if we assume a linear relation between volatility and growth, the negative coefficient for volatility is confirmed (Column 1 in Table 2 below). When introducing the different quartiles in which we divide observations according to their volatility, the results are also maintained: being in the second quartile leads to relatively higher growth while being in the fourth reduces it considerably (Column 2 in Table 2). All other controls for economic growth remain statistically significant, as well as the two included in the robustness tests, namely the physical capital accumulation and the level of financial development. Furthermore, the robustness tests confirm the Laffer curve shape of the relation between volatility and growth (Columns 3 and 4 in Table 2). This is also the case of the *F*-tests of equality of coefficients: in all specifications we reject that the coefficients of the second and fourth quartile are equal and the same is true between those of the second and third quartiles.

The policy implication of such Laffer curve is that very high volatility should clearly be avoided but that some volatility – basically that within the second quartile of the distribution - could be a first best in terms of economic growth. We now move to exploring

TABLE 2. RELATIONSHIP BETWEEN VOLATILITY AND GROWTH (PANEL)

Regressions	*1*	*2*	*3*	*4*
Std. deviation GDP growth	-0.507[b]			
	(0.0875)			
Quartile 2		0.00798[b]	0.00743[b]	0.00907[b]
		(0.00294)	(0.00281)	(0.00278)
Quartile 3		-0.00874[b]	-0.00878[b]	-0.00598[a]
		(0.00344)	(0.00355)	(0.00336)
Quartile 4		-0.0184[b]	-0.021[b]	-0.0139[b]
		(0.00423)	(0.0049)	(0.00457)
Log(GDP)	-0.00475[b]	-0.00424[b]	-0.00541[b]	-0.00679[b]
	(0.00175)	(0.00169)	(0.00167)	(0.00206)
Log(secondary schooling)	0.00652[b]	0.00687[b]	0.00588[b]	0.00776[b]
	(0.00215)	(0.00207)	(0.00212)	(0.00219)
Avg. population growth	-0.00419[b]	-0.00489[b]	-0.00609[b]	-0.00547[b]
	(0.0016)	(0.00168)	(0.00172)	(0.00173)
Log(investment rate)			0.0125[b]	
			(0.00427)	
Domestic credit to the private sector				0.00017[b]
				(0.000059)
Constant	0.0579[b]	0.0384[b]	0.0147	0.0484[b]
	(0.0129)	(0.0122)	(0.016)	(0.0132)
Number of observations	213	213	197	201
R^2	0.3427	0.3593	0.3984	0.397
p-values for the *F*-tests				
H_0: Quart 2 = Quart 3		0.0000	0.0001	0.0001
H_0: Quart 2 = Quart 4		0.0000	0.0000	0.0000
H_0: Quart 3 = Quart 4		0.0455	0.0224	0.1283

NOTE: Heteroskedasticity-robust standard errors.
[a] Significant at the 10% level. [b] Significant at the 5% level.

the reasons behind such Laffer curve, instead of a linear negative relation, between volatility and growth.

The nature of crisis and volatility

As previously mentioned, we explore empirically what explains why certain countries find themselves in higher –rather than lower – quartiles in terms of macroeconomic volatility. We focus on crisis events given their prominence in determining large swings in growth and the role they have acquired in the recent literature.

As a first exercise, we assess, using cross-section data and estimating with an ordered-logit, whether having more crises increases the probability of being in a higher quartile in terms of the macroeconomic volatility. We find that this is the case (Column 1, Table 3). This seems to confirm Hnatkovska and Loayza's suggestion that crises are behind the very negative relation between volatility.

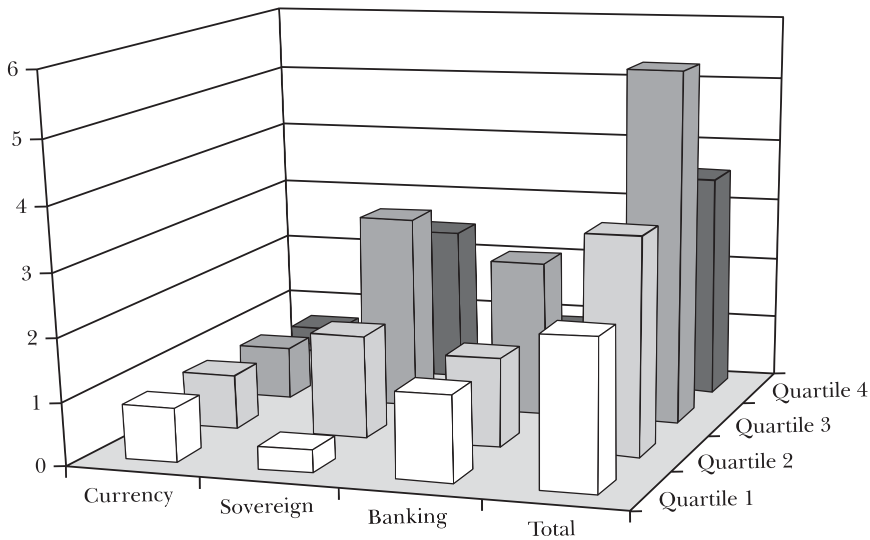
TABLE 3. DETERMINANTS OF VOLATILITY (CROSS-SECTION)

Regressions	*1*	*2*	*3*	*4*	*5*	*6*
Dependent variable is quartile of volatility (ordered logit used for estimation)						
Number of crises	0.184[b]					
	(0.0463)					
Currency crises		-0.147	-0.0573	-0.255	-0.308	-0.432[a]
		(0.195)	(0.264)	(0.213)	(0.282)	(0.232)
Banking crises		-0.0946	-0.0617	-0.143	-0.0704	-0.227[b]
		(0.0738)	(0.095)	(0.0785)	(0.0977)	(0.0996)
Sovereign Crises		0.108[a]	0.242[b]	0.0924[a]	0.1868[b]	0.0836
		(0.0532)	(0.07)	(0.0553)	(0.0586)	(0.0681)
Std. deviation of terms-of-trade growth			0.558			
			(1.737)			
Std. Deviation of inflation				0.473[b]		
				(0.17)		
Trade openness					0.405	
					(0.304)	
Domestic credit to the private sector						-0.0415[b]
						(0.00838)
Number of observations	151	151	98	146	108	108
Pseudo-R^2	0.0003	0.0130	0.0471	0.0528	0.0388	0.1091

NOTE: Heteroskedasticity-robust standard errors.
[a] Significant at the 10% level. [b] Significant at the 5% level.

We explore the issue further by distinguishing among three main types of crises: currency, banking and sovereign ones. Graph II below depicts the relation between the frequency of different types of crises and the volatility quartiles. The average number of

GRAPH II. DISTRIBUTION BY QUARTILE OF DIFFERENT CRISES



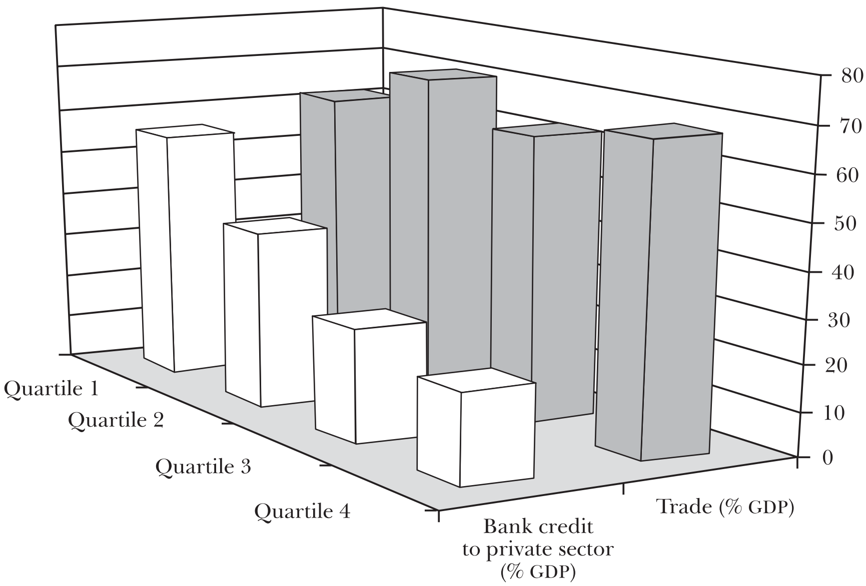
sovereign crises is higher for the third and fourth quartiles but that of banking crises is somewhat lower for the fourth quartile than the second, although it is much higher in the third. Finally, the average number of currency crises is practically the same across quartiles. We move to the regression analysis so as to take into account other potential determinants of macroeconomic volatility.

When regressing the frequency of each type of crises on the different volatility levels (from the first to the fourth quartile) with the same cross-sectional data as before, sovereign crises raise the likelihood of being in a higher quartile at a 1% significance level (Column 2 in Table 3). No significant impact is found for currency and banking crises.

As a robustness test, we control for other factors which may influence the level of macroeconomic volatility, such as the variability of the terms of trade, that of inflation, trade openness and the degree of financial development. The first two are relatively obvious factors. The third one has been found to raise volatility although economic growth (Kose, Prasad and Terrones, 2005). The last one has been associated with lower volatility (Easterly, Islam, and Stiglitz, 2000). Graph III below depicts the relation between these two variables and the four quartiles in which the observations of volatility of per capita GDP growth can be divided. Bank credit to the private sector is clearly lower in the higher volatility quartiles while no clear trend is seen for trade openness. Moving to the regression analysis, the volatility of the terms of trade does not appear to influence the volatility of per capita GDP growth (Column 3 in Table 3) while that of inflation increases it in a statistically significant way (Column 4 in Table 3). Trade openness does not seem to have an impact while a larger share of bank credit to the private sector reduces it in a significant way (Columns 5 and 6 in Table 3). In all cases, except the last, a higher frequency of sovereign crises is associated with a higher volatility quartile. One explanation for the lack of significance of the frequency of sovereign crises when controlling for financial sector development is that such development may allow agents to use insurance mechanism, thereby, reducing the macroeconomic volatility that a sovereign crisis would, otherwise, cause. In the same vein, only in the last robustness tests, when controlling for financial sector development, do we find that currency and banking crises actually reduce the level of volatility.

Finally, as for the growth equations, we re-run the above regressions with panel data. Again, suffering more crisis, of any sort,

GRAPH III. DISTRIBUTION OF VARIABLES BY QUARTILE



does seem to place countries in a higher quartile in terms of macroeconomic volatility (Column 1 in Table 4). The explanation is basically the same as before: more sovereign crises place countries in higher volatility levels (Column 2 in Table 4). When including other controls, the detrimental impact of sovereign crises – in terms of higher volatility – is confirmed but banking crises appear as beneficial when controlling for the variability of inflation and also financial system development (Columns 4 and 6 in Table 4).

The positive influence of banking crises on macroeconomic volatility is in line with Rancière et al. (2003) in as far as very sharp drops in credit generally occurred during –or right after – banking crises.

TABLE 4. DETERMINANTS OF VOLATILITY (PANEL)

Regressions	*1*	*2*	*3*	*4*	*5*	*6*
			Dependent variable is quartile			
Number of Crises	0.0697[a]					
	(0.0388)					
Currency Crises		-0.0221	0.037	-0.168	-0.119	-0.163
		(0.141)	(0.171)	(0.153)	(0.168)	(0.159)
Banking Crises		-0.104	-0.104	-0.182[b]	-0.123	-0.207[b]
		(0.0657)	(0.0799)	(0.0702)	(0.0798)	(0.0878)
Sovereign Crises		0.170[b]	0.312[b]	0.156[b]	0.274[b]	0.172[b]
		(0.0459)	(0.0569)	(0.0466)	(0.0498)	(0.0549)
Std. Deviation of terms-of-trade growth			0.349			
			(1.071)			
Std. Deviation of inflation				0.499[b]		
				(0.139)		
Trade openness					0.358[a]	
					(0.206)	
Domestic credit to the private sector						-0.0318[b]
						(0.00513)
Number of observations	302	302	196	291	230	225
Pseudo-R^2	0.0034	0.0163	0.0547	0.0585	0.0446	0.0984

NOTE: Heteroskedasticity-robust standard errors.
[a] Significant at the 10% level. [b] Significant at the 5% level.

All in all, sovereign crises a high inflation variability and low financial development seem to explain why countries find themselves in the right part of the Laffer curve relating macroeconomic volatility and growth (i.e., when such relation is negative). As for the right-hand side of the Laffer curve (i.e., a positive volatility and growth relation) the occurrence of banking crises may help but this result is less robust to different model specifications.

4. CONCLUSIONS

We build upon the general consensus since Ramey and Ramey (1995) that the volatility of per capita GDP growth reduces growth. To this end, we show empirically – using cross-section and panel analysis for over 100 countries during the period 1970-2000 – that a moderate degree of volatility can be growth-enhancing while very high volatility is clearly detrimental. These results point to the existence of a "Laffer curve" between volatility and growth.

When exploring what are the underlying reasons for such Laffer curve, we focus on the role of crises because of their relevance in explaining large swings in economic growth. While the consensus view is that crises - being associated with high volatility - are very detrimental for growth (Hnatkovska and Loayza, 2005), they could also serve as a catalyst for change and, thereby, long term growth, following Rancière et al. (2003). In this vein, we find evidence that the detrimental effect of high volatility is mainly explained by the occurrence of sovereign crises, as well as a low degree of financial development. Banking crises, in turn, reduce volatility for some model specifications, particularly when controlling for financial development. In sum, the existence of a "Laffer curve" between volatility and growth can be attributed, at least in part, to the different nature of the crisis buffeting each country.

Appendix

TABLE A.1. COUNTRIES INCLUDED IN THE SAMPLE AND TIME SPAN

	Emerging		
Developed	*1*	*2*	*3*
Australia	Algeria	Ghana	Pakistan
Austria	Antigua and Barbuda	Guatemala	Papua New Guinea
Belgium	Argentina	Guyana	Paraguay
Canada	Bahamas, The	Honduras	Peru
Denmark	Barbados	Hong Kong, China	Philippines
Finland	Bolivia	Hungary	Saudi Arabia
France	Botswana	India	Senegal
Greece	Brazil	Iran, Islamic Rep.	Singapore
Iceland	Burundi	Israel	South Africa
Ireland	Cameroon	Jamaica	Sri Lanka
Italy	Central African Republic	Jordan	Sudan
Japan	Chile	Kenya	Suriname
Korea, Rep.	China	Lesotho	Swaziland
Luxembourg	Colombia	Libya	Syrian Arab Republic
Mexico	Congo, Dem. Rep.	Madagascar	Thailand
Netherlands	Costa Rica	Malawi	Trinidad and Tobago
New Zealand	Cyprus	Malaysia	Tunisia
Norway	Dominica	Mali	Turkey
Spain	Dominican Republic	Malta	Uruguay
Sweden	Ecuador	Morocco	Zambia
Switzerland	Egypt, Arab Rep.	Nepal	Zimbabwe
United Kingdom	El Salvador	Nicaragua	
United States	Fiji	Nigeria	

TABLE A.2. DESCRIPTIVE STATISTICS TOTAL SAMPLE, 1978-2002 (n=90)

Dependent Variable:	*Full Sample*	*Quartile 1*	*Quartile 2*	*Quartile 3*	*Quartile 4*
Average per capita GDP growth	1.26	2.05	2.34	1.18	-0.43
Objective Variable:					
Std. Deviation GDP p.c. growth	3.77	1.749	2.961	4.231	6
Controls:					
Log initial per capita GDP	7.738	8.913	7.675	7.241	7.17
Secondary schooling enrolment	24.7	45.23	24.59	16	13.83

TABLE A.2 *(concluded)*

Dependent Variable:	*Full Sample*	*Quartile 1*	*Quartile 2*	*Quartile 3*	*Quartile 4*
Domestic credit to the private sector (% GDP)	35.4	56.02	39.52	25.39	20.08
Dom. Credit to the private sector growth	2.35	2.574	1.831	4.141	0.852
Trade (% GDP)	65.82	61.77	70.95	63.04	67.78
Investment (% GDP)	23.54	23.83	26.62	20.45	23.42
Average Inflation	67.19	9.14	38.3	38.96	178.6
Std. Deviation Inflation	169.2	8.168	123.34	45.46	490.7
Average terms-of-trade growth	-0.183	-0.0043	-0.323	-0.474	0.176
Std. Deviation terms-of-trade growth	9.554	5.59	9.238	11.82	12.58
Number of currency crises	0.811	0.864	0.864	0.826	0.696
Number of sovereign crises	1.911	0.364	1.636	3.087	2.478
Number of banking crises	1.556	1.364	1.409	2.478	0.957
Number of crises (of any kind)	3.744	2.364	3.409	5.565	3.565

REFERENCES

Acemoglu, D., and F. Zilibotti (1997), “Was Prometheus Unbound by Chance? Risk, Diversification and Growth”, *Journal of Political Economy,* vol. 105, pp. 1167-1200.

Aghion, F., A. George-Marios and K. Abhijit Banerjee (2005), *Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment,* mimeo, April.

Aizenman, J., and B. Pinto (2005), *Managing Volatility and Crises: A Practitioner’s Guide Overview,* NBER (Working Paper, nº 10602).

Bubula, A., and I. Otker-Robe (2003), *Are Pegged and Intermediate Exchange Regimes More Crisis-prone?,* IMF (Working Paper, WP/03/223).

Caprio, G., and D. Klingebiel (2003), *Episodes of Systemic and Borderline Financial Crises,* World Bank.

Domaç, I., and M. S. Martínez-Peria (2000), *Banking crises and exchange rate regimes: in there a link?,* Central Bank of Turkey and The World Bank (Policy Research Working Paper, nº 2489).

Easterly, W., R. Islam, and J. Stiglitz, (2000), *Shaken and Stirred, Explain Growth Volatility,* paper presented at the Annual World Bank Series of Development Economics.

Fatás, A. (2002), *The Effects of Business Cycles on Growth,* Central Bank of Chile (Working Papers, nº 156).

Hnatkovska, V., and N., Loayza (2005), "Volatility And Growth", The World Bank (Working Paper Serie, nº 3184); or in Joshua Aizenman and Brian Pinto (eds.), *Managing Economic Volatility and Crises: A Practitioner's Guide,* Cambridge University Press, Cambridge.

Imbs, J. (2002), "Why the Link Between Volatility and Growth is Both Positive and Negative", CEPR (Discussion Papers, nº 3561).

Kose, M., E., Prasad and M. Terrones (2005), *How Do Trade and Financial Integration Affect the Relationship Between Growth and Volatility?,* International Monetary Fund (Working Papers, nº 05/19).

Levine, R., and D. Renelt (1992), "A Sensitivity Analysis of Cross-Country Growth Regressions", *American Economic Review,* American Economic Association, vol. 82, nº 4, pp. 942-63.

Martin, P., and C. A. Rogers (1997), "Stabilization Policy, Learning By Doing, and Economic Growth", *Oxford Economic Papers*, vol. 49, nº 2, April, pp. 152-66.

Martin, P., and C. A. Rogers (2000), "Long-term growth and short-term economic instability", *European Economic Review*, vol. 44, nº 2, pp. 359-81.

Ramey, G., and V. Ramey (1995), "Cross-Country Evidence on the Link Between Volatility and Growth", *The American Economic Review,* vol. 85, nº 5, December, pp. 1138-51.

Rancière, R., A. Tornell and F. Westermann (2003), *Crises and Growth: A Reevaluation,* NBER, Cambridge, Massachusetts (Working Paper, nº 10073).

Servén, L. (1998), *Macroeconomic Uncertainty and Private Investment in Developing Countries, An Empirical Investigation,* The World Bank (Policy Research Working Paper, nº 2035).

Talvi, E., and C. A. Végh (2000), *Tax base variability and procyclical fiscal policy,* NBER (Working Paper, nº 7499).

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A comparison of Canadian and US universal banks: efficiency, productivity, and the role of technology

1. INTRODUCTION

The efficiency of the financial system is important to the productivity and long-term growth of the economy. An extensive survey of the literature by Dolar and Meh (2002) suggests that the quality of financial service provision is a key ingredient to economic growth. Banks play a vital role in the Canadian financial system,

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accounting for over 70 per cent of the total assets of the financial services sector, and providing over half of the short-term business credit in Canada.[1] Accordingly, bank efficiency is crucial to the sound functioning of the Canadian financial system.

This paper focuses on Canada's six largest banks, which account for over 90 per cent of the assets in the Canadian banking sector. These Canadian banks are compared with two groups of US banks: total US commercial banks and a subset of 12 large US bank-holding companies (BHCs). The 12 BHCs are selected from the top 20 BHCs in terms of assets; they are chosen because they have continuous data from 1986 and a business mix broadly comparable with the Canadian banks in the sample. The six large Canadian banks share more similarities with larger US BHCs than with an average US bank. For example, they are all significantly engaged in non-traditional businesses, such as investment banking and wealth management.

Comparing Canadian banks with US banks can provide insights for other countries. Canada's financial system is more bank-based than the US system, and many countries, including developing countries, have a similar system. To some extent, one can consider this study as a comparison of banks in different representative financial systems, with most countries having more similarities with the Canadian case than with the US case.

We compare Canada-US banking efficiency using several approaches. First, we directly compare the efficiency of Canadian banks and US banks through ratios related to bank efficiency and productivity. These ratios are commonly used to compare performance among banks and across time. We find that Canada-US comparisons are sensitive to how nominal output is measured. In contrast, use of different nominal output deflators does not lead to substantial differences.

Second, we measure economies of scale for our subset of banks in the two countries. If there are economies of scale or diseconomies of scale in bank cost structures, then banks are not operating at an efficient scale; i.e., they are not at the minimum of the average cost curve. This paper extends Allen and Liu (2005) by comparing results for Canada with those for major US BHCs. Mester (1997) argues that accounting for heterogeneity is important in studies using the cost-efficiency framework. We therefore limit our sample selection to very large banks with diversified business

[1] Department of Finance Canada ⟨http://www.fin.gc.ca/toce/2005/fact-cfsse.html⟩.

lines. The literature provides ample research that examines the economies of scale of smaller US banks and finds moderate economies of scale. See, for example, Ferrier and Lovell (1990) or Berger and Humphrey (1997) for a literature review. However, we are unaware of any study that focuses on banks as large as the six major Canadian banks and the US BHCs in our study.[2]

The third approach we take is to examine the amount of cost-inefficiency of the banks in each country. Cost-inefficiency is measured as a bank's cost level compared with that of the "best-practice" bank of similar size in each country (the efficient-frontier firm), controlling for the type of banking activities, the input prices it faces, and the technology with which banking inputs are transformed into outputs.

The analytical framework used to measure economies of scale and cost-inefficiency is the translog cost function. Banks are assumed to use labour, capital, and deposits to produce different types of loans and non-traditional activities. Because of the long time dimension of the data and non-stationarities, we estimate the translog cost function using a time-varying fixed-effects model, including leads and lags of the explanatory variables, known as panel dynamic ordinary least squares (PDOLS). Cost-inefficiency is obtained from the residual term of the fitted translog cost function. This exercise allows us to learn about the size and dispersion of cost-inefficiency of the banks in each country and, given the long time dimension of the data set, the evolution of that inefficiency.

The mean cost-inefficiency among Canadian banks is found to be about 10 per cent; that is, on average, Canadian banks are about 10 per cent less efficient than the most efficient domestic bank. For the US sample of comparable BHCs, mean cost-inefficiency is 16 per cent. This is higher than the 10 per cent average cost-inefficiency estimated by Stiroh (2000) for a set of 661 BHCs over the period 1991-97. A typical result in the literature, including US banks, is a calculation of average cost-inefficiency in the range of 15-20 per cent. These are relatively large cost-inefficiencies, suggesting that the return to organizational change at the least efficient banks to become more like the most efficient bank is high [(Carbó, *et al.* (2004)]. Current research has looked at management styles, organizational structure, and technological

[2] There are studies that investigate separately banks of asset size of more than $1 billion. The smallest bank in both our Canadian and US samples has an asset size of more than $80 billion.

investment to try to explain large estimated gaps in cost-efficiency. We focus on information and communication technology (ICT) investment as one way to explain the Canadian dispersion in cost-inefficiency. We focus on ICT investment because of the strong link made in the literature between ICT and productivity [Crawford (2003)].

The various financial ratios that we consider suggest that Canadian banks are at least as productive and efficient as US banks, aside from having a higher expense/revenue ratio due to higher unit labour costs. We also find larger economies of scale in Canadian banks than in US BHCs, which suggests that Canadian banks are less efficient in terms of scale. Controlling for economies of scale, large Canadian banks also seem to rank higher in efficiency rankings, suggesting that there is extra benefit from being bigger. We do not find the same result for US banks. Finally, we find that Canadian banks are closer to the domestic efficient frontier than are the US BHCs. As well, over time, Canadian banks have moved closer to the domestic efficient frontier than have their US counterparts by a small margin; that is, dispersion among Canadian bank cost-inefficiency has declined by more than in the US sample.

The paper is organized as follows. Section 2 provides an overview of the Canadian and US banking industry, including a discussion of the evolution of the regulatory environment for banks in both countries. Section 3 compares the performance of banks in both countries by looking at key ratios related to efficiency and productivity. Section 4 considers economies of scale and cost-inefficiency for the large Canadian banks and the US BHCs. Section 5 focuses on refining the estimation of the cost functions, particularly on variables related to technological progress. Section 6 concludes with suggestions for future research.

2. INDUSTRY STRUCTURE

The structures of Canadian and US banking industries are substantially different. We are interested, therefore, in examining differences in efficiency of banks conditional on industry structure and regulatory environments.

Historically, the structure of the Canadian banking industry was relatively stable. For instance, from 1920 to 1980, Canada consistently had eleven banks (Bordo, 1995). By May 2005, however, after several regulatory changes removing the sharp limits on the entry of foreign banks, there were over 60 banks operating in Canada: 19 domestic banks, 23 foreign bank subsidiaries, and 21 foreign bank branches. However, banking itself is relatively concentrated: the five largest banks hold close to 90 per cent of total bank assets. Canadian banks also account for over 70 per cent of the assets of the Canadian financial services sector, which contributes over 6 per cent of Canada's gross domestic product (GDP).[3] The total assets of Canadian banks amount to around $1.9 trillion, or close to 150 per cent of GDP. Canada's chartered banks also contribute 25 per cent of total business credit in the country.

In sharp contrast to the Canadian experience, and reflecting the relatively fragmented historical context of US banking, the number of US commercial banks has declined sharply from around 14,000 banks in 1920 to about 8,000 in 2005--and the speed of this consolidation accelerated in the late 1980s. The assets of the top five US banks account for less than 30 per cent of total banking assets in the United States. In addition, US banks play a less important role in the country's financial system, which is more market-based than that in Canada. For example, US banks account for a smaller percentage of domestic business credit compared with Canadian banks. US banks provide 7 per cent of business credit. Total assets of US commercial banks are US$ 8.4 trillion, or close to 75 per cent of US GDP.

2.1 Financial legislation and regulatory development

Important contributing factors to the striking difference in the structure of the banking industry in the two countries –especially historically– are the legislative and regulatory environments. Bordo (1995) argues that these features also determine the efficiency and stability of a banking system. Focusing on the period 1920 to 1980, he argues that Canada had a more stable and efficient banking system than the United States. This is attributed largely to the prohibition of interstate (nationwide) branch banking historically in the United States, which resulted in an inability to absorb major shocks without bank failures. However, since 1980 –the period of interest in this paper– both countries have experienced substantial changes in financial legislation, which

[3] By financial sector we mean banks, credit unions, trust companies, life and health insurance, property & casualty insurance, securities dealers, and financing/leasing companies.

have correspondingly influenced the evolution of their respective financial services industries, and in a broadly convergent manner.

In Canada, prior to 1980, the financial services industry had been segmented (by legislation, regulation, and practice) into distinct "pillars": commercial banking, trust business and residential lending, insurance underwriting and brokerage, and securities underwriting and dealing. As well, prior to 1980 there were sharp limits on the entry of foreign banks into the Canadian market. However, in the past 25 years, with changes in both market practice and a series of revisions in the governing financial legislation, there have been significant changes in the Canadian financial services sector generally, and in banking specifically. Key characteristics have been the entry of foreign banks and the expansion of banks into a range of financial services, including the trust business, insurance underwriting and sales (although not through bank branches), and securities underwriting and dealing. And while consolidation among various financial services firms has accompanied these developments, there have been no mergers among major Canadian banks themselves in years. For discussions of these and related developments in Canada, see Daniel, *et al.* (1992), Freedman (1998), and Engert, *et al.* (1999).

Canadian banks are federally incorporated and regulated primarily under the federal Bank Act, which defines their range of activities. Unlike their US counterparts, Canadian banks were never prohibited from conducting nationwide branching and banking. An important element of the Bank Act (and other federal financial legislation) is a "sunset" clause, which requires a periodic review of the legislation that governs Canadian financial services. This formal review process led to significant financial legislation amendments in 1980, 1987, 1992, and 1997, which have contributed to more diversified business lines and more market-oriented activities in Canadian banks. As will be seen later, the dates corresponding to some of these revisions are statistically significant in explaining the decline in banks' total costs over the sample 1983 to 2004.

In 1987 federal legislation was amended to permit Canadian banks to invest in securities dealers. All major banks subsequently made substantial investments in the securities business and purchased control of most of the existing large investment dealers. The 1987 amendments also allowed financial intermediaries to conduct brokerage activities. In 1992, Canadian banks were given the right to enter the trust business through the establishment, or acquisition, of trust companies. Most trust companies were subsequently purchased by Canada's largest banks. The financial difficulties that many trust companies experienced following the collapse of the speculative real estate boom in the late 1980s contributed to the ability of banks to acquire them. Also in 1992, banks were permitted to do in-house activities such as portfolio management and investment advice. In 1997, new legislation included various changes to update and revise the amendments made in 1992.

In contrast to Canada, the United States has had a dual system of banking in which some banks are chartered and regulated by the states, and others are federally chartered and regulated. The relatively large number of US banks reflects a historical aversion in the United States to concentration of bank wealth and influence, and is reflected in the 1927 McFadden Act, which explicitly prohibited interstate branching. Despite the prohibition of interstate branching for individual banks, some institutions have long been able to cross state boundaries via a BHC.

The BHC structure allows banks in different states to operate as separate subsidiaries of a parent BHC. These institutions were not subject to substantial regulation until the Bank Holding Company Act of 1956. An important consequence of this Act was the effective elimination of interstate expansion, except for single-bank BHCs. As a result, these single-bank BHCs grew rapidly in the 1960s. However, this loophole was closed by the US Congress in a 1970 amendment to the Bank Holding Company Act.

During the 1970s and 1980s, as in Canada, technological innovation, economic shocks, and deregulation fundamentally altered the banking environment in the United States and the move towards interstate and nationwide banking began in earnest. The Financial Institutions Reform, Recovery and Enforcement Act of 1989 (FIRREA) contributed to this trend by allowing BHCs to acquire savings and loan companies, conditional on certain standards.

The Riegle-Neal Interstate Banking and Branching Efficiency Act (IBBEA) of 1994 completed the consolidation trend by providing a consistent, national framework for interstate banking. Effective September 29, 1995, BHCs were allowed to acquire a bank in any state, and effective June 1st, 1997, banks were authorized to merge across state lines. As Holland, *et al.* (1996) point out, however, the IBBEA did not create interstate banking, but rather broadened the scope of the consolidation trends that were already taking place under the form of BHC ownership, which has become by far the most dominant bank ownership structure in the United States.

In addition to interstate-banking restrictions, the Glass-Steagall Act of 1933 imposed a rigid separation between commercial banking and investment banking. Between 1963 and 1987, banks challenged restrictions on their ability to underwrite securities such as municipal revenue bonds, commercial paper, and mortgage-backed securities. In most cases, the courts eventually permitted these activities for commercial banks. The US Federal Reserve in April 1987 allowed BHCs to establish separate Section 20 securities affiliates as investment banks. Under the Federal Reserve Board's interpretation of the law, these Section 20 subsidiaries did not violate Section 20 of the Glass-Steagall Act under some conditions (most notably in that the revenue generated from the subsidiaries' ineligible securities activities amounted to no more than 5 per cent of the revenues they generated).

The erosion of the Glass-Steagall Act continued into the 1990s, and in 1997 commercial banks were allowed to directly acquire existing investment banks as Section 20 subsidiaries rather than establish de novo Section 20 subsidiaries. Finally, in 1999, the US Congress passed the Financial Services Modernization Act which repealed the legal barriers between commercial banks, investment banks, and insurance companies, allowing financial institutions to engage in banking, securities, and insurance activities.

3. PERFORMANCE RATIOS

Policy-makers are often interested in the performance of domestic industries relative to the performance of similar industries in foreign countries. There is an interest in understanding the factors that determine cross-country differences in productivity, so that policies can be implemented to improve the overall standard of living in the domestic country. Also, financial and industry analysts are interested in productivity measures because an increase in productivity implies that a company or industry can produce (and sell) a given quantity using fewer inputs.

Bank output is difficult to measure, both as a conceptual and a practical matter.[4] The System of National Accounts (SNA), which

[4] Measuring nominal output in all components of the National Accounts aggregation "Finance, Insurance, and Real Estate" (FIRE) is inherently difficult, since these industries are providing services and not producing goods. We focus on banking, given its prominence and the detailed data set we have on the industry.

is used to generate official statistics, defines bank output as net interest income plus explicit service fees booked domestically. A major difficulty in this context lies in providing for an accurate measure of net interest income. Official statistics calculate nominal output as the sum of imputed interest plus service charges. Imputed interest is calculated by estimating a representative interest margin for a given (predetermined) business line, and multiplying that margin by the average annual balance outstanding for the business line. The accuracy of this approach to measure bank value-added has been called into question by researchers [see, for example, Wang (2003), and Triplett and Bosworth (2004)] as well as statistical agencies [see, for example, Daffin, *et al.* (2002)]. In addition, methodological differences among national statistical agencies' national accounts further complicate cross-country comparisons using such data.

This section compares the performance ratios of the six largest Canadian banks with a set of US BHCs and total US banks using different data sources than the SNA. The six Canadian banks are: Royal Bank Financial Group, Bank of Montreal, Canadian Imperial Bank of Commerce, TD Bank Financial Group, Bank of Nova Scotia, and National Bank. The 12 BHCs are JP Morgan Chase & Co., Bank of America Corp., Wachovia Corp., Wells Fargo & Co., US Bancorp, SunTrust Banks Inc., National City Corp., Citizens Financial Group Inc., BB&T Corp., Fifth Third Bancorp, Keycorp, and PNC Financial Services Group Inc. The 12 BHCs are selected from the top 20 in terms of assets as of 31 December 2004; they are chosen because they have continuous data from 1986 to 2004 and a business mix broadly comparable with the Canadian banks in the sample.[5] Table 8 presents summary statistics of the Canadian banks and the US BHCs included in our sample.

The data set we use for these banks is balance-sheet and income-statement data as reported to the supervisory authorities in Canada and the United States. To compare real output per country, we deflate all variables by the consumer price index (CPI), excluding food and energy prices, in their respective country.

Rao, *et al.* (2004) suggest, after detailed calculations, a purchasing power parity (PPP) measure of 1.09 for bank value-added in 1999 for the FIRE industry in Canada. PPP is notoriously difficult

[5] We benchmark with reference to percentage of revenue from retail activities. That is, most of these BHCs have a similar proportion of revenue from retail banking as the Canadian banks.

to estimate; therefore, some caution should be exercised when interpreting cross-country comparisons of performance ratios. We express all series in constant 1999 dollars and then apply a PPP measure of 1.09 to all Canadian series. For simplicity, we refer to constant 1999 US dollars as "dollars" in the rest of the text.

3.1 Expense ratio

The expense ratio, often referred to as the "efficiency ratio," is commonly used by industry analysts to evaluate the cost-effectiveness of banks. It is defined as the ratio of non-interest expense to net operating revenue (net interest income plus non-interest income).[6] Figure 1 compares the expense ratio of Canadian banks, the US BHCs, and total US banks. The expense ratio of Canadian banks was lower than those of their US counterparts in the late 1980s and early 1990s. The expense ratio, however, has been trending upwards in Canada and downwards in the United States over our sample period. In 2005, it stood at 68 per cent for Canadian banks, and 62 per cent and 59 per cent for the US BHCs and total US banks, respectively.

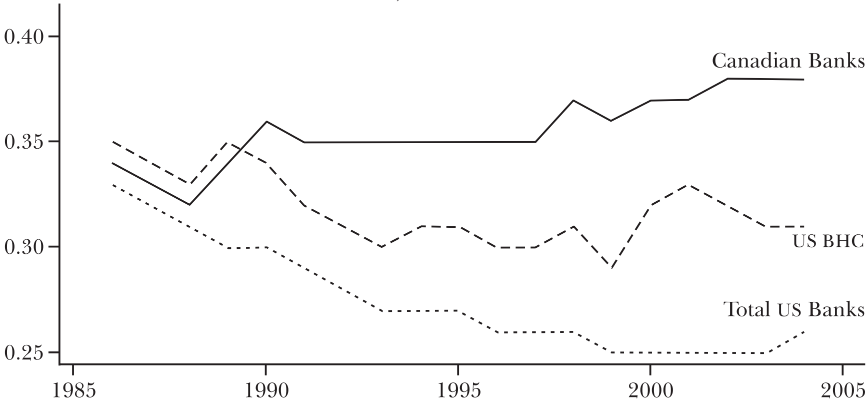
A breakdown of non-interest expenses provides a partial explanation for these trends. Figures 2 and 3 divide the expense ratio into the labour cost component and capital cost component,

FIGURE 1. EXPENSE RATIO, 1985-2005

[6] The denominator of the expense ratio –the net interest margin– depends on the risk differential between assets and liabilities. Accordingly, a change in the expense ratio can be due to changed risk-taking, and not necessarily changed efficiency. Thus, we prefer the term "expense ratio" for this measure, not "efficiency ratio," as it is sometimes called.

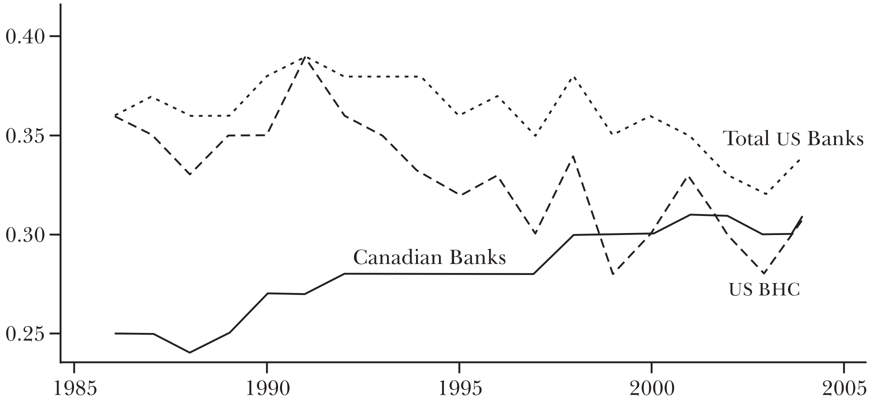
respectively. As shown in Figure 2, the labour expense ratio in Canada has been higher than in US banks in most of the sample period. That ratio has been trending slightly upwards in Canadian banks, while decreasing in US BHCs and even more sharply in total US banks. Similar trends are observed for the capital cost expense ratio, where capital cost is non-interest expense net of labour cost. It includes mostly physical capital expense in addition to administrative expenses. Canadian banks have a much lower capital cost expense ratio than US banks at the beginning of the sample. The difference narrows in the mid-1990s, as capital prices, defined as capital expenses on the stock of physical assets, increase more significantly in Canadian banks than in US banks. The stronger increase in capital prices in Canadian banks may be a result of increased competition in the adoption of new technology, a subject that will be addressed further in Section 5. Overall, it seems that the difference in the expense ratios can be currently attributed to a higher labour cost component at Canadian banks.

FIGURE 2. LABOUR EXPENSE RATIO, 1985-2005



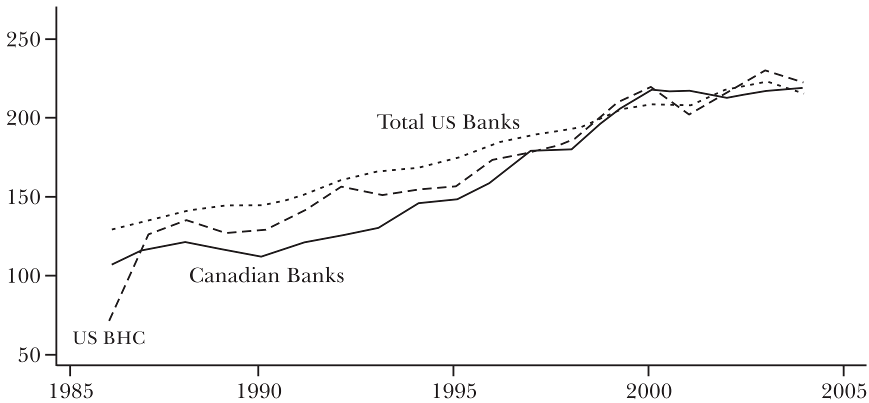
Given the higher labour cost of Canadian banks relative to US banks, we ask whether Canadian banks hire too many workers to produce the given amount of output, or pay their workers a premium. Figure 4 shows the net operating revenue per employee for the three groups of banks -- a measure of labour productivity. The ratio for Canadian banks was lower than that of the US banks in the late 1980s, but started to catch up in the early 1990s. In fact, the measures for the three groups of banks have converged since the late 1990s. Therefore, the current higher labour cost component in Canadian banks must come from a higher unit wage. This is apparent in Figure 5. The annual wage

FIGURE 3. CAPITAL EXPENSE RATIO, 1985-2005



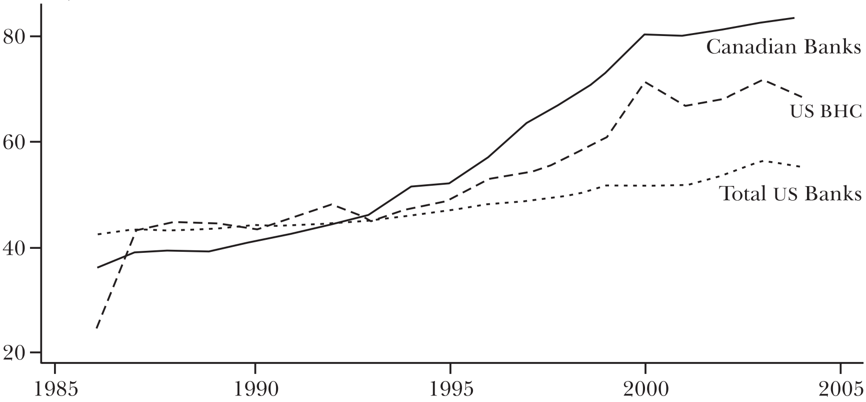
and benefit per employee in Canadian banks is plotted against those of the US BHCs and total US banks. Canadian banks compensated their average worker around 80,000 dollars in 2004, while the US BHCs compensation was close to 70,000 dollars, and an average US bank compensation was around 55,000 dollars.

FIGURE 4. NET OPERATING REVENUE PER EMPLOYEE, 1985-2005 (thousands of USD)



Two important wage differentials should be noted here, where by "wage" we mean salaries and benefits. The first is the difference between wages at the large banks (i.e., Canadian banks and US BHCs) and those at total US banks, which significantly arise only after 1993. This trend coincides with the increase in market-based activities of the Canadian banks and BHCs in the early 1990s. This increased wage differential may imply that the banks' engagement in market-based activities has created more high-paying

FIGURE 5. ANNUAL WAGE AND BENEFITS PER EMPLOYEE, 1985-2005 (thousands of USD)



positions, like investment bankers, advisers, and brokers, particularly in the bull market of the 1990s.

The second wage differential of note is between Canadian banks and the US BHCs. Given that both groups of banks have a similar business mix, the overall wage differential is unlikely to come from the different skill sets employed by large banks in the two countries. While we do not have sufficient data to explain the apparent wage premium received by Canadian bankers, this wage differential itself does not imply disparities in efficiency levels. Therefore, a perception that Canadian banks are less efficient than US banks, which is based on the comparison of the expense ratio (Figure 1), can be misleading. A more valid comparison should be based on other measures, such as those that consider productivity more directly.

3.2 Productivity ratios

Another measure of efficiency is labour productivity, which is defined as output per hour of labour worked. A more productive bank can provide services in a more cost-effective way. Furthermore, productivity gains of banks contribute significantly to total productivity growth in the economy.

The measurement of banking output is a challenge and of constant debate, including at the National Accounts level. The 1993 SNA recommends measuring nominal bank output by combining net interest income with explicit services fees booked domestically. Both Canada and the United States use this approach to measure nominal bank output in their respective National Accounts. Each country, however, uses a different method to measure the volume of bank output; that is, real output. In 1999, the US Bureau of Economic Analysis (BEA) adopted a quantity indicator of bank output developed by the Bureau of Labour Statistics (BLS) to track volumes of banking transactions, such as the number of cheques written or the number of transactions on automated banking machines, to better capture the growing number of transactions. In Canada, the volume of bank output is calculated by simply deflating the nominal bank output measure by the aggregate consumer price index (CPI).

No known study has estimated the discrepancy created by the different methodologies adopted by the two countries. Published National Accounts data allow us to compare the annual output and price deflator for an aggregation of "monetary authorities and credit intermediaries" in the two countries from 1997. Figure 6 shows the two price deflators used in the National Accounts measure of banking output in Canada and the United States. If 1999 is used as the base year, then it is apparent that using the specific "credit intermediation deflator" itself can imply higher banking output in the United States relative to the methodology used in Canada.

Since a measure of the output of banks is not available from the National Accounts, we define banking output in both countries as net operating revenue (net interest income plus non-interest income booked worldwide). In principle, this should be fairly close to the conceptual definition of nominal banking output in the 1993 SNA, although our measure of output is on a consolidated, global basis.[7]

As noted earlier, to avoid a discrepancy created by the use of different deflators, we deflate our measure of banking output by CPI excluding food and energy in both countries. Assuming a constant number of hours in a work week, we compare the ratio of net operating revenue per full-time-equivalent employee across the three groups of banks.

Again, Figure 4 shows the net operating revenue per full-time-

[7] Wang (2003) takes a fundamentally different approach to measuring bank output. She develops a model of bank operations that excludes risk-related returns on borrowing and lending from the definition of value-added. This measure, however, is not yet practical for making cross-country comparisons. Future work might benefit from using Wang's definition of banking output to measure labour productivity, since it appears (at least conceptually) to be a truer measure of banking activity than provided by National Accounts measures.

equivalent employee in Canadian banks, large US BHCs, and total US banks in constant 1999 US dollars. According to this measure, Canadian banking workers were less productive than US banking workers in the late 1980s, but started to catch up in the early 1990s. In fact, labour productivity in the three groups of banks has converged since the late 1990s, suggesting that, currently, Canadian banks are as productive as their US counterparts. Factors that may have contributed to such a catching-up of Canadian banks include their change of business mix towards more market-oriented activities, and their investment in technology. We will investigate the possibility of the latter in Section 5.

FIGURE 6. PRICE DEFLATORS USED IN NATIONAL ACCOUNTS FOR BANKING SERVICES, 1996-2004

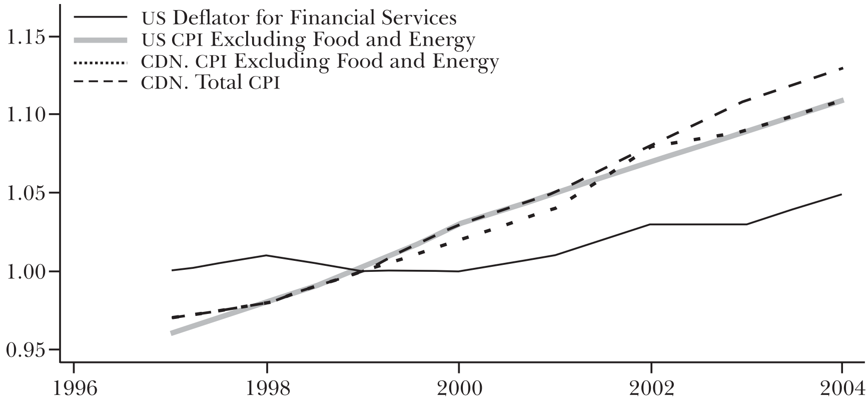
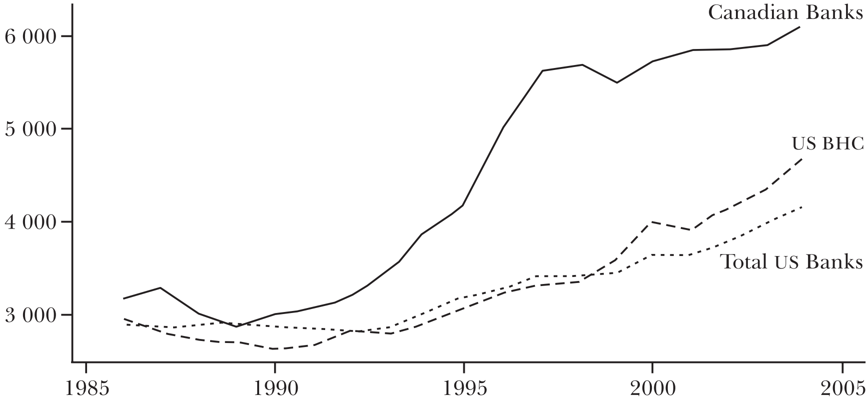


Figure 7 compares total assets per full-time-equivalent employee across Canadian banks, the US BHCs, and total US banks. Total assets is the typical definition of bank output in econometric studies of cost and profit functions [see Berger and Humphrey (1997) for a review of the literature]. Using total assets as a measure of bank output, we calculate that a Canadian bank employee produced almost 40 per cent more assets than a US bank employee in the past decade. The divergence also took place in the early 1990s, consistent with our other measure of banking productivity. Based on this measure, Canadian banks are much more productive than US banks.

As was the case of using the expense ratio as a measure of efficiency, there are also challenges inherent in using assets per employee as a measure of productivity. The decision of banks to have loans, for example, on-balance sheet or off-balance sheet (via securitization) is an optimal response to historical, institutional,

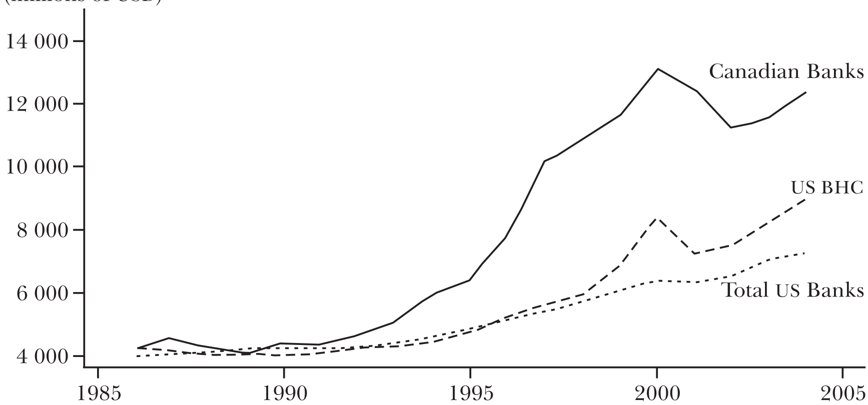
FIGURE 7. TOTAL ASSETS PER EMPLOYEE, 1985-2005 (millions of USD)



and regulatory differences across countries. It is possible therefore that banks use different approaches to generate similar profits. Engert and Freedman (2003) discuss different patterns of securitization in Canadian and US banking, and reasons for these differences. The point is clearest when comparing net operating revenues. Canadian and US banks have similar net operating revenues per employee, as shown in Figure 4.

Finally, for completeness, Figure 8 adds to total assets from Figure 7 a measure of off-balance-sheet (OBS) assets. The value of OBS assets is estimated using the approach of Boyd and Gertler (1994), explained below. Figures 7 and 8 suggest that Canadian banks are more productive than US banks, whether or not one includes OBS activities.

FIGURE 8. TOTAL ON- AND OFF-BALANCE SHEET ASSETS PER EMPLOYE, 1985-2005 (millions of USD)



4. MEASURING ECONOMIES OF SCALE AND X-EFFICIENCY

Allen and Liu (2005) measure economies of scale and cost-efficiency for Canada's six largest banks. A multi-output translog cost function is estimated using quarterly data from 1983 to the third quarter of 2003. In this paper, we apply the same framework to the group of 12 US BHCs and re-estimate the cost function for the large Canadian banks using data up to and including the fourth quarter of 2004.

4.1 Specification and estimation

Banks in both countries are assumed to use three inputs (labour, capital, and deposits) and to produce five outputs (consumer loans, non-mortgage loans, mortgage loans, other financial assets, and non-traditional banking activities, including OBS). This intermediation approach of Sealey and Lindley (1997) is now standard in the banking literature.

We define bank output as the book value of total bank assets booked worldwide. This definition is adopted in almost all empirical research on bank economies of scale and efficiency. This measure is relatively easy to collect and there is little ambiguity in the definition. One problem with this measure, however, is that non-traditional banking activities, especially those related to OBS activities, are not captured. As a solution, Boyd and Gertler (1994) suggest generating a hypothetical portfolio that would be required to generate non-interest income. We use this approach, with one caveat. The underlying assumption required to construct the hypothetical portfolio is that off-balance-sheet assets yield the same rate of return as on-balance-sheet assets. This ignores differences in risk. For robustness we provide a range of estimates for economies of scale based on different assumptions regarding the return to OBS activities.

The translog cost function [Christensen, *et al.* (1971), Diewert (1974)] is given below:

$$c(q,w) = \alpha_0 + \sum_{l=1}^{m}\alpha_l q_l + \sum_{j=1}^{k}\beta_j w_j + \frac{1}{2}\sum_{l=1}^{m}\sum_{j=1}^{m}\sigma_{lj} q_l q_j + \sum_{l=1}^{m}\sum_{j=1}^{k}\gamma_{lj} q_l w_j + \frac{1}{2}\sum_{l=1}^{k}\sum_{j=1}^{k}\delta_{lj} w_l w_j + \sum_{l=1}^{L}\theta_l G_l + \xi + \varepsilon, \tag{1}$$

where variables are in logarithms and certain restrictions apply:

$\sum_{j}^{k}\beta_j = 1$, $\sum_{j}^{k}\gamma_{lj} = 0$, and $\sum_{j}^{k}\delta_{lj} = 0$ (homogeneity). Due to multicollinearity, we also impose $\sigma_{lj} = 0$. Variable cost is given by c, outputs denoted by q, inputs denoted by w, exogenous variables denoted by G, the firm fixed effect denoted by ε, and the error term denoted by ξ. Examples of G include, in the Canadian case, the 1987 and 1997 changes to the Bank Act ($G1_{CAN}$ and $G3_{CAN}$, respectively) and the complete implementation of the IBBEA in the United States by 1997 ($G3_{US}$).

Economies of scale are defined as:

$$\zeta = (\sum_{l=1}^{k}\alpha_l + \sum_{l=1}^{k}\sum_{i=2}^{k}\gamma_{ij}\log(W_l/W_j))^{-1}. \quad (2)$$

There are increasing returns to scale if $\zeta > 1$, constant returns to scale if $\zeta = 1$, and decreasing returns to scale if $\zeta < 1$.

To derive a measure of cost-efficiency, the cost frontier intercept is first defined as $\hat{\alpha}_{0t} = \min_j(\hat{\xi}_{jt})$, and inefficiency is given by $\hat{\varepsilon}_{it} = \hat{\xi}_{it} - \hat{\alpha}_{0t}$. The time-invariant case is nested if the same firm is selected for all t. Cost-efficiency is derived as:

$$CE_{it} = \exp\{-\hat{\varepsilon}_{it}\}.$$

Estimation of cost-efficiency with the translog cost function is based on the error term from equation (1). Accordingly, reliable inference regarding cost-efficiency depends on accurately estimating the cost-function. To avoid confounding the estimates of cost-efficiency, information on Canadian banks and US BHCs is not pooled, but rather separate cost functions are estimated for each country. Given, among other things, differences in institutional and regulatory environments, pooling the data would reduce the accuracy of the parameter estimates and render the error term uninterpretable. The approach we take is consistent with Mester (1997), who argues that, in estimating cost functions, the measure of X-efficiency is sensitive to the amount of heterogeneity in the bank sample.

An additional parameter of interest is technology, which we proxy by a quadratic time trend. The derivative of cost with respect to time is a measure of technological progress. Although interesting as a first step, we present alternatives in Section 5.

For robustness, we present two estimators. A fixed-effects model is estimated by generalized least squares and by panel dynamic ordinary least squares (PDOLS). Given the non-stationarity of the data, however, the PDOLS estimator is the only one that gives consistent parameter estimates and correct standard errors. Kao and Chiang (2000) also show, via Monte Carlo simulations, that PDOLS outperforms other similar estimators, such as bias-corrected least squares and fully-modified least squares. Allen and Liu (2005) show that the standard estimator, which ignores the non-stationarity of the data, can substantially overestimate economies of scale. Consider a generic fixed-effects model:

$$y_{it} = X_{it}'\beta + \xi_{it} + u_{it}, \tag{3}$$

where ξ_{it} are the potentially time-varying fixed effects and u_{it} are the residuals. Assume that the regressors follow a unit root process:

$$X_{it} = X_{it-1} + \nu_{it}.$$

We rewrite equation (3) to estimate β consistently:

$$y_{it} = \xi_i + X_{it}'\beta + \sum_{j=-q}^{q} c_{ij}\Delta X_{it+j} + \omega_{it}. \tag{4}$$

The PDOLS estimator is:

$$\hat{\beta}_{PDOLS} = [N^{-1}\sum_{i=1}^{N}(\sum_{t=1}^{T} z_{it}z_{it})^{-1}(\sum_{t=1}^{T} z_{it}\tilde{y}_{it})]_1,$$

where z_{it} is the $2\times(q+1)\times 1$ vector of regressors, $z_{it} = [x_{it} - \overline{x}_i, \Delta x_{i,t-q}, \ldots, \Delta x_{i,t+q}]$, $\tilde{y}_{it} = y_{it} - \overline{y}_i$, and the subscript 1 on the outside brackets indicates that we take only the first elements of the vector.

4.2 Results

Estimates of economies of scale in Canada for the period 1983 to 2004 are presented in Table 1. The estimate of economies of scale is 6.2 per cent in "Model REG" and 8.2 per cent in "Model T". Model REG includes dummy variables to capture the effects of periodic regulatory changes in Canada, and Model T includes a quadratic time trend to capture technological progress. The potential dummies for regulatory changes, first mentioned in Section 2.1, are: 1987Q2, 1989Q1, 1991Q1, 1992Q1, 1994Q1, and 1997Q1. The dummies are zero before these dates, and one afterwards. Regulatory changes that took place in 1987 and 1997 are statistically significant. We also include a third specification, which includes both the regulatory dummies and time trend

$<(REG+T)$. Parameter estimates for Model $REG+T$ are presented in Table 9. In this case, economies of scale are approximately 7.1 per cent. In all cases, we reject constant returns to scale at the 5 per cent significance level.[8] The estimates of economies of scale are not statistically affected by our assumption regarding the return of OBS activities.

TABLE 1. ECONOMIES OF SCALE FOR CANADIAN BANKS

		$H_0: \zeta = 1$	
Model	ζ	*Statistic*	*P-value*
Model REG	1.062	6.109	0.0134
Model T	1.082	10.36	0.0013
Model REG and T	1.071	7.922	0.0049

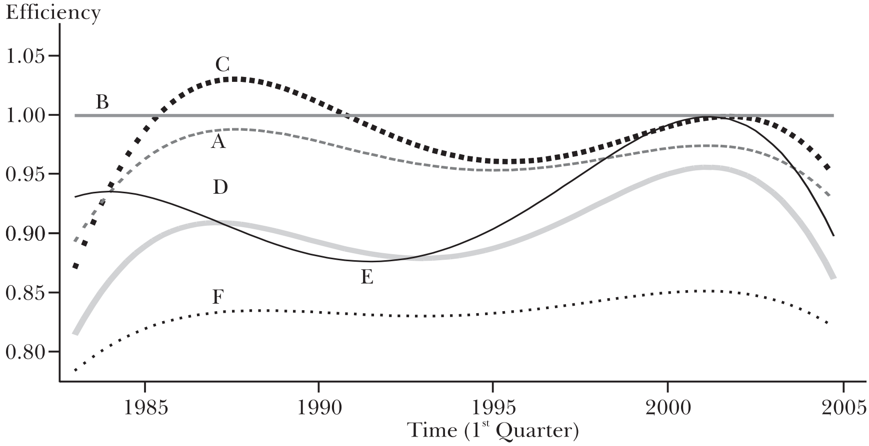
NOTE: The restriction imposed on equation (1) is actually $\zeta^{-1} = 1$ and $\Sigma_j \delta_{lj} = 0 \forall l$ since returns to scale is defined as $\partial C/\partial_{ql} = \Sigma_l \alpha_l + \Sigma\Sigma\delta_{lj}\log(\bar{W}_j / \bar{W}_1)$ where $\bar{\cdot}$ is the sample mean.

In addition to economies of scale, we also find a strong correlation between bank size and bank efficiency, and relatively large coefficients on technological progress (1.28 per cent per quarter in Model T). Furthermore, the cost-efficiency gap between the most efficient Canadian bank and the average bank is approximately 10 per cent. Figure 9 shows the time-varying cost-efficiency measures for the six Canadian banks in Model REG. Bank identities are not disclosed, for confidentiality reasons. Time-varying cost-efficiency is plotted relative to bank "B," which is why the estimate can be greater than one.

The same exercise is repeated for the 12 US BHCs. Model REG includes regulatory dummy variables. Four potential regulatory dates seem a priori important: 19872Q2, 1989Q1, 1997Q3, and 1999Q1. Statistically, the only significant date is 1997Q3, and therefore we report only the estimation results with a 1997Q3 dummy variable. Recall that, at the time, banks were officially allowed to merge across state lines. The second model (Model T) includes a quadratic time trend. The time trend is statistically significant. We also have a third model that combines both the regulatory dummy and the time trend. Parameter estimates are presented in Table 9.

[8] The parameters in this paper are estimated more precisely, given the extra data and the revisions, than in Allen and Liu (2005), but are qualitatively the same.

FIGURE 9. TIME-VARYING COST-EFFICIENCY OF CANADIAN BANKS, 1983-2005



Similar to the Canadian case, the variables in the cost function for US BHCs are found to be non-stationary through unit root tests.[9] By conducting unit root tests on the residuals from the cost function (1), we do find, however, that the cost function is co-integrated. Table 2 reports results for the null hypothesis that the

TABLE 2. UNIT ROOT TESTS ON THE US BHC COST FUNCTION RESIDUALS

	Fisher test	*MADF*
Model *BASE*		
Test statistic	38.31	70.25
P -value	0.032	0.000
Model *REG*		
Test statistic	36.45	70.31
P -value	0.050	0.000
Model *T*		
Test statistic	42.05	79.61
P -value	0.013	0.000
Model *REG* and *T*		
Test statistic	45.24	82.18
P -value	0.006	0.000

NOTE: The Fisher test uses the least squares estimator and an augmented Dickey-Fuller test with four lags and is distributed χ^2_{12}. Under the null hypothesis of non-stationarity. Estimation is done using the seemingly unrelated regression estimator and the distribution of the test statistic is via simulation.

[9] Results are available upon request.

residuals of the cost-function for the US BHCs are non-stationary. We report the Fisher test and modified augmented Dickey-Fuller test, introduced by Maddala and Wu (1999) and Sarno and Taylor (1998), respectively. The null hypothesis that all residuals are non-stationary is rejected at the 5 per cent level.[10]

The data on US BHCs are not as clean as those for Canadian banks. A reason for this is the relatively large number of bank mergers in the sample, and, more specifically, how banks treat them in their quarterly reports. A BHC can either account for the acquisition as a purchase or as a pooling of interests. In the former case, BHCs report a large increase in cost due to the merger followed by a sharp decrease in cost when operations are back to "normal." Data reporting when banks pool interests is more complicated. Rather than report large changes in reported variables, BHCs typically spread the gains and the large costs of a merger over what is potentially several years. This reporting scheme allows researchers to examine banks without structural breaks in the data.[11] Most mergers are treated as pooling of interests and therefore the balance-sheet data are smoothed over the period of the merger. There are, however, some episodes where purchases result in excess volatility of balance-sheet items. These changes in balance-sheet items are removed from the regression analysis by using dummy variables.[12] Specifically, we remove: *i)* 1998 for Bank of America, since that coincided with the purchase of Barnett Bank Inc; *ii)* 1999 and 2001 for Fifth Third, to account for the purchase of Peoples Bank Corporation of Indianapolis, and acquisitions in 2001 accounting for $ 25 billion in assets; and *iii)* 2000 for Wachovia, to account for the purchase of Everen.[13]

[10] The null hypothesis is set up such that if there are some residuals that are stationary, then the null hypothesis is rejected. There is no clear approach to determine whether "some" means all or less than all.

[11] A detailed breakdown of mergers/acquisitions for BHCs can be provided upon request.

[12] Focarelli and Panetta (2003) find that there are long-term efficiency gains from mergers and acquisitions using Italian bank deposit data. Panetta, *et al.* (2005), using the same Italian data set, find further that informational benefits, which reduce costs, arise from mergers and acquisitions. Cost savings are related to informational processing. In a review of case studies, Rhoades (1998) reports that four out of nine mergers in the United States resulted in cost-efficiency gains, while five mergers were not cost-efficient. Rather than perform case studies of each merger, we smooth the data or remove volatile periods caused by a merger or acquisition.

[13] Obviously, there is some subjectivity regarding which episodes to remove

Results on economies of scale for the US case are presented in Table 3. The null hypothesis of constant returns to scale is rejected. Evaluated at the sample mean, the measured economies of scale are 7.5 per cent for Model *REG* and 2.4 per cent for Model *T* . The model that combines both the regulatory dummy variable and the time trend also produces an economy-of-scale measure that is significantly different from zero, approximately 2.2 per cent.[14]

TABLE 3. ECONOMIES OF SCALE FOR US BHCs

		$H_0 : \zeta = 1$	
Model	ζ	*Statistic*	*P-value*
Model *REG*	1.075	89.04	0.0000
Model *T*	1.024	9.307	0.0023
Model *REG* and *T*	1.022	8.715	0.0032

NOTE: The restriction imposed on equation (1) is actually $\underline{\zeta}^{-1} = 1$ and $\Sigma_j \delta_{lj} = 0$ $\forall\ l$ since returns to scale is defined as $\partial C/\partial_{ql} = \Sigma_l \alpha_l + \Sigma\Sigma\delta_{lj} \log(\bar{W}_j / \bar{W}_1)$ where $\bar{\ }$ is the sample mean.

We also consider the sensitivity of these results to different assumptions regarding the return associated with OBS activities. The measure developed by Boyd and Gertler (1994) necessarily assumes that the return on assets for OBS activities is the same as for on-balance-sheet activities. This is a natural assumption regarding the portfolio of banks, but does ignore risk. With respect to the estimate of economies of scale, this assumption turns out to be innocuous. We consider the effect of increasing the return on assets for OBS activities by 5 to 10 percentage points; the effect is marginal and not statistically significant.

In addition to measuring economies of scale, we report measures of cost-efficiency. The time-invariant measures of cost-efficiency are given in Table 4. Wells Fargo is consistently the most cost-efficient bank across models. Other banks that are fairly close include National City and US Bancorp. The identity of the least cost-efficient bank depends on the model. Consistently poor performers, however, include Citizens Bank and Fifth Third.

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from the regression analysis. However, results are robust to different specifications related to mergers and acquisitions. A detailed list of bank merger activity from 1980 to 1998 is provided by Rhoades (2000).

14 The estimates for economies of scale are slightly larger if purchase-type mergers/acquisitions are not treated properly. The differences, however, are small.

TABLE 4. COST-EFFICIENCY FOR US BHCs

Bank	*Model REG*	*Model T*	*Model REG and T*
Wells Fargo	100	100	100
National City	89.4	93.0	92.7
US Bancorp	88.3	89.9	89.3
Keycorp	85.9	88.9	88.8
BB&T Corp.	79.3	87.4	87.84
SunTrust	87.7	87.9	87.83
Wachovia	89.8	86.8	86.6
PNC Financial	83.5	84.6	84.2
Citizens Bank	73.1	82.4	83.2
Fifth Third	73.6	82.1	81.8
Bank of America	85.0	81.9	81.5
JP Morgan Chase	87.1	80.4	79.5

NOTE: The most efficient bank has a ranking of 100 per cent and other banks cost-efficiency are relative to that bank.

The time-varying measures of cost-efficiency are presented graphically in Figure 10. Most of the BHCs are at least 10 per cent less efficient than the frontier bank. Furthermore, the gap between the most cost-efficient bank, Wells Fargo, and the other banks appears to have been increasing over time.[15] Indeed, several banks were more cost-efficient than Wells Fargo at the beginning of the sample.

In addition, for Model T , the measure of technological progress is estimated to be approximately 0.26-0.29 per cent per quarter. This is substantially less than for Canadian banks, which is estimated to be approximately 1.28 per cent per quarter. We examine technological progress more closely in the following section.

As another robustness check, we compare the estimates for ordinary least squares to dynamic least squares for the 12 US BHCs in the sample. Allen and Liu (2005) compare estimates of economies of scale for the Canadian banks using the standard least squares estimator (which ignores non-stationarity) to the dynamic

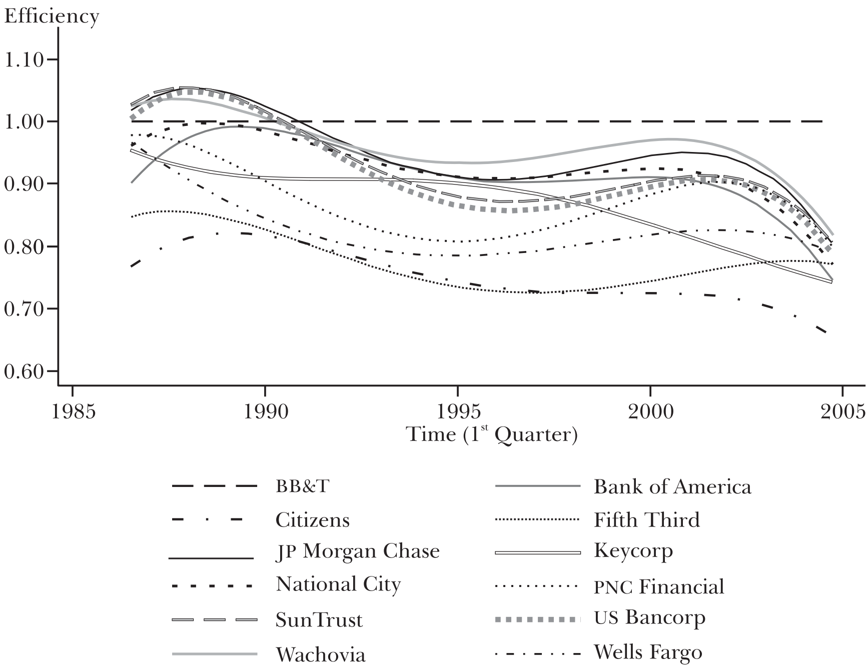
[15] Berger and Mester (2003) find that the cost-efficiency of US banks decreased over the period 1991-97. They also find that profit efficiency improved in that period, and argue that banks provided better quality of service at a higher cost but raised revenue by more than the cost increase. While we are aware of the advantages of estimating a profit function, it would be hard to justify the use of the DOLS estimator, which would suggest a non-zero profit in the long run.

least-squares estimator and, as stated earlier, find substantial bias in the former estimator. For example, in a Canadian-bank cost function with regulatory dummies, the least-squares estimate of economies of scale is close to 20 per cent, whereas if one uses the correct dynamic least-squares estimator, the estimate is approximately 6.2 per cent. Phillips and Moon (1999) suggest that as the number of cross-sectional observations increases, the noise in the cross-section should attenuate the persistence in the time series. That is, the least-squares estimate should become "better" as the number of cross-sectional observations increases. It is an open question as to the finite sample properties of panel least squares in the presence of non-stationarity.

We find that for the sample of US BHCs the bias of the ordinary least squares estimate of economies of scale is negligible and the cost-efficiency rankings are only marginally affected. It may therefore be sufficient to use the standard estimator for even moderate sample sizes, as in the case of the US BHCs. One would not want to use the PDOLS estimator for smaller sample sizes, as in the case of Canadian banks.

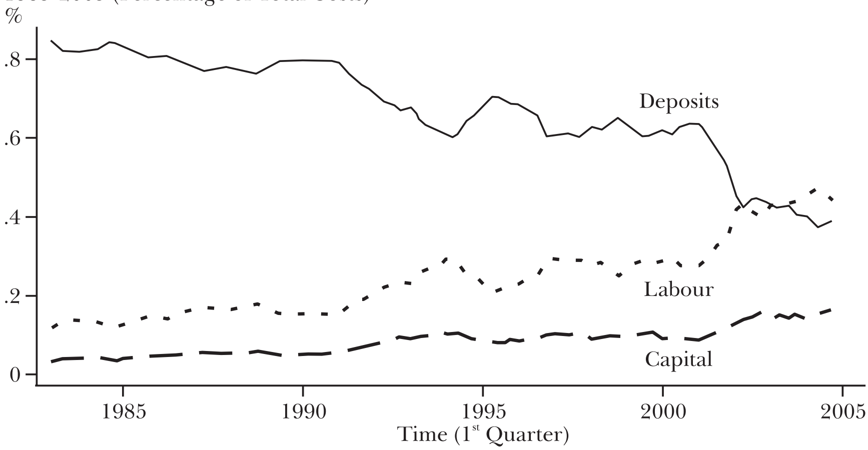
So far, we have shown, using the translog cost function, that:

FIGURE 10. TIME-VARYING COST-EFFICIENCY FOR U.S. BHCs, 1986-2004



economies of scale are larger in the Canadian sample relative to the US sample; average cost-inefficiency is lower in the Canadian sample; and the time trend, which proxies technological progress, is four times larger in the Canadian sample relative to the US sample.[16] A natural question is whether banks in the respective countries face different cost structures that could lead to different rates of technological progress. Figures 11 and 12 show cross-sectional averages of the cost breakdown (capital, labour, and deposits) for Canadian banks and US BHCs, respectively. The cost structures appear to be similar, with Canadian banks experiencing a slightly higher cost of deposits for most of the sample. Given the similarity between cost structures across countries, we consider more closely the substantially larger rate of technological progress estimated for Canadian banks. The model attributes most of the increase in Canada's relative productivity (Figure 8) to faster technological progress in Canada.

FIGURE 11. CROSS-SECTIONAL AVERAGE OF TOTAL COSTS - CANADIAN BANKS, 1985-2005 (Percentage of Total Costs)



5. CAPTURING THE CANADIAN TIME TREND

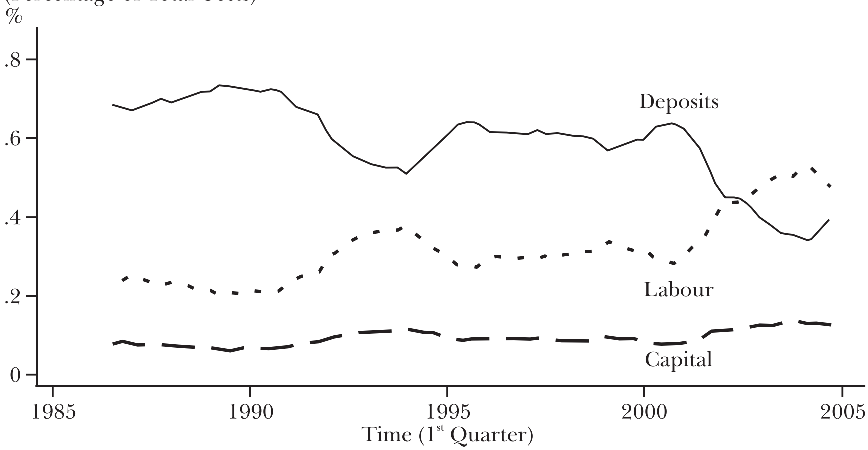
Thus far, we have proxied technological progress using a quadratic time variable and find that technological progress is approximately 1.28 per cent per quarter for Canada's banks, and

[16] Research on productivity growth in FIRE (for example, by Tang and Wang, 2004) also suggests that such growth has been larger in Canada than in the United States, although not by a large margin.

between 0.26 and 0.29 per cent per quarter for the US BHCs. In this section, we consider several explanatory variables that help explain within-Canada technological progress, and provide some intuition for between-country differences.

The average cost-inefficiency in the Canadian banking sector is roughly 10 per cent, and in the United States it is about 16 per cent, after controlling for size, factor inputs, output composition, and the regulatory environment. These are relatively large cost-inefficiencies, suggesting that the return to organizational change at the least efficient banks to become like the most efficient bank is high (Carbó, *et al.*, 2004).

FIGURE 12. CROSS-SECTIONAL AVERAGE OF TOTAL COSTS - U.S. BHCs, 1985-2005 (Percentage of Total Costs)



We examine whether ICT investments made by Canadian banks can explain the dispersion in cost-efficiency. A review of the literature suggests that productivity growth and ICT investment are tightly linked (Crawford, 2003). For example, Stiroh (2002) finds a strong correlation between ICT investments and the post-1995 productivity revival in the United States. Financial intermediation is an information technology-intensive industry, with front-office operations such as branch, telephone, and Internet banking, and back-office operations such as payments clearing and settlement. Accordingly, banks use advances in technology to cut costs and increase revenues. ICT can raise productivity by improving information processing and delivery, and by improving the quality and range of products offered (Berger, 2003). ICT investments, therefore, can increase productivity and improve the cost-efficiency of the banking industry. Anecdotal evidence provided during interviews with Canada's large banks suggests that ICT investments are largely made for cost-efficiency reasons. The impact on productivity of these investments is claimed to be substantial. Quantifying the impact of ICT investment in a service industry such as banking is, however, difficult.

Figure 9 presents the time-varying cost-efficiency measures of Canada fit to a fourth-order time polynomial of Model *REG* . Furthermore, if we include the time trend explicitly in the cost function, the average cost-inefficiency is small relative to what is reported in the literature and relative to a model without the time trend. Very little understanding of banks, however, is obtained by simply using time trends. Instead, we want to consider measurable advances in technology. Our measure of technological progress therefore should capture the movements of cost-efficiency over time, as well as have an economic interpretation. In the results reported in this section, therefore, we do not include the time trend.

Canadian banks, unlike their US counterparts, have for the past 20 years reported consolidated expenditures on "computers and equipment." This includes depreciation of computers and equipment, maintenance, equipment purchases, software, and network costs. We include in the cost-function estimation of Model *REG* the log of the ratio of technology expenditures to the capital stock (*ITK*). The notion is that if, over time, banks have more heavily invested in new technology (which is more cost-efficient than older technologies), then costs should fall in the long run. The contemporaneous coefficient is, however, small (-0.013) and not statistically significant.

In addition to considering the contemporaneous effect of IT investment, we look at lagged effects. IT executives of the big Canadian banks suggest that there is typically a lag between implementing new technology and reaping productivity gains from the new technology. Leung (2004) provides empirical evidence of this phenomena for Canadian firms. We therefore include four lags of the *ITK* ratio in the cost function. Results are reported in Table 5. The results are consistent with the anecdotal evidence. That is, at short lags an investment in technology is correlated with higher costs (although not statistically significant), and at longer lags it is correlated with lower costs.

Given that measured investment in new technology is not substantially significant, we consider some other reasonable proxies for technological change. Results are collected in Table 6. For example, we proxy banks' effective adoption of technology using

TABLE 5. IT INVESTMENT

ITK	*Coefficient*	*Standard error*
t - 1	0.0374	0.0229
t - 2	0.0102	0.0236
t - 3	-0.0607*	0.0231
t - 4	-0.0271	0.0215

NOTE: Estimates are for model *REG*. * Is significant at the 5% level.

expenditures on employee training. New technology requires new training, and the better the training the larger should be the gains of adoption. Adding training expenditures on employees has two effects on the estimation of the cost function. First, it can partially capture movements previously captured by the quadratic time trend. Secondly, training expenditures can partially explain the cost-inefficiency differences between Canadian banks. The mean cost-inefficiency drops from 7.3 per cent to 6.4 per cent.

TABLE 6. AVERAGE COST-INEFFICIENCY FOR CANADIAN BANKS

Model	*Average cost-inefficiency (%)*
Base	10.02
Regulatory dummies	7.32
Regulatory dummies and time trend	4.36
Regulatory dummies and training	6.36
Regulatory dummies and ABM per branch	6.66

NOTE: The "Base" model does not include any regulatory variable or time trend.

Next we consider the number of automated banking machines (ABM) per number of bank branches. Data for Canada are reported annually in the bank annual reports. This ratio in Canada has increased from an average of 0.2 in 1985 to over 2 in 2004. ABMs are a low-cost distribution channel compared with brick-and-mortar branches. Assuming that two banks have the same number of customers, the bank that has the largest ABM network should have a higher proportion of customers using ABMs. The bank with a high ratio of ABMs to branches, therefore, should be more cost-effective. Humphrey, *et al.* (2006) find substantial cost-savings in a sample of 12 European countries from investments in ABMs relative to branches. On the other hand, Bernhardt and Massoud (2002) show that there could be an overprovision of ABMs, which would reduce bank profitability. Stavins 2000) documents that there have been very little cost-savings gained by

TABLE 7. DATA DESCRIPTION

		Variable definitions
Y_1	Consumer loans	Dollar value of personal loans for non-business purposes
Y_2	Non-mortgage loans	Dollar value of secured call and other loans to investment dealers and brokers + loans to regulated financial institutions + loans to domestic and foreign governments + lease receivables + reverse repurchase agreements + loans to individuals and others for business purposes
Y_3	Mortgage loans	Dollar value of residential and non-residential mortgage loans
Y_4	Other	Dollar value of other financial assets on a bank's balance sheet
$Y5$	OBS	Asset-equivalent measure of off-balance-sheet activities
L	Price of labour	Total salaries, pensions, and other staff benefits divided by the number of full-time-equivalent employees and hours in a year
K	Price of capital	Rental expense on real estate and depreciation on premises, furniture, fixture, computer and equipment divided by total stock of land, buildings, and equipment, less accumulated depreciation
D	Price of deposits	Total interest expense on deposits divided by the total dollar amount of deposits
C	Total costs	Interest cost + labour expenses + capital costs

US banks by expanding their ABM network. Consumers have simply responded to the increased convenience of ABMs by increasing their overall number of transactions. We find that the coefficient on the number of ABMs per bank branch is negative (-0.064) and significantly different from zero. This implies that a 1 per cent increase in ABMs relative to bank branches decreases bank costs over the sample period by 6.4 per cent. Including the number of ABMs per branch also reduces the amount of unexplained technological progress attributed to the time trend in the model. It was previously 1.28 per cent and is now 1.04 per cent. Finally, the number of ABMs per branch can also reduce the estimate of the cost-inefficiency differences across Canadian banks.[17] The average cost-inefficiency falls from 7.33 per cent to 6.66 per cent.

[17] We find in analyzing the US BHC experience from 1995 to 2004 a negative but not statistically significant coefficient on the ratio of ABMs to branches. Annual data are reported for US banks either in their annual reports or 10K forms required at the Securities and Exchange Commission. The reporting of the size

TABLE 8. SUMMARY STATISTICS OF LARGE CANADIAN BANKS AND US BHCs

Bank	*Total asset*	*Percentage of revenue from retail banking*	*Number of service delivery units*	*Number of province or state operating*
Canadian banks (millions of C$)				
Royal Bank	451.4	48	2084	10
TD Canada Trust	311.0	50	1,290	10
Bank of Nova Scotia	279.2	42	1,871	10
CIBC	278.8	44.5	1,073	10
Bank of Montreal	265.2	42.5	1,174	10
National Bank	88.8	47	462	10
US BHCs (millions of US$)				
JP Morgan Chase	1,157.2	24	2508	17
Bank of America	1,112.0	54	5,889	29
Wachovia	493.3	45	3,604	49
Wells Fargo	427.8	60	6046	50
U.S. Bancorp	195.1	42	2,370	24
SunTrust	159.1	45	1,710	9
National City	139.3	69	1,650	43
Citizens Bank	136.8	61	1,613	13
BB&T Corp.	100.5	77	1,413	20
Fifth Third	94.5	51	1,011	9
Keycorp	90.7	37	940	45
PNC Financial	79.7	40	875	36

NOTE: Based on 2004 annual reports. Retail banking refers primarily to deposit and loan services to individuals and small businesses. Non-retail banking includes wealth management, investment banking, insurance, brokerage, corporate lending, etc. Service delivery units include branches and client service centres.

6. CONCLUSION

This paper examines banking efficiency for Canada and the United States in three ways. First, we compare key performance ratios, and find that Canadian banks are as productive as US banks. Second, we investigate whether there are economies of scale in the production functions of Canadian banks and comparable US bank-holding companies (BHCs). We find larger economies of scale for Canadian banks than for US BHCs, which suggests that Canadian banks are less efficient in terms of scale, and have more

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of a bank's ABM network is rather poor, which is the reason for the small sample size and why we do not put much weight in the result.

TABLE 9. DOLS: MODEL *REG* + *T*

	Canada		*United States*	
Variable	*Coefficient*	*T-statistic*	*Coefficient*	*T-statistic*
θ_1	-0.01291		-0.00291	
θ_2	0.000075		-0.000022	
$G1_{CAN}$	-0.03010**	3.396	-	-
$G3_{CAN}$	-0.08245**	8.279	-	-
$G3_{US}$	-	-	-0.02123*	2.224
α_1	1.48064**	3.006	0.46124**	8.314
α_2	3.19045**	7.600	0.23874**	4.264
α_3	-2.01638**	5.576	0.29250**	4.993
α_4	-0.99546*	2.013	0.06982	1.253
α_5	0.44801*	1.931	0.35296**	6.526
β_2	7.62442**	10.701	-0.86630**	4.890
β_3	-2.14519*	2.145	1.28352**	4.992
δ_{12}	0.37314**	8.240	-0.06397*	2.012
δ_{13}	-0.23642**	12.934	-0.04440*	2.175
δ_{23}	0.04150*	2.029	-0.08306**	4.132
γ_{12}	-0.10954**	2.706	-0.02290**	4.367
γ_{13}	0.04102*	1.919	0.05888**	4.106
γ_{22}	-0.25280**	7.304	0.00923*	1.720
γ_{23}	0.02299$^\lozenge$	1.384	0.07377**	5.121
γ_{32}	0.17858**	6.015	-0.00054	0.101
γ_{33}	-0.09905**	4.816	-0.02692**	2.372
γ_{42}	0.09591*	2.309	0.024700**	4.534
γ_{43}	-0.06914**	3.550	0.01993$^\lozenge$	1.372
γ_{52}	-0.00779	0.418	-0.04131**	7.883
γ_{53}	0.13484**	12.093	-0.09494**	6.785

NOTE: **, *, $^\lozenge$: significant at the 1, 5, and 10 percent levels, respectively. The *T*-statistics in for the null hypothesis that the parameter is zero and is defined as:

$$T\text{-}stat = \frac{\sqrt{N}(T - lags - leads - 1)\hat{\Theta}}{sqrt[VAR(\hat{\Theta})]}$$ where $\hat{\Theta}$ is the vector of parameter estimates.

to gain in terms of efficiency benefits from becoming larger. Third, we measure cost-inefficiency in Canadian banks and in US BHCs relative to the domestic efficient frontier in each country (the domestic best-practice institution). We find that Canadian banks are closer to the domestic efficient frontier and relatively close to each other in terms of cost-efficiency, closer than the US BHCs.

Finally, how can one interpret the large estimate of technological progress for Canadian banks relative to the US BHCs? In Canada, the estimate of technological progress is 1.04 per cent in the most detailed model. The comparable estimate for the US is 0.3 per cent, substantially lower than in Canada. It is possible that the trend is capturing a substantial increase in total assets per labour input for Canadian banks over the sample period, evident in Figure 8. As well, the time trend might be capturing improvements in Canada's payments system, including the establishment of an efficient large-value payments system in the late 1990s. In this regard, for example, Milne (2006) provides a theoretical model to explain the empirical observation that countries with higher banking concentration (such as Canada) have more efficient payments systems. These and other possibilities might explain the substantial measure of trend progress in the cost function. Given the current lack of relevant data, but the increasing amount of data collection, it is hoped that these questions can be addressed in future research.

REFERENCES

Allen, J., and Y. Liu (2005), *Efficiency and Economies of Scale of Large Canadian Banks,* Bank of Canada (Working Paper, nº 2005-13); Also forthcoming in *Canadian Journal of Economics*.

Berger, A. (2003), "The Economic Effects of Technological Progress: Evidence from the Banking Industry", *Journal of Money, Credit, and Banking,* vol. 35, pp. 141-76.

Berger, A., and D. Humphrey (1997), "Efficiency of Financial Institutions: International Survey and Directions for Future Research", *European Journal of Operational Research,* vol. 98, pp. 175-212.

Berger, A., and L. Mester (2003), "Explaining the Dramatic Changes in Performance of U.S. Banks: Technological Change, Deregulation, and Dynamic Changes in Competition", *Journal of Financial Intermediation,* vol. 12, pp. 57-95.

Bernhardt, D., and N. Massoud (2002), *Endogenous ATM Location and Pricing,* mimeo.

Bordo, M. (1995), *Regulation and Bank Stability: Canada and the United States, 1870-1980,* World Bank (Working Paper, nº 1532).

Boyd, J., and M. Gertler (1994), "Are Banks Dead? Or Are the Reports Greatly Exaggerated", *Federal Reserve Bank of Minneapolis Quarterly Review,* vol. 18, nº 3, pp. 2-23.

Carbó Valverde, S., D. Humphrey, and R. López del Paso (2004), *Opening the Black Box: Finding the Source of Cost Inefficiency,* January (Working Paper).

Christensen, L., D. Jorgenson, and L. Lau (1971), "Conjugate Duality and the Transcendental Logarithmic Production Function", *Econometrica,* vol. 39, pp. 255-56.

Crawford, A. (2003), *Sustaining Global Growth and Development*, chapter 3, Productivity Growth in Canada and the G-7, Ashgate Publishing, England.

Daffin, C., G. Reed, and P. Vaze (2002), "Labour Productivity Measures for the Non-Production Industries", *Economic Trends*, nº 579, December, pp. 54-62.

Daniel, F., C. Freedman, and C. Goodlet (1992), "Restructuring the Canadian Financial Industry", *Bank of Canada Review,* Winter, pp. 21-45.

Diewert, W. (1974), "Applications of Duality Theory", in M. D. Intriligator and D. A. Kendrick (eds.), *Frontiers of Quantitative Economics,* vol. II, North-Holland, Amsterdam, pp. 106-71.

Dolar, V., and C. Meh (2002), *Financial Structure and Economic Growth: A Non-Technical Survey,* Bank of Canada (Working Paper, nº 2002-24).

Engert, W., B. Fung, L. Nott, and J. Selody (1999), "Restructuring the Canadian Financial System: Explanations and Implications", in *The Monetary and Regulatory Implications of Changes in the Banking Industry*, Bank for International Settlements.

Engert, W., and C. Freedman (2003), "Financial Developments in Canada: Past Trends and Future Challenges", *Bank of Canada Review,* Summer, pp. 3-16.

Ferrier, G., and C. Lovell (1990), "Measuring Cost Efficiency in Banking", *Journal of Econometrics,* vol. 46, pp. 229-45.

Focarelli, D., and F. Panetta (2003), "Are Mergers Beneficial to Consumers? Evidence from the Market for Bank Deposits", *American Economic Review,* vol. 93, pp. 1152-72.

Freedman, C. (1998), *The Canadian Banking System*, Bank of Canada (Technical Report, nº 81).

Holland, D., D. Inscoe, R. Waldrop, and W. Kuta (1996), "Interstate Banking: The Past, Present, and Future", *FDIC Banking Review,* Fall, pp. 1-17.

Humphrey, D., M. Willesson, G. Bergendahl, and T. Lindblom (2006), "Benefits from a Changing Payment Technology in European Banking", *Journal of Banking & Finance,* vol. 30, pp. 1631-52.

Kao, C., and M. Chiang (2000), "On the Estimation and Inference of a Cointegrated Regression in Panel Data", *Advances in Econometrics,* vol. 15, pp. 179-222.

Leung, D. (2004), *The Effects of Adjustment Costs and Organizational*

Change on Productivity in Canada: Evidence from Aggregate Data, Bank of Canada (Working Paper, nº 2004-1).

Maddala, G., and S. Wu (1999), "A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test", *Oxford Bulletin of Economics and Statistics,* vol. 61, pp. 631-52.

Mester, L. (1997), "Measuring Efficiency at U.S. Banks: Accounting for Heterogeneity Is Important", *European Journal of Operational Research,* vol. 98, pp. 230-42.

Milne, A. (2006), "What is in it for Us? Network Effects and Bank Payment Innovation", *Journal of Banking & Finance,* vol. 30, pp. 1613-30.

Panetta, F., F. Schivardi, and M. Shum (2005), *Do Mergers Improve Information? Evidence from the Loan Market,* CEPR (Discussion Paper, nº 4961).

Phillips, P., and H. Moon (1999), "Linear Regression Limit Theory for Nonstationary Panel Data", *Econometrica,* vol. 67, pp. 1057-111.

Rao, S., T. Tang, and W. Wang (2004), *Productivity Levels Between Canadian and U.S. Industries,* Industry Canada (Working Paper).

Rhoades, S. (1998), "The Efficiency Effects of Bank Mergers: An Overview of Case Studies of Nine Mergers", *Journal of Banking & Finance,* vol. 22, pp. 273-91.

Rhoades, S. (2000), *Bank Mergers and Banking Structure in the United States, 1980-1998,* Board of Governors (Staff Study, nº 174).

Sarno, T., and M. Taylor (1998), "Real Exchange Rates Under the Current Float: Unequivocal Evidence of Mean Reversion", *Economic Letters,* vol. 60, pp. 131-37.

Sealey, C., and J. Lindley (1997), "Inputs, Outputs, and Theory of Production Cost at Depository Financial Institutions", *Journal of Finance,* vol. 32, pp. 1251-66.

Stavins, J. (2000), "ATM Fees: Does Bank Size Matter?," *New England Economic Review,* January-February, pp. 13-24.

Stiroh, K. (2000), "How Did Bank Holding Companies Prosper in the (1990)s?", *Journal of Banking and Finance,* vol. 24, pp. 1703-1747.

Stiroh, K. (2002), "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?", *American Economic Review,* vol. 92, pp. 1559-76.

Tang, J., and W. Wang (2004), "Sources of Aggregate Labour Productivity Growth in Canada and the United States", *Canadian Journal of Economics,* vol. 37, pp. 421-44.

Triplett, J., and B. Bosworth (2004), *Productivity in the U.S. Services Sector: New Sources of Economic Growth*, Brookings Institution, Washington.

Wang, J. (2003), *Loanable Funds, Risk, and Bank Service Output,* Federal Reserve Bank of Boston (Working Paper, nº 03-4).

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