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Determinants of commercial banks' cost of financial intermediation in Jamaica: a maximum likelihood estimation approach

I. INTRODUCTION

The cost of financial intermediation (CFI) is defined as the wedge between the gross cost of loans paid by a borrower and the net return received by a saver (or depositor).[1] The empirical study of the cost of financial intermediation to the public has become increasingly relevant to monetary policy, particularly in developing countries.[2] For example, a high CFI in a low interest rate competitive market structure is viewed as evidence of oligopolistic tendencies. These tendencies become more pronounced as liquidity concentration levels increase among a small number of dominant institutions. In the case of Jamaica, market liquidity levels tend to be concentrated in the larger banks. As a result, banks with relatively high liquidity levels are able to influence private money

[1] As defined by Bernanke (1983).
[2] See Brock and Franken (2002).

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market interest rates significantly. This could have adverse implications for the integrity of monetary policy and eventually the stability of the banking system.

Most of the empirical literature indicates that individual bank characteristics are not strongly correlated with bank spreads and margins in a competitive banking sector structure. This is because bank spreads are largely determined at the industry level and individual bank performance is more likely to be reflected in variables other than spreads, such as profits. However, if oligopolistic tendencies exist, the cost of financial intermediation may partly be influenced by bank-specific variables to the extent that individual bank strategies may affect product mix and the price of loans.[3] For example, larger banks would have the ability to exploit economies of scale, record relatively lower interest margins and pass on a higher portion of overhead costs to customers. In addition, well-capitalized banks may earn higher margins by virtue of incurring lower funding costs. The influences of large and well-capitalized banks in a competitive market structure are minimized so that the explanatory power of bank-specific variables becomes less significant and hence lower spreads prevail. The maintenance of low and stable bank spreads in developing countries is crucial for policymakers as they aim to minimize excess liquidity levels, as well as facilitate the process of economic development.

The costs of financial intermediation in Jamaica, particularly bank spreads, have received considerable scrutiny by market participants in the last four years. One major concern is that spreads have remained relatively high in a context where interest rates have declined significantly since 2003. There have been recent studies on commercial banks spreads in Jamaica. Robinson (2002) utilized a mathematical decomposition of bank spreads and concluded that administration cost was a major contributor to the levels of bank spreads. An update of this study by White (2005), which employed a more granular decomposition of each bank's spread also concluded that administration costs was the main contributor to the level of bank spreads in Jamaica. An investigation by the Fair Trading Commission of Jamaica (FTC) in 2005 concluded that the structural conditions of the banking sector favoured

[3] See Hauswald and Marquez (2005).

collusion.[4] The maintenance of high bank spreads not only has adverse implications for the competitive market structure of the banking system but also threatens the prospects of real sector investments and ultimately economic growth.

The purpose of this research paper is to determine the factors that influence the cost of financial intermediation in Jamaica's commercial banking sector. This is with a view to determine the level of competitiveness in the banking system based on the explanatory power of bank-specific vis-à-vis non-bank-specific variables. The benefit of examining the CFI of individual banks is to account for characteristics that may be unique to a particular institution and assess its impact on the determination of margins and spreads. In this context, the first aspect of the exercise will seek to explain individual bank spreads and margins in a dynamic panel data model framework. The explanatory variables include proxies for bank characteristics (akin to CAMELS ratings), aggregate risks, structure of the banking system and policy decisions.[5] The regressions of the different measures of the CFI are compared to determine whether or not the impact of the explanatory variables is the same across all measures of the CFI. This was done to assess consistencies in the influence of policy decisions and macroeconomic trends on commercial banks' CFI.

The remainder of the paper is organized in the following manner. Section II provides the literature review, which includes a theoretical and empirical perspective of the determinants of the CFI. A trend analysis of the three measures of the CFI for Jamaican commercial banks is presented in section III. The purpose of this section is to provide a brief description of recent trends in the costs of financial intermediation and highlight notable monetary policy changes that would have influenced these trends. Section IV provides an econometric approach to model each bank's CFI with a view to determine the influence of bank-specific variables vis-à-vis non-bank-specific variables. As previously mentioned, if

[4] See ⟨http://www.jftc.com/news&publications/Speeches/Reports/Banking_JMA_Public_Allegation_of_collusion_FINAL_2_08_06.pdf⟩.

[5] The CAMELS rating system is an international bank-rating system used by bank supervisory authorities to rate institutions according to six factors. The six factors are represented by the acronym "CAMELS", where C=Capital Adequacy, A=Asset Quality, M=Management Quality, E=Earnings, L=Liquidity and S=Sensitivity to Market Risk.

the CFI is largely influenced by bank-specific variables, then this is evidence of oligopolistic tendencies in the banking sector. Section V examines the data used in the analysis. Section VI explains the results and section VII provides some policy implications and recommendations.

II. LITERATURE REVIEW

1. Theoretical background

a) The Dealership model

In their seminal paper, Ho and Saunders (1981) outlined a Dealership bank model in which the role of a bank is to provide liquidity to the market. In this model, a bank is assumed to be a risk-averse dealer that serves as an intermediary between persons who demand funds (borrowers) and those that supply funds (depositors). Since the arrival times of deposit supplies and the demand for loans tend to be heterogeneous, the bank faces the problem of either a surplus or a shortage of funds at any arbitrary point in time. This surplus or shortage of funds defines the bank's net inventory (I), which the theory assumes is the difference between loans (L) and deposits (D).

The existence of a short-term money market resolves the problem of a surplus or shortage of funds, in that, a bank can invest or access funds at the short-term risk free rate, r. The bank is exposed to interest-rate risk whenever it holds an unmatched portfolio of deposits and loans, largely because of the uncertainty regarding transaction arrivals. When a deposit arrives first, the bank invests the funds in the short-term money market at rate, r. If r falls below the deposit interest rate r_D, the bank will not be able to pay the full interest on its customers' deposits. Similarly, when a loan arrives first, the bank borrows the funds in the short-term money market at rate r and makes loans at the loan interest rate r_L. If r rises above r_L, the bank faces a problem of not being able to pay the full interest on the funds borrowed in the money market. Therefore the bank will require a fee to account for the exposure to risk when customers perform deposit withdrawals and demand loans.

The theory posits that the optimal bank spread is derived from the maximization of a mean-variance utility function. The bank's problem is to solve for *a* and *b* such that $r_L = \tilde{r}_I + b$ and $r_D = \tilde{r}_I - a$ maximizes the bank's objective function subject to the total wealth of the bank, $\tilde{W}$. The maximization problem assumes that the issue of loans and arrival of deposits occur according to Poisson processes at rates $\lambda_L = \alpha - \beta b$ and $\lambda_D = \alpha - \beta a$, respectively.

Note that *a* and *b* are the fees charged for the immediacy of each unit of deposit received and each unit of loan provided by the bank, respectively. The variable α is the intercept of the deposit arrival function of the bank, while β is the slope of the loan demand function of the bank. It is also assumed that loan deposit transactions are of the same size, *Q*.

The bank maximizes the following utility function:

$$U = E(\tilde{W}) - \frac{1}{2}\rho Var(\tilde{W}) \tag{1}$$

subject to:

$$\tilde{W} = \gamma(1 + \tilde{r}_\gamma) + M(1 + r) + I(1 + \tilde{r}_I) \tag{2}$$

Note that $\rho = \frac{U''}{U'}$ is the absolute risk aversion coefficient, γ is a fixed portfolio of marketable assets with $\tilde{r}_\gamma$ as its random return, *M* is the net money market position and *I* is the net inventory position with random return, $\tilde{r}_I$ (the inter-bank rate).

Based on the maximization, a positive margin (termed a pure spread) tends to exist in highly competitive banking markets, provided there is transactions uncertainty. Also, a bank that faces relatively inelastic supply of deposits (or demand for loans) against the margin enhances its ability to exert monopoly power. Consequently, the model indicates that the optimal net interest margin depends on four factors: *i)* market power; *ii)* degree of bank risk aversion; *iii)* average size of bank transactions; and *iv)* interest rate risk. The maximization of the bank's objective function results in the optimal spread, *s,* between the loan rate and deposit rate;

$$s = a + b = r_L - r_D = \frac{\alpha}{\beta} + \frac{\sigma_I^2 Q\rho}{2(1+r)} \text{ [6]} \tag{3}$$

[6] See Ho and Saunders (1981) and Angbazo (1997) for details and the derivation of equation (3).

The first expression (α/β) is the risk neutral spread[7] as chosen by a risk-neutral banker.[8] The second part of equation (3) is a risk premium, which is proportional to the degree of risk aversion, ρ, and increases with the variance of return on credit market activities of the bank, σ_I^2, and with the size of the transaction, Q. Finally, the risk premium decreases with an increase in the monetary policy rate, r.

b) The Monti-Klein model

Another approach used to examine the determinants of the CFI is the Monti-Klein bank model.[9] This approach, based on industrial organization literature, was motivated by the Lerner (1981) critique of the Dealership model in which the bank's spread solely reflects the cost of providing liquidity to the market. The Lerner critique posits that the bank's spread, which is the difference between the cost of money and the price at which it is loaned, must be high enough to cover operating costs of the bank, as well as provide a return on equity.

The underlying assumption of the model is that the indicative bank is monopolistic and constrained by a downward sloping loan demand function and an upward sloping supply of deposits. The intuitive result of the model was that banks' intermediation margins increase with market power.[10] Another result was that the response of the optimal spread, s, to a change in the monetary policy rate depended on the elasticities of the demand of loans and the supply of deposits. The oligopolistic version of the Monti-Klein model (the Cournot equilibrium) shows that the spread is inversely related to the degree of competition and becomes less sensitive to changes in r as the degree of competition increases.

[7] The elasticities of demand for loans and supply of deposits are determined by the sizes of α and β, respectively. Consequently the ratio α/β provides a measure of the degree of monopoly power.

[8] Traditional explanations for risk aversion behavior in banks include: management's inability to diversify its human capital, insufficient owner diversification, incentive problems such as moral hazard and adverse selection and bankruptcy cost. In practical grounds, the dealership framework needs this assumption for the spread to exist, as well as, to ensure a finite bank size.

[9] The model was originally posited by Klein (1971) and Monti (1972).

[10] See Diamond (1984) and Cesari and Daltung (1994).

Additionally, a decline in the number of banks causes an increase in the spread, provided that the semi-elasticities of supply of loans and demand for deposits are finite. A decline in managerial costs due to enhancements in operation efficiency was shown to cause a reduction in spreads.

c) Other theoretical models

There are other theories in the literature that address the impact of non bank-specific variables on bank margins and spreads. One of the issues discussed is the influence of concentration on the pricing behaviour of banks.[11] The Structure Performance Hypothesis (SPH) claims that an increase in concentration implies oligopolistic tendencies. On the other hand, the Efficient Structure Hypothesis (ESH) posits that concentration is a consequence of more efficient banks taking over less efficient counterparts, thus preserving the competitive market structure. Both theories have been used to explain ambiguous effects of concentration on banks spreads.[12]

In some models, a positive shock to income causes an improvement in borrowers' net worth and hence reduces bank spreads.[13] In other models, such as that outlined in Holmstrom and Tirole (1994), a negative shock to the value of assets (collateral squeeze) has an ambiguous effect on interest rate spreads, while either a savings squeeze or a credit boom results in an unambiguous decrease in spreads. These results contrast with the ambiguous effects of a positive expenditure shock (which will probably translate into a credit boom) on spreads in an IS-LM framework of the Bernanke and Blinder (1988) model. A version of the Bernanke and Blinder (1988) model predicts that a negative productivity shock (that could cause a saving squeeze) has a positive influence on bank lending spreads.[14] Further, loan rate stickiness[15] or deposit rate rigidities[16] add more complexity to the

[11] See Berger and Hannan (1989).

[12] See Brock and Franken (2002).

[13] See Bernanke and Gertler (1989, 1990). The CFI is viewed as the collateralizable net worth of firms, since higher collateral values reduces agency costs associated with the enforcement of loan contracts.

[14] See Agenor, Aizenman and Hoffmaister (1999).

[15] See Petersen and Rajan (1995).

effects of macroeconomic shocks on spreads, making it difficult to predict the overall change in spreads.

2. Empirical literature

The vast empirical literature on bank behaviour emphasizes that the degree of banking competition and the macroeconomic environment have significant influences on bank spreads. The higher the degree of competition in the industry, the lower the level of bank spreads, while macroeconomic volatility may increase default risk and hence bank spreads.[17] Further, individual bank characteristics are often not correlated with spreads in a competitive market. This is because spreads are to a large extent determined at the industry level, while individual bank features are reflected in other variables, such as profits.[18]

One of the first influential studies on bank spreads was based on the Dealership model. In this study, Ho and Saunders applied equation (3) to quarterly data on 53 major US commercial banks between December 1976 and December 1979. The relationship between spreads and the variables outlined in equation (3) was found to hold true. They also found that smaller banks have a larger NIM than bigger banks, due to the fact that smaller banks, which operate in less competitive local markets, are able to exploit regional monopoly positions. These monopoly positions arise when there is no readily available substitute for services offered by the branch of a bank in a particular region.

There have been modifications of the Ho and Saunders model that address the impact of banking sector dynamics on the CFI. Wong's (1997) game theoretic analysis demonstrates that the optimal net interest margin increases with market power, operating expenses, credit risk and interest rate risk in an environment where there is exposure to both interest rate risk and credit risk.[19]

[16] Deposit rate rigidities caused by differences in market concentration [Neumark and Sharpe (1992)].

[17] See Gelos (2006).

[18] See Ho and Saunders (1981).

[19] An increase in operating expenses leads to a rise in the marginal administrative cost of loans, which induces the bank to increase loan interest rates to compensate for the costs.

Saunders and Schumacher (2000) examined the bank margins in seven Organization for Economic Co-operation and Development (OECD) countries between 1988 and 1995 using the Ho and Saunders model. The authors found that the degree of monopoly and interest rate risk exposure had significant positive effects on the institutions' Net Interest Margin (NIM) and implicit interest payments had the largest positive effect amongst the other variables. The capital-to-asset ratio was also found to have a significant positive impact on the NIM. Saunders and Schumacher (2000) posited that equity capital reduces bank profitability and the bank seeks to compensate for this via a higher net interest margin.

The principles outlined in the Ho and Saunders and the Monti-Klein models have been used to examine bank spreads and the impact on lending activity and hence economic growth. Recent evidence indicates that financial intermediation is correlated with economic growth and is a causal factor of economic performance.[20] In this context, low levels of lending were found to be the main obstacle to growth and economic performance in Latin America.

Most empirical studies employ panel data regressions to simultaneously model spreads and margins for individual banks. For example, Gelos (2006) examined determinants of bank spreads using bank-level and country-level data from 85 countries, which included 14 Latin American economies. The low level of lending in this region was primarily attributed to the prevalence of large intermediation costs which have remained high by international standards.[21] It was found that in relation to their counterparts, the spreads in Latin America countries were to a large extent influenced by relatively higher interest rates, less efficient bank operation and larger reserve requirements. It was also noted that inflation and bank profit taxation had similar positive influences on bank spreads for all 85 countries.

Other studies on Latin American spreads focused on the importance of macroeconomic volatility as a determinant of the CFI. For example, Brock and Suarez (2000) examined the spreads of 7 Latin American countries in a panel framework and found that in

[20] See Laeven and Claessens (2004).
[21] See Gelos (2006).

addition to administration costs and reserve requirements, macroeconomic volatility appeared to have a positive influence on high spreads.

Brock and Franken (2002) examined a panel data set on interest margins and interest rate spreads in Chile between 1994 and 2001. This was the first attempt at using individual bank data on spreads and margins to investigate the factors that influence the CFI. A maximum likelihood estimation (MLE) framework, which accounts for fixed effects amongst individual institutions, was employed in the estimation process. For each measure of CFI, the authors used a dynamic panel model within a framework in which $0 < \lim \frac{N}{T} < \infty$; where N is the number of institutions and T is a fixed time period between 1994 and 2001.[22] Hahn and Kuersteiner (2002) showed that under this asymptotic constraint, the MLE of a dynamic panel data model with fixed-effects is consistent and asymptotically normal, albeit not centered at the true parameter value. To counter the latter, Hahn and Kuersteiner posited a bias-corrected estimator by examining the non-centrality parameter. To illustrate the MLE in a univariate model context, consider the equation:

$$y_{it} = \gamma y_{i,t-1} + \alpha_i + u_{it}$$

The bias-corrected estimator for the above equation is:

$$\hat{\hat{\theta}} = \left(\left(1 + \frac{1}{T} \right) \times \hat{\theta} \right) + \frac{1}{T}$$

where $\hat{\theta}$ is the MLE Fixed Effects estimator. Hanh and Kuersteiner also showed that $\hat{\theta}$ is asymptotically efficient.

Based on results of the panel regressions, Brock and Franken (2002) found that the impact of industry concentration, as well as business cycle and monetary policy variables on interest rate spreads and interest margins differed significantly. They concluded that caution should be taken in the interpretation of policy implications as it relates to the variables that had the largest differences in explanatory power. Brock and Franken (2003)

[22] In their study, N=27 and T=85.

found that macroeconomic volatility, bank size and concentration measures were significant determinants of interest rate spreads in Chile.

Other notable studies on bank spreads include Maudos and Guevara (2004). In this study, the authors account for banks' operating costs and use the Lerner Index[23] as a direct measure of the degree of competition.[24] Using a panel data set comprising five European Union countries, the authors concluded that operating costs and market power had positive effects while the quality of management had a negative effect on net interest margins. Park (2006) assessed the determinants of the CFI using Korean bank data between 1992 and 2004. It was found that unlike the theoretical expectation, bank size and bank concentration did not affect the CFI. However, bank size had become a critical influence (albeit ambiguous) on the CFI subsequent to the financial crisis in 1997.

III. A TREND ANALYSIS OF THE MEASURES OF COMMERCIAL BANKS' CFI IN JAMAICA: SEPTEMBER 1996 TO JUNE 2006

The trends in the Net Interest Margin (NIM) and Gross Interest Margin (GIM) for commercial banks virtually mirrored each other over the period September 1996 to June 2006. With respect to the interest rate spread, there was a trend decline between September 1996 and December 2000, followed by an upward trend between March 2001 and June 2006 (see Figure 1a).

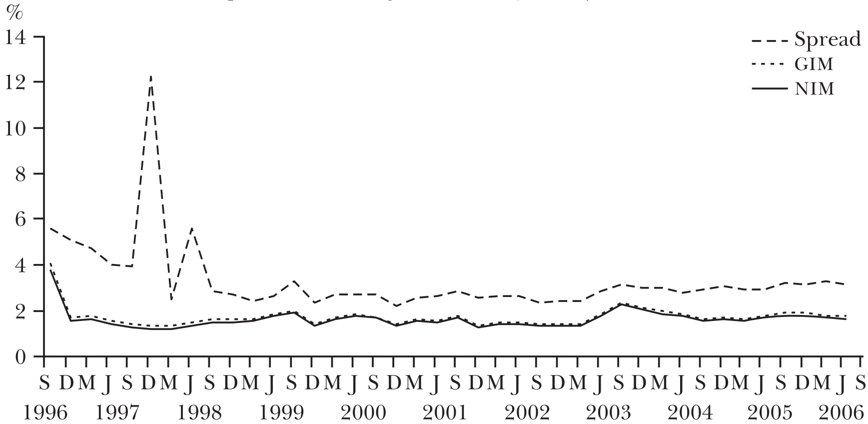
The most notable change in the spread during the review period was a sharp increase in the December 1997 quarter. This increase is attributed to the lagged effect of the Bank's change to an indirect monetary policy regime in early 1996, which contributed to deterioration in loan quality (see Figure 2).[25] The Bank's use of short-term securities to conduct open market operations facilitated a deepening of the domestic securities market. This resulted

[23] The Lerner Index measures a firm's market power directly as (price - marginal cost)/price. The Lerner index of a firm ranges from 0 to 1 with an index close to 0 representing low market power.

[24] See Lerner (1981).

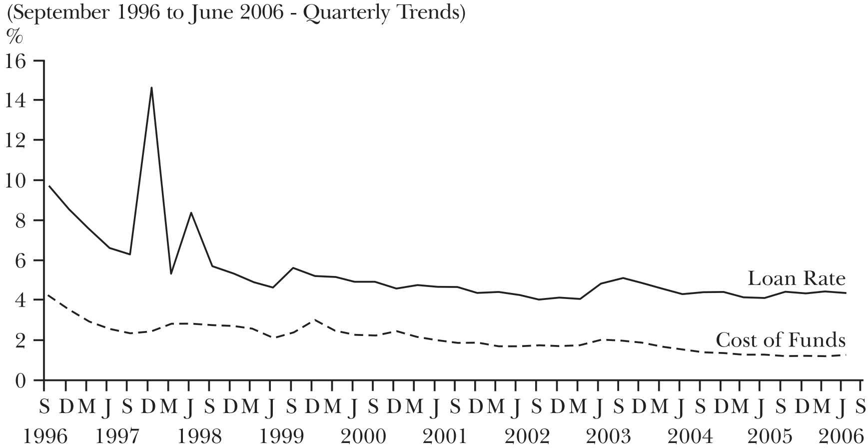
[25] Loan quality is measured by the ratio of Non-Performing Loans to Total Loans.

FIGURE 1a. MEASURES OF COMMERCIAL BANKS' COST OF FINANCIAL INTERMEDIATION (CFI) (September 1996 to June 2006 - Quarterly Trends)



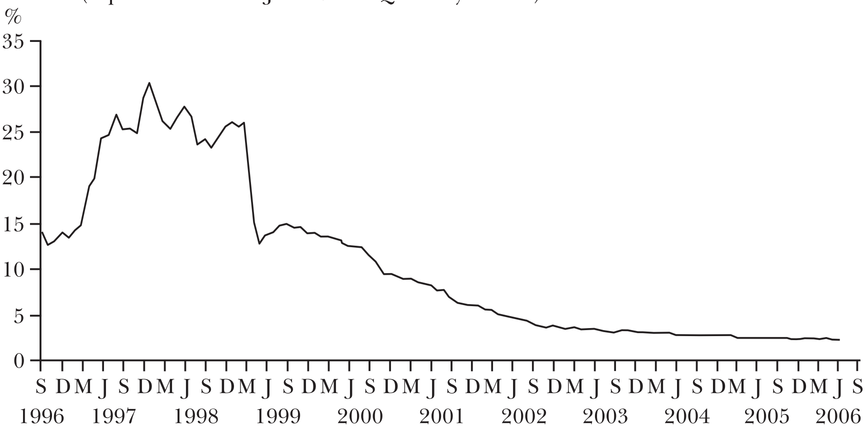
in increased levels of liquidity in the financial system, which coincided with an increase in loans to the non-productive sector, particularly other financial institutions. These other institutions were faced with significant liquidity constraints which adversely affected their ability to service loans. The increased delinquency in loan repayments led to consolidation in the banking system, as several institutions were forced to trade non-performing loan portfolios for Government securities. This process of consolidation translated into a gradual improvement in loan quality after December 1997 and largely explains the decline in commercial banks' loan rates in March 1998. The continued improvement in

FIGURE 1b. IMPLICIT RATE EARNED ON LOANS VS. COST OF SOURCES OF FUNDS (September 1996 to June 2006 - Quarterly Trends)



loan quality translated into a normalization of loan rates and hence bank spreads.

FIGURE 2. RATIO OF NON-PERFORMING LOANS TO TOTAL LOANS - COMMERCIAL BANKS (September 1996 to June 2006 - Quarterly Trends)



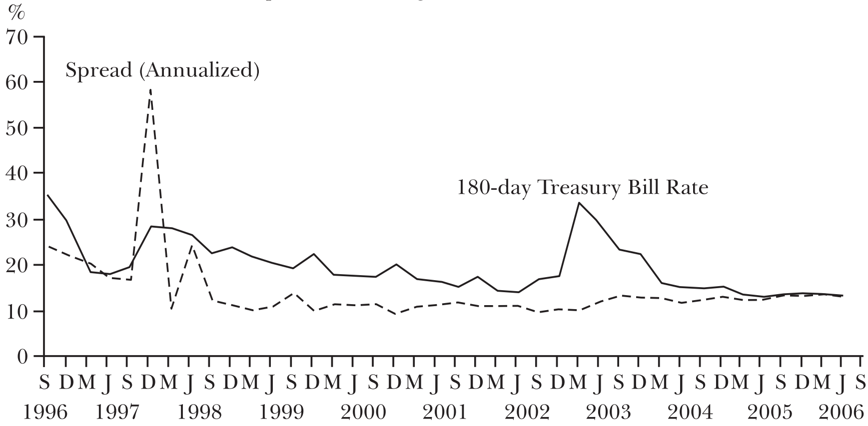
All three measures of the CFI exhibited notable increases between March 2003 and September 2003. The increase in bank spreads was largely reflected in the cost of loans. During this period, the banks maintained high loan rates given the Central Bank's commitment to preserve the value and integrity of the Jamaica Dollar (JMD) via a tightened monetary policy stance.[26] This was in a context where there was significant deterioration in foreign currency flows and other macroeconomic fundamentals during the March 2003 quarter, which spurred bouts of volatility in the foreign exchange market. The banks' maintenance of relatively high loan rates explains the slower rate of decline in bank spreads relative to interest rates (see Figure 3). Intensive marketing strategies of loan products influenced the maintenance of strong demand for bank loans despite the relatively high cost of loans.[27] The sustained demand for loans allowed banks to adjust loan rates at a slower pace relative to changes in domestic market interest rates. This could be attributed to oligopolistic tendencies in the banking sector.

The three measures of the CFI, particularly bank spreads remained

[26] The rate on the Bank's 365-day Open Market Operations (OMO) tenor instrument peaked at 35.95 per cent in March 2003.

[27] See 2004 BOJ Annual Report: Commercial Banks section, page 19.

FIGURE 3. COMMERCIAL BANKS' ANNUALIZED *EX POST* SPREAD VS. 180-DAY TENOR TREASURY BILL RATE (September 1996 to June 2006)



relatively high between September 2003 and June 2006, despite a decline in domestic interest rates.[28] During this period, there was a slower rate of reduction in bank spreads relative to the decline in domestic interest rates (see Figure 3). This was due to the banks' maintenance of high implicit loan rates, which was accompanied by a trend decline in the cost of the sources of funds (see Figure 1b). The integrity of the banking system was questioned in 2005 on market participants' concerns that the decline in bank spreads was not commensurate with the trend reduction in Central Bank interest rates.[29] It was therefore suggested that there were oligopolistic tendencies in the banking system, which compromised monetary policy and macroeconomic objectives.

IV. ECONOMETRIC METHODOLOGY

The econometric estimation of the CFI for each of Jamaica's six commercial banks adapted a similar procedure employed by Brock and Franken (2002). This approach was chosen given its superiority in estimating panel data models with a small number of cross-sectional data points relative to the number of time periods.

[28] The rate on the BOJ 180-day tenor repo fell to 12.80% at end June 2006 from 23.50% at end September 2003.

[29] See ⟨http://www.jftc.com/news&publications/Speeches/Reports/Banking_JMA_Public_Allegation_of_collusion_FINAL_2_08_06.pdf⟩.

In the case of Jamaica, the panel data model comprised 6 cross-sections (6 commercial banks) and 40 time periods (40 quarters). The approach includes an asymptotic constraint which ensures that the MLE of the dynamic panel data model with fixed-effects yields consistent and asymptotically efficient estimates.
The empirical specification of the dynamic panel data model is:

$$y_{it} = c + \alpha_i + \gamma_1 y_{i,t-1} + \beta' x_{it} + \beta_1' x_{i,t-1} + \beta_2' x_{i,t-2} + \beta_3' x_{i,t-3} + \phi' z_t + \phi_1' z_{t-1} + \phi_2' z_{t-2} + \phi_3' z_{t-3} + \delta_I d_{Y2K} + u_{it}$$

where:

– $i=1,\ldots\ldots N t=2,\ldots\ldots\ldots T$[30]

– u_{it} is i.i.d.

– y_{it} is the dependent variable (spread, net interest margin, gross interest margin)

– x_{it}, $x_{i,t-1}$, $x_{i,t-2}$, $x_{i,t-3}$ are vectors of bank-specific explanatory variables

– z_t, z_{t-1}, z_{t-2}, z_{t-3} are vectors of non-bank specific explanatory variables

– d_{Y2K} is a dummy variable that accounts for an increase in spreads during the December 1999 quarter.

– $[c, \alpha_i, \gamma_1, \beta, \beta_1, \beta_2, \beta_3, \varphi, \varphi_1, \varphi_2, \varphi_3, \delta_I]$ is a vector of parameters with α_i representing the fixed-effects.

Bank-specific and non-bank-specific variables were included with lags to account for delays in data availability to the public and to moderate endogeneity problems in estimation. Most of the empirical literature constrains γ_1 to be equal to zero. That is, the regression does not include a lagged dependent variable. The implicit assumption is that all regressors are strictly exogenous, which is crucial for consistency of the fixed-effects estimator.

The variables were first tested for the presence of unit roots to confirm stationarity. As suggested by Choi (2001), for small number of cross-sections, the Dickey Fuller GLS$^{\mu}$ test was best suited to conduct unit root tests. Secondly, a dynamic panel model with

[30] In this paper, N = 6, T = 39.

fixed effects was estimated in a maximum likelihood framework for the three measures of CFI in Jamaican commercial banks.[31] To obtain bias-corrected estimates of the parameter vector, the following procedure was incorporated in the estimation. Consider the following model:

$$y_{it} = c + \alpha_i + \gamma_1 y_{i,t-1} + \beta' x_{it} + u_{it}$$

where x_{it} is assumed to be strictly exogenous. Individual effects are first eliminated by subtracting individual means; i.e.

$$y_{it} - \overline{y_i} = \gamma_1 \left(y_{i,t-1} - \overline{y_{i-}} \right) + \beta \left(x_{it} - \overline{x_i} \right) + \left(u_{it} - \overline{u_i} \right)$$

where:

$$\overline{y_i} = \frac{\sum_{t=2}^{T} y_{it}}{(T-1)}, \quad \overline{y_{i-}} = \frac{\sum_{t=2}^{T} y_{i,t-1}}{(T-1)}, \text{ and } \overline{x_i} = \frac{\sum_{t=2}^{T} x_{it}}{(T-1)}$$

Secondly, the following three regressions were estimated: *i)* $y_{it} - \overline{y_i} = \theta_1 \left(x_{it} - \overline{x_i} \right)$ and call the residuals $\hat{y}_{it}$; *ii)* $y_{i,t-1} - \overline{y_{i-}} = \theta_2 \left(x_{it} - x_i \right)$ and call the residuals $\hat{y}_{i,t-1}$; *iii)* $\hat{y}_{it} = \gamma_1 \hat{y}_{i,t-1}$ to obtain the estimator $\hat{\gamma}_1$. The estimate, $\hat{\gamma}_1$, was then used to obtain a bias-corrected estimator of γ_1 as follows:

$$\hat{\hat{\gamma}}_1 = \left(1 + \frac{1}{T} \right) \hat{\gamma}_1 + \frac{1}{T}$$

Finally, a variable $z_{it} = y_{it} - \bar{y}_i - \hat{\hat{\gamma}}_1 \left(y_{i,t-1} - \bar{y}_{i-} \right)$ was defined and the following regression estimated:

$$z_{it} = \beta \left(x_{it} - \overline{x_i} \right)$$

to obtain the bias corrected estimate of β.

V. DATA

The three measures of the CFI reflect specific dimensions of commercial banks' operations. The NIM gives a measure of the rate earned on the core operations of the institutions, abstracting

[31] similar to that used in Hahn and Kuersteiner (2002).

from loan service charges. The GIM is a broader measure of the earnings on the banks' core operation, which incorporates service charges incurred as a result of the intermediation process. The *ex post* spread (hereafter called the spread) is the difference between the implicit rate earned on loans and the implicit cost of funds.[32] The reason for expanding the sources of funds available for banks to finance the acquisition of assets is that in recent years, borrowings and private repurchase agreements (repos) have become a significant component of commercial banks' source of funds (see Figure 4). The three measures of commercial banks' CFI are defined as:

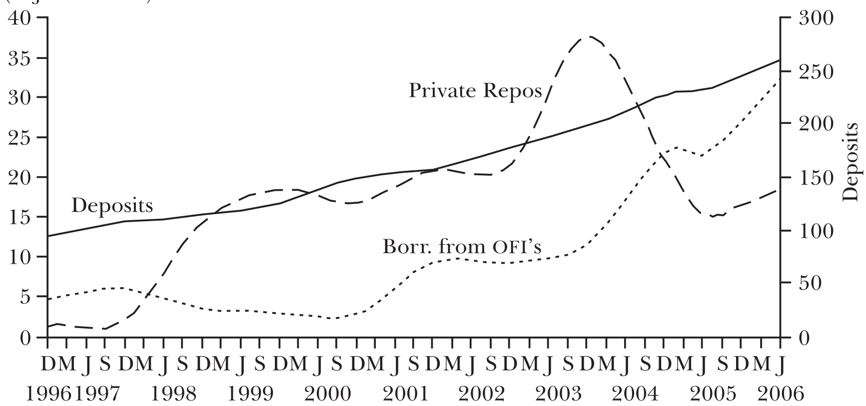
$$GIM = \frac{Total\ Interest\ Income - Total\ Interest\ Expenses}{Average\ Total\ Assets}$$

$$NIM = \frac{Total\ Interest\ Income - Total\ Interest\ Expenses - Loan\ Service\ Charges}{Average\ Total\ Assets}$$

$$ExpostSpread = \frac{Interest\ Income\ from\ Loans}{Average\ Stock\ of\ Loans} - \\ - \frac{Interest\ Expenses}{Average\ Stock\ of\ Sources\ of\ Funds}$$

These measures of commercial banks' CFI were computed using

FIGURE 4. COMMERCIAL BANKS' SOURCES OF FUNDING (December 1996 to June 2006) (in JMD Millions)



[32] Due to lack of data, there are almost no studies that use actual loan and deposit interest rate data by individual banks.

quarterly data from the institutions' balance sheets and income and expenditure statements.[33]

A summary of the explanatory variables used in the regressions are outlined in Table 1. The bank-specific variables include a proxy for the change in implicit interest payments and indicators similar to the well-known CAMELS ratings system.[34] Implicit payments, measured as overhead costs net of service charges, fees and commissions, was included to account for the net administrative costs incurred by the banks as a result of the intermediation

TABLE 1. DESCRIPTION OF VARIABLES USED IN PANEL REGRESSIONS

Variable	*Description*
Bank Characteristics :	
Implicit Payments	Implicit Payments[a]
C	Tier Capital divided by Risk-Weighted Assets (CAR)
A	Non-performing Loans divided by Gross Loans (NPLs)
E	Return on Equity
L	Outstanding Debt over Total Deposits
Aggregate risk :	
Inflation	Squared deviation between actual and targeted inflation
Exchange rate	Daily standard deviation of exchange rate per month
Industry Structure :	
Size	Assets of bank i over Total Assets of the banking system
Concentration	Inverse of Herschmann-Herfindahl Index[b]
Policy issues :	
Output gap	Deviation of GDP from its mean
Terms of Trade gap	Deviation of TOT from its mean
Slope of yield curve	Differential of long and short term Government of Jamaica (GOJ) instruments
Depreciation in REER	Quarterly depreciation in real effective exchange rate
Dummy	Accounts for increase in spread in December 1999 quarter

[a] Other operating expenses - service charges, fees and commissions. [b] The Herfindahl-Hirschman Index (HHI) attempts to rectify some of the drawbacks of concentration ratios by taking into account the number and market shares of all firms in the market. The HHI is calculated by summing the squared market shares of all firms in the market. See Duncan (2002) for derivation.

[33] The use of quarterly data in the analysis was due to the unavailability of income and expenditure data on a monthly basis.

[34] Data required to calculate the M (management efficiency) component of the CAMELS ratings for each bank was unavailable. The proxy for asset quality was the ratio of non-performing loans to total loans.

process. Implicit payments are unique to regressions with margins as the independent variable.[35] However, it was included in the regression involving the spread for the benefit of comparison across the three measures of the CFI.

The non-bank-specific variables included in the panel regressions were categorized into three sub-groups. Aggregate risk, which comprises proxies for inflation and exchange rate risks, was included to account for macroeconomic volatility. Industry Structure, which comprises each bank's asset share and a proxy for concentration within the banking sector, was included to capture the relative importance of each bank in the sector. Policy issues were captured using proxies for business cycle changes and monetary policy decisions. The output gap and terms of trade gap were used to capture changes in the business cycle. Monetary policy decisions were captured by the inclusion of the slope of the Government of Jamaica yield curve[36] and quarterly depreciation in the real effective exchange rate.[37]

VI. EMPIRICAL RESULTS[38]

The results of the MLE of the three measures of commercial banks' cost of financial intermediation are outlined in Table 2. The coefficient on each explanatory variable represents that variable's net influence on banks' net interest margin, gross interest margin and interest rate spreads. The net influence of each explanatory variable summarizes the responses of individual bank spreads and margins to changes in that particular explanatory variable. The variables contemplated were included with similar lags across the three measures of the CFI for comparability purposes.

Tests for unit roots revealed that all variables except implicit

[35] see Brock and Franken (2002).

[36] Spread between the yields on the 30 year GOJ LRS bond and the 30 day GOJ Treasury Bill.

[37] Captures losses in the degree of Jamaica's competitiveness in the export market, largely as a result of relative movements in exchange rates within Jamaica and its major trading partners.

[38] Panel Regression Method: Bias Corrected Fixed effects, GLS-Weighted, White Heteroskedasticity Consistent-Robust Covariance Matrix.

payments (Imp) were found to be stationary. The signs on the coefficients of all explanatory variables were broadly in line with expectations and had similar influences across the three measures of the CFI for individual banks.

TABLE 2. RESULTS OF PANEL REGRESSIONS[a]

	NIM	*GIM*	*Spread*
Bank Specific Variables			
chgImp	0.2220	-0.4880[b]	-0.0858
chgImp(-1)	0.9583[c]	-0.4360[d]	-0.1479
chgImp(-2)	0.9419[b]	-0.1531	-0.1926
chgImp(-4)	0.5836[c]	0.0697	-0.1129
C	2.0600[c]	0.9470[b]	0.9930[c]
C(-2)	1.2300	-1.0400[c]	-0.9640[d]
C(-4)	1.8400[c]	0.1180[b]	-0.2543
A	-12.2300[b]	-5.5900[b]	-3.7000[b]
A(-1)	-2.1100	-2.0600[d]	-3.4800[c]
A(-2)	2.5300	2.5100[c]	0.2121
A(-3)	-7.3100[b]	-2.8500[c]	-0.6315
E	1.7500	-9.0300[b]	0.5446
E(-1)	-5.9800[b]	-2.4900[b]	-0.4949
E(-2)	-15.7100[b]	-4.6300[b]	0.4035
L	-7.1100[b]	-2.0700[b]	-0.6773
L(-4)	2.9100[b]	1.7000[b]	0.6622[d]
log(Size)	-1.1600	-0.7570[c]	-0.0777
log(size)(-2)	0.1335	-0.0835	-0.3990
log(size)(-3)	-2.6600[b]	-1.3900[b]	-0.1213
log(size)(-4)	-0.3960	0.3787	-0.3237
Non Bank-Specific Variables	0.0000	0.0000	0.0000
Inflation uncert.	-0.0176	-0.0205	-0.0050
Inflation uncert.(-1)	-0.0060	0.0018	0.0013
Inflation uncert.(-2)	-0.0025	0.0094	-0.0157
Inflation uncert.(-3)	0.0404	0.0114	0.0024
Exchange Rate Vol	1.3600	0.7328[d]	-0.1567
Exchange Rate Vol(-3)	1.1100	1.1400[c]	0.7529[d]
Conc	1.7100	1.4100	0.6225
Conc(-3)	2.4400	1.0800	3.3300[b]
OutputGAP	-0.0002[d]	-0.0001	-0.0001
OutputGAP(-3)	3.877E-05	0.00000	0.00000
TOTGap	-0.001404	-0.00008	-0.00008
TOTGap(-2)	-0.04292	-0.00002	0.00003
TOTGap(-3)	0.02987	-0.00007	0.00001

(continue)

TABLE 2 *(conclusion)*

	NIM	*GIM*	*Spread*
Slope of Yield Curve	1.85	-0.00416	-0.01350
Slope of Yield Curve(-1)	-1.86	-0.00329	0.01870
REER Dep	0.037836	0.00013	-0.01220
REER Dep(-1)	-0.042009	-0.00039	-0.00002
REER Dep(-4)	-0.017726	-0.00037	-0.00021
Dummy	-0.51681 0	-0.00283	-0.00730
Adjusted R^2	0.76503	0.8180	0.5521
No. of Time Series	40	40	40
No. of Cross Sections	6	6	6
Total Observations	204	204	210

[a] See Appendix A for details of diagnostic tests. [b] At 1% of significance level. [c] At 5% of significance level. [d] At 10% of significance level.

From a regulatory perspective, two offsetting effects of capital requirements were evident in the regressions. On the one hand, an increase in the CAR (via capital) had a positive influence on bank spreads and margins, given the higher average cost of funds, relative to deposits and borrowings that would result from the increase in capital.[39] On the other hand, a build up in capital reduces the exposure to insolvency risk and hence increases lending capacity. The higher lending capacity increases the level of competition for prospective borrowers, which reduces bank spreads and margins. In a competitive banking sector, this negative effect would outweigh the positive influence. This is because a higher lending capacity increases the level of competition amongst individual institutions resulting in lower spreads. The regression results for the NIM indicated no negative influences, suggesting evidence of oligopolistic tendencies.

In a competitive banking structure, the cost of financial intermediation would be affected by an improvement in asset quality, which is measured as a decrease in the ratio of non-performing to total loans.[40] It is expected that any deterioration in asset quality

[39] Capital may also be used to finance the acquisition of assets, in extreme circumstances.

[40] Asset quality measures the risk exposure of a bank's loan portfolio and is also an ex post proxy for default risk. That is, an improvement in asset quality

(higher exposure to default risk), results in an increase in the compensation premium charged by banks, which would then be reflected in their margins and spreads. Similarly, any improvement in asset quality results in a decrease in the compensation premium charged by banks, which would translate into lower margins and spreads. However, the regression results revealed that a decrease in the ratio of non-performing loans to total loans had a positive influence on all three measures of the CFI. This deviation from expectations suggests evidence of oligopolistic tendencies, in a context where banks were intent on maintaining high spreads despite the sustained improvement in asset quality since 1997 (see Figure 2).

Consistent with expectations, bank size had a negative influence on the NIM and GIM. This was due to the fact that larger banks have the ability to exploit economies of scale, earn relatively lower interest margins and pass on a higher portion of overhead costs to customers. There were offsetting influences of bank liquidity (measured as the ratio of total loans outstanding to total deposits) on the measures of CFI. It is expected that an increase in loans relative to deposits would warrant a contemporaneous increase in deposits, as banks seek to contain the maturity and interest rate gaps between interest sensitive assets and interest sensitive liabilities.

The narrowing of these gaps ensures the containment of exposure to liquidity and interest rate risks. As banks compete for additional deposits, they would be inclined to pay customers more in an attempt to secure financing for the new loans. Therefore, interest expenses would rise and the three measures of the CFI would decline. The regressions revealed that bank liquidity had a negative influence on the NIM and GIM, which was consistent with expectation. However, the regressions also revealed that an increase in bank liquidity, four quarters before the current period, had a positive influence on the three measures of the CFI. This deviation from expectations suggests evidence of oligopolistic tendencies, in that banks which were unable to source deposits (or borrowings) to finance the contemporaneous increase in loans, were forced to use higher-cost capital, which translated into larger spreads.

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implies reduced exposure to default risk.

With respect to non-bank-specific variables, exchange rate volatility and inflation uncertainty were the variables used to capture the banks' exposure to macroeconomic risks. Exchange rate volatility had a positive influence on the GIM and spread. This positive influence is consistent with expectations, as banks will require increased premia as exposure to risk becomes higher. The regression results revealed no influence of inflation risk on the CFI. Concentration in the banking sector, measured by the inverse of the Herfindahl-Hirschman index, had a positive influence on the individual bank spreads. This positive influence is consistent with the Structure Performance Hypothesis, which claims that a more concentrated banking sector will exhibit oligopolistic tendencies.

In terms of the impact of policy decisions on the measures of the CFI, it is assumed that a positive output gap reflects a positive demand-driven shock and a positive terms of trade gap reflects a positive supply-driven shock. The estimation results revealed no significant influence of supply-driven shocks and that demand-driven shocks had a positive but negligible influence on the NIM. With respect to monetary policy decisions, an increasing yield curve slope[41] indicates the expectation of tighter monetary policy. Therefore, in a competitive banking sector, any easing of policy via a reduction in rates should translate into a commensurate fall in loan rates. However, an increase in the slope of the Government of Jamaica yield curve had no influence on the three measures of CFI. This suggests oligopolistic tendencies in the banking system.

The analysis was extended to determine if the relationship between bank spreads and the explanatory variables was driven by the major components of the spread. In this context, a mathematical decomposition of the spread was conducted in order to determine how aspects of banking operations contributed to the levels of the spread for each bank.[42] This decomposition revealed that administration costs and gross profits were the main contributors to the levels of the spread. Having determined the main components of bank spreads, panel regressions were estimated using administration costs and gross profits as the independent

[41] An increase in the slope is the result of faster increase in the return on long-term relative to short-term securities.

[42] The methodology for decomposition is adapted from an unpublished research paper by the author of this paper.

variables. The results showed that these components were largely explained by bank-specific variables, thereby validating the previous evidence of oligopolistic tendencies in the banking system (see Appendix B).

The panel regression analysis also examined whether the relationship between bank spreads and the explanatory variables was driven by large banks vis-à-vis small banks.[43] This was done by re-estimating the model using the spreads of the large banks and small banks separately. Results of each model showed that the statistically significant explanatory variables comprised both bank-specific and non-bank-specific variables (see Appendix C). This was evidence that the lack of responsiveness of commercial bank spreads to non-bank-specific-variables was characteristic of the banking sector as a whole and was not driven by any of the sub-groups of banks considered.

VII. CONCLUSION

The underlying purpose of this paper was to determine the relative importance of bank-specific and non-bank-specific variables in explaining bank spreads and margins, with a view to determine the level of competitiveness in the banking system. It was found that the cost of financial intermediation was primarily influenced by bank-specific variables and that the influences of capital adequacy, asset quality and liquidity contravened competitive market expectations. With respect to non-bank-specific variables, only the output gap and exchange rate volatility had statistically significant influences on the NIM and GIM, respectively. Additionally, concentration and exchange rate volatility had statistically significant influences on bank spread. The lack of responsiveness of the CFI to other non-bank-specific variables corroborates the claim of low competition and hence oligopolistic tendencies in the Jamaican commercial banking sector. The findings of the analysis support recent empirical evidence of declining competition in the banking system.[44] An extension of the regression analysis revealed

[43] Large banks were defined as banks that accounted for at least 14% of total banking sector assets, on average, over the sample period.

[44] See Duncan (2002).

that the relationship between bank spreads and the explanatory variables was not driven by any sub-group of banks. Another simulation of the model showed that the lack of responsiveness of bank spreads to non-bank-specific-variables was also evidenced in the major components of bank spreads. This suggests evidence of low competition and hence oligopolistic tendencies in the Jamaican commercial banking sector. The results also support recent empirical evidence of declining competition in the Jamaican banking system.

Appendix A

SUMMARY OF DIAGNOSTIC TESTS OF PANEL REGRESSIONS

	NIM	*GIM*	*Spread*
Log Likelihood	606.73768	767.91352	-239.22964
Standard error	0.0311742	0.0063545	0.85447
Chi-Squared(5) – Test for equal variance of residuals	70.976266 (0.000000)	58.145518 (0.000000)	18.599015 (0.00228220)
F-statistic	16.0219	21.7323	6.2773

NIM: ANALYSIS OF VARIANCE FOR RESIDUALS

Source	*Sum of Squares*	*Degrees*	*Mean Square*	*F-Statistic*	*Signif*
Time	0.0019485470963	34	0.0000590468817	0.3435	0.9997126
Error	0.0292256142909	170	0.0001719153782		
Total	0.0311741613871	204			

GIM: ANALYSIS OF VARIANCE FOR RESIDUALS

Source	*Sum of Squares*	*Degrees*	*Mean Square*	*F-Statistic*	*Signif*
Time	0.0004747610452	34	0.0000143866983	0.4114	0.9982054
Error	0.0059453427097	170	0.0000349726042		
Total	0.0064201037548	204			

SPREAD: ANALYSIS OF VARIANCE FOR RESIDUALS

Source	*Sum of Squares*	*Degrees*	*Mean Square*	*F-Statistic*	*Signif*
Time	2.78189754104	34	0.08429992549	0.1176	1.0000000
Error	121.88327708607	170	0.71696045345		
Total	124.66517462711	204			

Appendix B

RESULTS OF PANEL REGRESSIONS OF THE MAJOR COMPONENTS OF THE SPREAD

	Admin Costs	*Gross Profits*
Bank Specific Variables		
chgImp	0.3049[a]	-1.3714[a]
chgImp(-1)	0.2729[a]	-1.3233[a]
chgImp(-2)	0.1196	-0.5636[b]
chgImp(-4)	0.0604	0.1195
C	0.2906[b]	1.2630[b]
C(-2)	-0.5778[b]	-1.2623[c]
C(-4)	0.1831	1.2818[b]
A	0.5465	-6.3036[a]
A(-1)	-0.3905	-3.4551[b]
A(-2)	-0.3904	2.6278
A(-3)	-0.4711	-1.9565
E	0.0811	-9.9263[a]
E(-1)	0.6922[c]	-2.7875[b]
E(-2)	-0.0064[a]	-3.2663[a]
L	0.6597[a]	-3.1728[a]
L(-4)	-0.2010	1.6619[a]
log(Size)	-0.9733[a]	0.1940
log(size)(-2)	-0.3837	0.0961
log(size)(-3)	0.3410	-1.9929[b]
log(size)(-4)	0.3688	0.1055
Non Bank-Specific Variables		
Inflation uncert.	-0.0202	-0.0211
Inflation uncert.(-1)	0.0036	0.0080
Inflation uncert.(-2)	0.0013	0.0382
Inflation uncert.(-3)	0.0115	0.0097
Exchange Rate Vol	0.1689	0.9243
Exchange Rate Vol(-3)	-0.0355	0.5227
Conc	-0.2019	1.1902
Conc(-3)	0.1364	-0.5526
OutputGAP	0.0000	0.0000
OutputGAP(-3)	0.0000	0.00004
TOTGap	0.00162	-0.01209
TOTGap(-2)	-0.01038	0.02510
TOTGap(-3)	0.01460	-0.01415
Slope of Yield Curve	-0.71521[c]	0.04571
Slope of Yield Curve(-3)	0.76091	0.22475

REER Dep	0.01336	-0.03644
REER Dep(-1)	0.01030	-0.03957
REER Dep(-4)	-0.00037	-0.04794
Adjusted R^2	0.7193	0.7832
No. of Time Series	40	40
No. of Cross Sections	6	6
Total Observations	204	204

[a] At 1% of significance level. [b] At 5% of significance level. [c] At 10% of significance level.

Appendix C

RESULTS OF PANEL REGRESSIONS OF THE SPREAD OF LARGE AND SMALL BANKS

	Spread	
	Small Banks	*Large Banks*
Bank Specific Variables		
chgImp	0.0017	-0.0218
chgImp(-1)	-0.0033	-0.3216
chgImp(-2)	-0.1757	-0.3535
chgImp(-4)	-0.1712	0.2681
C	-0.0358	0.5519
C(-2)	-4.2892[a]	-1.0273[c]
C(-4)	-1.5626	0.1260
A	-0.3091	4.2745
A(-1)	-0.3010	-17.2455[a]
A(-2)	1.1284	3.2179
A(-3)	-0.1232	-1.5689
E	16.7632[c]	-0.0884
E(-1)	3.1410	-1.2278
E(-2)	7.4487	-0.3741
L	0.1823	-0.1174
L(-4)	-0.1002	0.3548
log(Size)	0.7103	1.1013
log(size)(-2)	0.1421	-1.6658
log(size)(-3)	-0.4428	-0.9627
log(size)(-4)	1.1761	3.9886[b]
Non Bank-Specific Variables		

Inflation uncert.	-0.0202	-0.0211
Inflation uncert.(-1)	0.0036	0.0080
Inflation uncert.(-2)	0.0013	0.0382
Inflation uncert.(-3)	0.0115	0.0097
Exchange Rate Vol	-0.2240	-0.9441
Exchange Rate Vol(-3)	2.3612[c]	-0.6438
Conc	-1.5360	-2.1793
Conc(-3)	3.7189[a]	3.3151[a]
OutputGAP	0.0000	-0.0001
OutputGAP(-3)	-0.0001	-0.00021[b]
TOTGap	0.02063	-0.03228
TOTGap(-2)	0.02145	-0.04445[c]
TOTGap(-3)	0.05588[c]	0.05615[c]
Slope of Yield Curve	-1.29167	-0.89336
Slope of Yield Curve(-1)	2.90553	4.00264[b]
REER Dep	0.04280	0.02440
REER Dep(-1)	0.05520	-0.02646
REER Dep(-4)	0.02082	0.06104
Adjusted R^2	0.6417	0.7800
No. of Time Series	40	40
No. of Cross Sections	3	3
Total Observations	102	102

[a] At 1% of significance level. [b] At 5% of significance level. [c] At 10% of significance level.

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Guillermo Vuletin

What is the size of the pie? Measuring the informal economy in Latin America and the Caribbean

I. INTRODUCTION

The measurement of the size of the informal economy has evoked considerable interest in both academic environments and policy circles, especially given its importance for emerging markets and developing countries. At the same time, measuring the informal economy is not an easy task. The biggest challenge arises from the lack of a clear definition of the informal economy. A wide range of similar terms are used in the literature such as hidden economy, shadow economy, clandestine economy, parallel economy,

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subterranean economy, unreported economy, cash economy and black economy. However, as a result of recent comprehensive publications and handbooks, there seems to exist some level of consensus regarding some terms. Following Feige (2005):

- The *illegal economy* consists of the income produced by those economic activities pursued in violation of legal statutes defining the scope of legitimate forms of commerce.
- The *unreported economy* consists of those legal and illegal economic activities that evade fiscal rules as codified in the tax laws.
- The *informal economy* comprises those economic activities that circumvent the costs and are excluded from the benefits and rights incorporated in the laws and administrative rules covering property relationships, commercial licensing, labor contracts, torts, financial credit and social systems. A summary measure of the informal economy is the income generated by economic agents who operate informally. Similarly, Portes et al. (1989) defines the informal economy as "a process of income-generation characterized by one central feature: it is unregulated by the institutions of society, in a legal and social environment in which similar activities are regulated".

Measuring the size of the informal economy is important for many reasons. First, there seems to be strong evidence that suggests a direct and clear link between the size of the informal economy and tax evasion. Table 1 shows, by using data for the early 90s from Schneider and Enste (2000) and Silvani and Brondolo (1993), that there is a clear positive relationship between these two concepts. As extreme cases, countries like Bolivia, which had an informal economy share of approximately 65 percent, experienced VAT tax evasion of about 45 percent; while countries like New Zealand, which had a low share of informal activity, around 12 percent, had a much lower level of tax evasion, close to 5 percent. Second, the informal economy, as a job provider, has an impact on the viability of social security institutions, specifically in terms of the latter's ability to provide protection while receiving enough financial support. For example, in the early 90s, while 94 percent of the labor force contributed to the social security system in Netherlands, this percentage was only 19 for Honduras.[1] Third, inaccurate perceptions about the actual size of the economy could seriously decrease the effectiveness of a wide variety of policies.

TABLE 1. SIZE OF THE INFORMAL ECONOMY AND VAT TAX EVASION

	Informal economy, early 90s (%)	*VAT tax evasion, early 90s (%)*
New Zealand	12	5
Sweden	16	6
Argentina	21	30
Honduras	47	35
Bolivia	66	44

SOURCES: Schneider and Enste (2000) and Silvani and Brondolo (1993).

This paper estimates the size of the informal economy and the relative contribution of each underlying factor in the ECCU and 26 mainly Latin American countries in the "early 2000s", being the first study to address this issue for the Eastern Caribbean Currency Union (ECCU) economies and many other Central American and Caribbean countries. For this purpose, a structural equation model approach that considers the informal economy as a latent variable with multiple causes and indicators is used. This approach surpasses typical limitations of some commonly used time series methods because, among other reasons, it does not require information regarding the absolute value of the informal economy for *each* country at some point in time to pin down the evolution of the informal economy over time. On the contrary, this cross section approach needs this information for *only one country* in the sample. This method also allows the exclusive use of *real* variables, as opposed to *monetary* ones, which might underestimate and misrepresent the relevance of the informal economy in countries subject to high degree of dollarization in circulating currency.

We find that a stringent tax system and regulatory environment, higher inflation, dominance of the agriculture sector, and weakness in governance are the key factors underlying the informal economy. The evidence obtained also confirms that a higher degree of informality reduces labor unionization, the

[1] Based on information from Forteza and Rama (2001).

number of contributors to social security schemes and enrolment rates in intermediate education.

The size of the informal economy varies considerably from around 16 percent of total GDP for Bahamas to 70 percent for Paraguay. Notwithstanding, the average size of the informal economy for the ECCU and Caribbean countries (around 33 percent of GDP) is lower than for Latin American economies (average of 43 percent of GDP).

The relative contribution of each underlying factor to the overall size of the informal economy is also estimated for each country. For some countries like Antigua and Barbuda, Barbados and Trinidad and Tobago, the key element is tax burden. For example, for the period under consideration, Antigua and Barbuda had the highest marginal corporate and personal tax rates of 55 and 35 percent respectively. For others like St. Vincent and the Grenadines, St. Lucia and Belize, the importance of the agriculture sector appears to be decisive, with around 75 percent of exports concentrated in agriculture and food products. For other countries like Paraguay and the Dominican Republic, labor rigidities are some of the most important factors, with minimum wages representing 170 percent and 90 percent of the corresponding GDP per capita.

The paper is organized as follows. The next section reviews the different methods used by the literature to estimate the size of the informal economy. It also carefully explains the *Multiple Indicators, Multiple Causes* (MIMIC) approach, which is the econometric method used in this study. Section III presents the set of countries and variables used in the analysis. The empirical results are discussed in Section IV, and Section V contains some concluding remarks.

II. METHODS FOR MEASURING THE SIZE OF THE INFORMAL ECONOMY

Many alternative methods have been used to measure the size of the informal economy.[2] Some approaches use direct methods

[2] A thorough review of these approaches is discussed in Schneider and Enste (2000) and the OECD handbook "Measuring the Non-Observed Economy"

based on surveys, but most studies use indirect methods based on: *i)* the discrepancy between national expenditure and income statistics; *ii)* the discrepancy between the official and actual labor force; *iii)* the *electricity approach* of Kauffman and Kaliberda (1996); *iv)* the monetary *transaction approach* of Feige (1979); *v)* the *currency demand* approach of Cagan (1958) and others; and *vi)* the Multiple Indicators, Multiple Causes (MIMIC) approach. A brief description of each methodology, as well as a detailed explanation of the MIMIC approach, is provided below.

Surveys:[3] These micro approaches use surveys and samples based on voluntary replies, or tax auditing and other compliance methods to measure the informal economy. While providing great detail about the structure of the informal economy, the results are sensitive to the way the questionnaire is formulated and the respondents' willingness to cooperate. Therefore surveys are unlikely to capture all informal activities.

Discrepancy between national expenditure and income statistics:[4] If those working in the informal economy were be able hide their incomes for tax purposes but not their expenditure; the difference between national income and national expenditure estimates could be used to approximate the size of the informal economy. If all the components of the expenditure side were measured without error and were constructed so that they were statistically independent from income factors, then this approach would indeed yield a good estimate of the size of the informal economy. Unfortunately this gap also reflects other types of omissions and errors and several expenditure estimates are based on income calculations; thus the reliability of this method is seriously arguable.

Discrepancy between official and actual labor force:[5] If the total labor force participation is assumed to be constant, a decline in official labor force participation can be interpreted as an increase in the importance of the informal economy. Since movements in the participation rate might have many other explanations, such as the position in the business cycle, difficulty in finding a job and

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released in 2002.

[3] See for example Isanchen and Strom (1985), Witte (1987), Mogensen et al. (1995), Ivan-Ungureanu and Pop (1996) and Feige (2005).

[4] See for example MacAfee (1980) and Yoo and Hyun (1998).

[5] See for example Contini (1981), Del Boca (1981) and O'Neil (1983).

education and retirement decisions, these estimates represent weak indicators of the size of the informal economy.

Electricity approach:[6] Kaufmann and Kaliberda (1996) endorse the idea that electricity consumption is the single best physical indicator of overall (official and unofficial) economic activity. Using some findings that the electricity-overall GDP elasticity is close to one[7], these authors suggest using the difference between growth of electricity consumption and growth of official GDP as a proxy for the growth of the informal economy. This method is simple and appealing, but has many drawbacks, including: *i)* not all informal economy activities require a considerable amount of electricity (e.g. personal services) or use other energy sources (like coal, gas, etc.), hence only part of the informal economy growth is captured; and *ii)* the electricity-overall GDP elasticity might significantly vary across countries and over time.

Transaction approach:[8] Using Fischer's quantity equation, *Money Velocity = Prices·Transactions*, and assuming that there is a constant relationship between the money flows related to transactions and the total (official and unofficial) value added, i.e. *Prices Transactions = k (official GDP + informal economy)*, it is straightforward to obtain the following equation *Money Velocity = k (official GDP + informal economy)* . The stock of money and official GDP estimates are known and money velocity can be estimated. Thus, if the size of the informal economy as a ratio of the official economy is assumed to be known for a benchmark year, then the informal economy can be calculated for the rest of the sample. Although theoretically attractive, this method has several weaknesses; for instance: *i)* the assumption of *k* constant over time seems quite arbitrary; and *ii)* other factors like the development of checks and credit cards could also affect the desired amount of cash holdings and thus velocity.

Currency demand approach:[9] Assuming that informal transactions take the form of cash payments, in order not to leave an observable

[6] See for example Del Boca and Forte (1982), Portes (1996) and Johnson et al. (1997).

[7] See Dobozi and Pohl (1995).

[8] See for example Feige (1979), Boeschoten and Fase (1984) and Langfeldt (1984).

[9] See for example Cagan (1958), Gutmann (1977), Tanzi (1980, 1983), Scheneider (1997) Johnson et al. (1998).

trace for the authorities, an increase in the size of the informal economy will, consequently, increase the demand for currency. To isolate this resulting "excess" demand for currency, Tanzi (1980) suggests to use a time series approach in which currency demand is a function of conventional factors, such as the evolution of income, payment practices and interest rates, and factors causing people to work in the informal economy, like the direct and indirect tax burden, government regulation and the complexity of the tax system. The size and evolution of the informal economy can be calculated by following two steps. First, the difference between the evolution of currency when government regulations and the direct and indirect tax burden are held at their lowest value and the development of currency with the current (higher) burden of taxation and government regulations is calculated. Secondly, assuming the same income velocity for currency used in the informal economy as for legal money in the official economy, the size of the informal economy can then be computed and compared to the official GDP. However there are several problems associated with this method and its assumptions: *i)* this procedure may underestimate the size of the informal economy, because not all transactions take place using cash as means of exchange; *ii)* at least in the United States, increases in currency demand deposits seem to occur mainly because of a slowdown in demand deposits rather than an increase in currency used in informal activities; *iii)* it seems extremely arbitrary to assume equal velocity of money in both types of economies and; *iv)* the assumption of no informal economy in a base year is open to criticism.

Multiple Indicators, Multiple Causes (MIMIC) approach:[10] All methods described above consider only one indicator or manifestation of the informal economy (e.g. electricity consumption, money or cash demand). However, there exist several manifestations or symptoms showing up simultaneously. The MIMIC approach explicitly considers several causes, as well as the multiple effects of the informal economy. The methodology makes use of the associations between the observable causes and the observable effects of an unobserved variable, in this case the informal economy, to estimate the unobserved factor itself. The model for one latent variable can be described as follows:

[10] See for example Giles (1999) and Loayza (1997).

$$y = \lambda\, IE + \varepsilon \tag{1}$$

$$IE = \gamma' x + \upsilon \tag{2}$$

where, IE is the unobservable scalar latent variable (the size of the informal economy), $y' = (y_1, ..., y_p)$ is a vector of indicators for IE, $x' = (x_1, ..., x_q)$ is a vector of causes of IE, λ and γ are the (px1) and (qx1) vectors of the parameters and ε and υ are the (px1) and scalar errors. In other words, equation (1) links the informal economy with its indicators or symptoms, while equation (2) associates the informal economy with its causes. Assuming that these errors are normally distributed and mutually uncorrelated with $\mathrm{var}(\upsilon) = \sigma_\upsilon^2$ and $\mathrm{cov}(\varepsilon) = \Theta_\varepsilon$, the model can be solved for the reduced form as a function of observable variables by combining equations (1) and (2):

$$y = \pi\, x + \mu \tag{3}$$

where $\pi = \lambda\,\gamma'$, $\mu = \lambda\,\upsilon + \varepsilon$ and $\mathrm{cov}(\mu) = \lambda\,\lambda'\ \sigma_\upsilon^2 + \Theta_\varepsilon$.

Because *y* and *x* are observable data vectors, equation (3) can be estimated by maximum likelihood estimation using the restrictions implied in both the coefficient matrix π and the covariance matrix of the error μ. Since the reduced form parameters of equation (3) remain unaltered when λ is multiplied by a scalar and γ and σ_υ^2 are divided by the same scalar, the estimation of (1) and (2) requires a normalization of the parameters in (1), and a convenient way to achieve this is to constrain one element of λ to some pre-assigned value.

Since the estimation of λ and γ is obtained by constraining one element of λ to some arbitrary value, it is useful to standardize the regression coefficients $\hat{\lambda}$ and $\hat{\gamma}$ as follows:

$$\hat{\lambda}^s = \hat{\lambda}\left(\frac{\hat{\sigma}_{IE}}{\hat{\sigma}_y}\right) \qquad \hat{\gamma}^s = \hat{\gamma}\left(\frac{\hat{\sigma}_x}{\hat{\sigma}_{IE}}\right)$$

The standardized coefficient measures the expected change in the standard-deviation units of the dependent variable due to a one standard-deviation change of the given explanatory variable when the other variables are held constant. Using the estimates of the γ^s vector and setting the error term υ to its mean value of zero, the predicted *ordinal* values for the informal economy (IE)

can be estimated by using equation (2). Then, by using information regarding the specific value of informal activity for some country (if it is a cross country study) or for some point in time (if it is a time series study), obtained from some other source, the within-sample predictions for *IE* can be converted into *absolute* series.

The MIMIC approach is chosen as the most appropriate method to calculate the size of the informal economy for this sample of countries because of the following reasons:

- Tax auditing and other similar survey based methods are unavailable for most Caribbean countries in the sample.
- The methods based on statistical and labor force discrepancies present, as described before, serious limitations and weaknesses.
- Aside from above mentioned critiques, the electricity, transaction and currency demand approaches share a common crucial limitation. Since the three approaches are based on time series regressions, extra information[11] for *each country* is required in order to pin down the absolute size of the informal economy. Without this extra knowledge, the most one can learn is the growth pattern of the informal economy. While for some countries like Argentina, Mexico and Chile this extra information is possible to obtain, for the ECCU countries and other Caribbean countries there is no such data. On the contrary, the proposed cross section MIMIC approach requires extra information regarding the absolute size of the informal economy for *only one country* in the sample.

This paper only focuses on *real* cause and indicator variables, as opposed to *monetary* ones, which might underestimate and misrepresent the relevance of the informal economy in countries subject to a high degree of dollarization in circulating currency.[12]

[11] This extra information could be obtained either by knowing the absolute value of the informal economy for a certain year or by assuming a base year without informal economy.

[12] There exist the presumption and some concrete evidence based on Feige et al. (2001, 2002) and Feige (2003, 2005) that dollarization in circulating currency is a relevant issue for both low inflation and non crisis countries like the ECCU, because of tourism and currency substitution issues, and for typically high

This occurs because although monetary data is easily obtained for local currency, data is not available for foreign currency circulating. In this sense, the present study follows closely the study conducted by Loayza (1997) who estimates the size of the informal economy for 14 Latin American countries for the early 90s using real variables.[13]

III. DATA

The cross section study considers the ECCU countries and 26 mainly Latin American countries for the early 2000s.[14] The countries included are: Antigua and Barbuda, Argentina, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Cyprus, Dominica, Dominican Republic, Ecuador, El Salvador, Fiji, Grenada, Guatemala, Guyana, Honduras, Jamaica, Malta, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, The Bahamas, Trinidad and Tobago, Uruguay and Venezuela. The cause and indicator variables considered, and their expected relationship with the size of the informal economy, are presented below.[15]

1. Cause variables

First, the *tax burden* is proxied by the average of corporate and personal marginal income tax rate. The highest rate is used when there is more than one rate. The hypothesis is that an increase of the tax burden boosts the incentive to work in the informal economy.

Second, increases in legal restrictions on the labor market are hypothesized to increase the size of the informal economy. *Labor rigidities* are captured by two alternative indices:[16]

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inflation countries like Argentina and Mexico, due to asset substitution issues.

[13] Loayza uses the used tax burden, labor market restrictions and governance measures as cause variables and tax evasion and the share of the labor force contributing to social security schemes as indicators of the informal economy.

[14] Most of the data is based on 2002 or 2003 information.

[15] More details regarding the construction and sources of the data used can be found in the Appendix.

[16] Most empirical studies use the labor rigidity index developed by Forteza

– Labor rigidity index #1 considers minimum wage constraints and is calculated as the ratio of the annual minimum wage to GDP per capita.

– Labor rigidity index #2 equals the average of two normalized components, one of which is the minimum wage ratio as described before, and the other of which captures mandated benefits, as measured by the social security contribution rates as a percentage of wages. Following Loayza (1997) in spirit, this second rigidity index is divided by GDP per capita in order to account for differences in labor productivity across countries.

Third, the *importance of agriculture* in the economy is included, since many studies endorse the idea that informal working is highly segmented by sector, with clear prevalence in the agricultural and related sectors. One of the most important reasons for this is the minimum enforcement capacity prevalent in rural areas. The importance of agriculture is measured as agriculture and food exports as a percentage of total exports to reduce prob-

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and Rama (2001). This index is constructed by averaging the normalized values of four labor-related variables, including minimum wage restrictions, mandated benefits, labor unions (measured by the membership of the labor movement as percentage of the labor force) and government employment (measured as the employment in the government as percentage of the labor force). These last two factors are not included in the labor rigidity indices developed in this study for the following reasons:

Labor unionization seems to be, at least for emerging and developing countries, a consequence of the informal economy more than its cause since bigger informal sectors seem to weak the bargain power of the workers in the formal sector. For example, countries with well known important informal sectors, like Peru and Ecuador, have very low degree of unionization, approximately 5 to 10 percent of the labor force; while countries with traditional lower informality like Argentina and Mexico have percentages close to 35 percent. For this reason, labor unionization is included as an indicator variable and it is expected to be negatively related with the size of the informal economy.

Higher *government employment,* far from increasing labor rigidity and consequently incrementing the size of the informal economy, could reduce the informality, since most public employees contribute to social security systems and are regulated by most institutions of the society. This variable is not included separately as another cause variable because it might be also subject to the Wagner's law and consequently subject to some endogeneity problem if the degree of development is related with the size of the informal economy.

lems of endogeneity.[17] The more prominent the agriculture sector, the bigger the expected size of the informal economy.

Fourth, following Giles (1999) the *inflation* rate is included to allow for the upward "creep" of tax brackets, and the associated incentive for tax-payers to engage in informal activities. A more pervasive effect of inflation is that, as it tends to be uneven across sectors, it alters the income distribution, and this may induce disrespect for tax law. The higher the inflation, the larger the expected size of the informal economy.

Last, the *strength of enforcement system* is proxied by an average of three indicators developed by International Country Risk Guide (ICRG), specifically quality of bureaucracy, corruption in government and rule of law. The stronger the enforcement capability of government, the lower is the expected size of the informal economy.

2. Indicator variables

First, following Loayza (1997) the percentage of the labor force *contributing to the social security system* is included. The bigger the informal economy, the lower the expected number of contributors to the social security system.

Second, the *degree of unionization*, measured as the percentage of labor force with membership in some labor union, is considered. The bigger the informal economy, the weaker the bargain power of the workers in the formal sector and, therefore, the lower the degree of unionization.

Last, the *gross enrolment ratio for secondary school* is included as an informal economy indicator. Most countries in the world have signed the International Labor Organization Convention 138, which made fourteen the minimum working age; however one of the most well-recognized consequences of the informal economy is child labor and the effect it has on rates of education enrolment.[18] Thus, the bigger the informal economy, the lower is the expected enrolment rate.

[17] The share of agriculture as percentage of GDP was also considered with similar results.

[18] The primary net enrolment rate would be maybe the best proxy to capture this phenomenon, however because of data unavailability for most ECCU countries

IV. EMPIRICAL RESULTS

1. Preliminary evidence

Table 2 shows the correlation between each cause and indicator variable. If both the conjectured relation between the cause variables and the informal economy and the hypothesized association between the informal economy and its indicators are present, there should be a specific pattern in the correlations between the cause and indicator variables. For example, if stronger labor rigidities are expected to increase the size of the informal economy and the latter effect is supposed to decrease the percentage of contributors to social security, then there should exist a negative relationship between labor rigidity and percentage of contributors to social security. It is clear from Table 2 that, aside for the relationship between tax burden and degree of unionizations (top-right cell), all the rest of the observed correlations matches their expected signs. Therefore, there seems to be strong preliminary support for our hypothesis.

TABLE 2. CORRELATIONS BETWEEN CAUSE AND INDICATOR VARIABLES

	Workers contributing to social security	*Gross enrolment ratio for secondary school*	*Degree of unionization*
Tax burden	-0.14	-0.12	0.07
Labor rigidity index #1	-0.59	-0.60	-0.39
Labor rigidity index #2	-0.59	-0.53	-0.36
Importance of agriculture	-0.39	-0.32	-0.31
Inflation	-0.40	-0.29	-0.30
Strength of enforcement system	0.82	0.58	0.49

SOURCE: Author's calculation.

2. MIMIC estimation results

The benchmark MIMIC specification, Model 1, is represented in Figure 1. The labor rigidity index #1, the tax burden, importance

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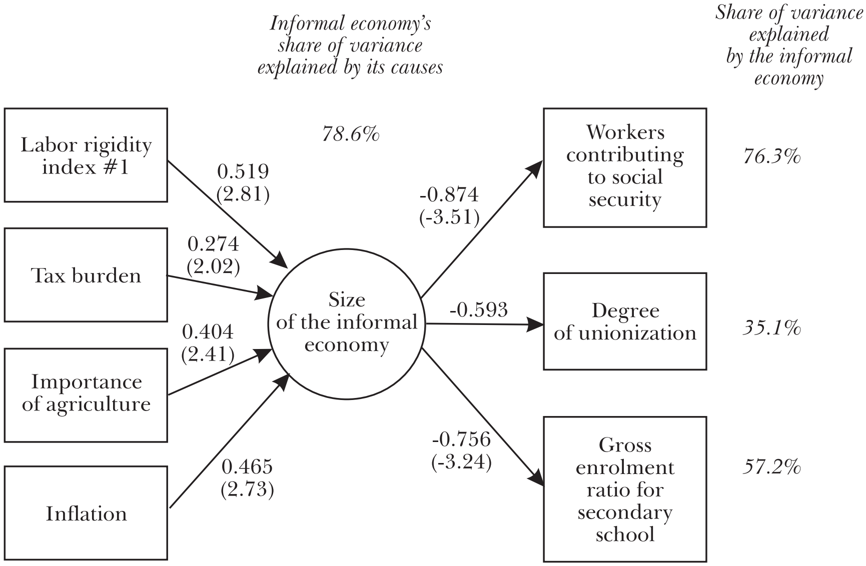
and since for the countries with such information there is a high correlation with the secondary gross enrolment rate, the last measure is used.

of agriculture and inflation are the cause variables of the informal economy, while the number of contributors to the social security system, the degree of unionization and the gross enrolment ratio for secondary school are the indicator variables.[19] Before analyzing the estimation results it is important to remark that several goodness-of-fit statistics support the underlying model (see grey

FIGURE 1. MIMIC ESTIMATION RESULTS: MODEL 1



Overall model fit:
Discrepancy function (CMIN) (p-value): 0.932
Goodness of fit index (GFI): 0.973
Adjusted goodnes of fit index (AGFI): 0.907
Root mean square error of approximation (RMSEA): 0

SOURCE: Author's calculation.

NOTES: The standardized regression coefficients and their respective t-values, indicated in parenthesis, are displayed by the arrow pointing in the direction of influence. In order to remove the structural indeterminacy of the coefficients, the non-standardized coefficient associated with *Degree o unionization* was set to -1. For this reason a t-test cannot be performed on this coefficient. The same standardized coefficients are obtained by setting the coefficient of another indicator equal to -1.

[19] Although most variables are subject to certain extent to some endogeneity problem, strength of enforcement system might be the one which could be more severely affected. For this reason it is not included in the benchmark specification.

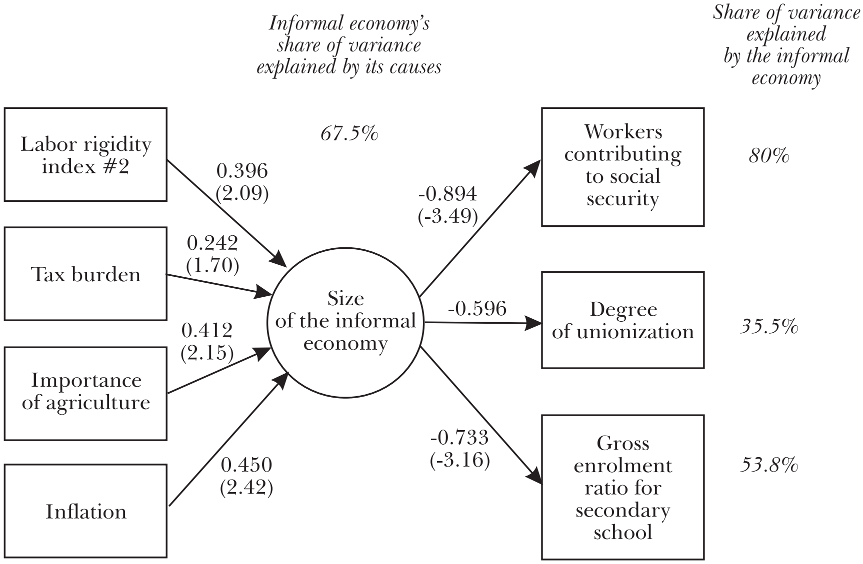
box in Figure 1). These set of goodness-of-fit measures are based on fitting the model to sample moments, which means to compare the observed covariance matrix to the one estimated on the assumption that the model being tested is true. The Discrepancy function (CMIN) is one of the most common fit tests and it is the minimum value of the discrepancy function between the sample covariance matrix and the estimated covariance matrix. The chi-square value should not be significant if there is a good model fit, while a significant chi-square indicates lack of satisfactory model fit. The goodness-of-fit index (GFI) and the adjusted goodness to fit index (AGFI) tests are also measures of discrepancy between the predicted and observed covariances. The GFI can be interpreted as the percent of observed covariances explained by the covariances implied by the model. The AGFI is a variant of the GFI which adjusts GFI for degrees of freedom. By convention, both GFI and AGFI should by equal to or greater than 0.90 to accept the model. The root mean square error of approximation (RMSEA) is also a fit test that some authors argue is less sensitive to sample size than the above mentioned tests [see for example Fan et al. (1999)]. By convention, there is good model fit if the RMSEA less than or equal to 0.05.

The coefficients on the causal and indicator variables have the expected signs and are statistically significant mostly at 1 or 5 percent. Specifically, one standard deviation increases in the tax burden, labor rigidities, importance of agriculture and inflation increase the size of the informal economy by 0.274, 0.519, 0.404 and 0.465 standard deviations, respectively. Even more, the joint influence of these four cause variables explains approximately 79 percent of the variance of the informal economy.

We find that increases in the informal economy reduce the number of workers contributing to the social security system, the degree of unionization and the secondary enrolment ratio, and explains 76, 35 and 57 percent of their respective variances.

Alternative MIMIC specifications are considered for robustness purposes. Models 2 and 3, respectively displayed in Figures 2 and 3, include an alternative measure of labor rigidity and strength of enforcement system. They both confirm the results obtained in the benchmark model, and Model 3 also presents evidence suggesting that the strength of enforcement appears to be an important determinant of the size of informal economy.

FIGURE 2. MIMIC ESTIMATION RESULTS: MODEL 2



Overall model fit:
Discrepancy function (CMIN) (p-value): 0.951
Goodness of fit index (GFI): 0.977
Adjusted goodnes of fit index (AGFI): 0.918
Root mean square error of approximation (RMSEA): 0

SOURCE: Author's calculation.

NOTES: The standardized regression coefficients and their respective t-values, indicated in parenthesis, are displayed by the arrow pointing in the direction of influence. In order to remove the structural indeterminacy of the coefficients, the non-standardized coefficient associated with *Degree o unionization* was set to -1. For this reason a t-test cannot be performed on this coefficient. The same standardized coefficients are obtained by setting the coefficient of another indicator equal to -1.

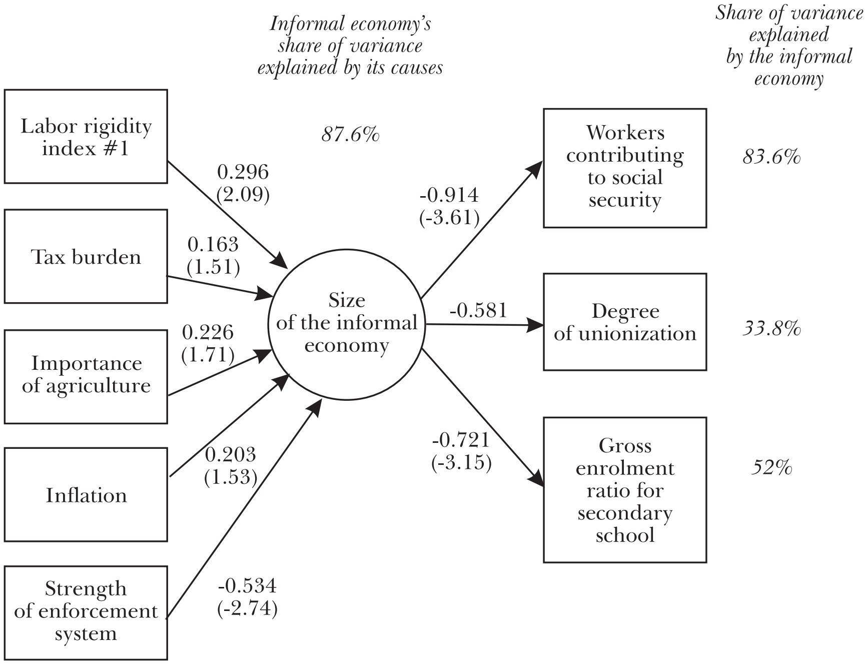
3. Estimations of the size of the informal economy

Using the estimates of the benchmark model, Table 3 and Figure 4 show the standardized *ordinal* values of the size of the informal economy for the countries in the sample. Since these ordinal values only identify the relative position of the countries, we set the informal economy of Jamaica equal to 35 percent of total GDP in order to estimate the *absolute* values of the informal economy as percentage of total GDP.[20] Bahamas, Cyprus, Grenada, St.

[20] According to a study conducted by De La Roca et al. (2002), the informal

Kitts and Nevis, Trinidad and Tobago and Barbados are among the countries with the smallest informal economies, with values ranging from 16 to 25 percent of GDP. These values are among the lowest not only for the Caribbean region, but also in

FIGURE 3. MIMIC ESTIMATION RESULTS: MODEL 3



<u>Overall model fit</u>:
Discrepancy function (CMIN) (p-value): 0.914
Goodness of fit index (GFI): 0.965
Adjusted goodnes of fit index (AGFI): 0.885
Root mean square error of approximation (RMSEA): 0

SOURCE: Author's calculation.

NOTES: The standardized regression coefficients and their respective t-values, indicated in parenthesis, are displayed by the arrow pointing in the direction of influence. In order to remove the structural indeterminacy of the coefficients, the non-standardized coefficient associated with *Degree o unionization* was set to -1. For this reason a t-test cannot be performed on this coefficient. The same standardized coefficients are obtained by setting the coefficient of another indicator equal to -1.

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economy in Jamaica accounted for about 35 percent of the total GDP in 2000-2001.

relation with most Latin American countries. On the other hand, St. Vincent and the Grenadines, Belize and Dominican Republic are among the countries with the largest informal economies in the Caribbean, with sizes varying between 41 and 51 percent. Notwithstanding, these estimates are smaller than those for the countries with the highest levels of informal activity in Latin America like Paraguay and Nicaragua, with values around 70 percent. The

TABLE 3. SIZE OF THE INFORMAL ECONOMY: STANDARDIZED AND ABSOLUTE VALUES

Country	*Standardized value*	*Absolute value (% of GDP)*
The Bahamas	-1.766	15.9
Cyprus	-1.496	19.3
Grenada	-1.244	22.5
St. Kitts and Nevis	-1.108	24.2
Trinidad and Tobago	-1.092	24.4
Barbados	-1.087	24.5
Mexico	-0.797	28.2
Brazil	-0.779	28.4
Malta	-0.752	28.7
Antigua and Barbuda	-0.562	31.2
Chile	-0.486	32.1
Argentina	-0.428	32.9
Dominica	-0.322	34.2
Jamaica	-0.259	35.0
Uruguay	-0.161	36.2
El Salvador	-0.150	36.4
Guyana	-0.122	36.7
Peru	-0.017	38.1
St. Lucia	0.251	41.5
Costa Rica	0.274	41.8
Guatemala	0.318	42.3
Venezuela	0.369	43.0
Colombia	0.410	43.5
Panama	0.480	44.4
Dominican Republic	0.515	44.8
Belize	0.673	46.8
St. Vincent and the Grenadines	0.974	50.6
Ecuador	0.980	50.7
Honduras	1.247	54.1
Fiji	1.719	60.1
Nicaragua	2.061	64.4
Paraguay	2.357	68.2
Mean	0.000	38.3
Standard deviation	1.000	12.7

SOURCE: Author's calculation based on Model 1 MIMIC results.

FIGURE 4. SIZE OF THE INFORMAL ECONOMY

SOURCE: Author's calculation based on Model 1 MIMIC results.

rest of the Caribbean countries have sizes of the informal economy similar to the most developed countries in Latin America like Argentina, Chile, Mexico and Uruguay.

As detailed before, the *absolute* values of the informal economy, unlike the *ordinal* measures, rely on extra information pinning down the absolute value of the informal economy for one country, in this case Jamaica. The information for Jamaica is based on a comprehensive study by De La Roca et al. (2002) that used different methodologies and data collected as part of the 2001 Jamaica Survey of Living Conditions, and is therefore a very attractive data source to pin down the absolute series of the informal economy.[21] Since the *order* of countries according to the size of the informal economy is independent of this extra information, while the *absolute* values of the informal economy do depend on this data, a word of caution should be taken regarding the use of the latter values as accurate measures of the degree of informality.

Table 4 shows the absolute values of the informal economy for the ECCU and other Caribbean countries by using the different specifications employed in Model 1, 2 and 3. It can be inferred that the estimated absolute sizes of the informal economy are similar

TABLE 4. ABSOLUTE SIZE OF THE INFORMAL ECONOMY UNDER DIFFERENT MIMIC SPECIFICATIONS

Country	*MIMIC Model 1*	*MIMIC Model 2*	*MIMIC Model 3*
The Bahamas	15.9	11.5	15.1
Grenada	22.5	31.8	22.9
St. Kitts and Nevis	24.2	24.6	24.4
Trinidad and Tobago	24.4	25.2	24.8
Barbados	24.5	36.6	24.3
Antigua and Barbuda	31.2	29.7	31.7
Dominica	34.2	38.8	35.0
Jamaica	35.0	35.0	35.0
Guyana	36.7	57.3	37.3
St. Lucia	41.5	52.0	41.8
Dominican Republic	44.8	46.1	45.3
Belize	46.8	56.5	47.4
St. Vincent and the Grenadines	50.6	58.4	51.4

SOURCE: Author's calculation.

[21] De La Roca et al. (2002) studies the informal economy for Jamaica in the early 2000s to evaluate the impact of the 1990s structural reforms. They found similar informal economy estimates using macroeconomic approaches like monetary and electricity consumption approach and microeconomic approaches based on the addition of the total amount of wages of the informal workers, the unreported income of the formal workers in the economy and the value added generated by household's independent activities whether agricultural or non-agricultural.

across models. The Spearman's rank correlation coefficient is 0.89 between Model 1 and 2, 0.98 between Model 1 and 3 and 0.85 between Model 2 and 3. The null hypothesis that the estimated absolute sizes of the informal economy are independent across models is rejected at the 1 percent level of significance for all comparisons.

The estimates reported here are similar to those for “late 1990s” reported in Schneider (2002). For 15 common countries, there is a positive correlation of 0.37 between the absolute sizes of the informal economy, and the spearman’s rank correlation test has a rho value of 0.44, which rejects at the 10 percent level of significance the null that these rankings have zero correlation.

4. Relative contribution of each cause variable to the size of the informal economy

Table 5 shows the relative contribution of each cause variable to the size of the informal economy for all countries studied, and Figure 5 displays these values for the Caribbean economies. On average tax burden, labor rigidity, importance of agriculture and inflation constitute around 35, 26, 31 and 8 percent of the overall size of the informal economy respectively. However, this profile differs importantly across countries:

- For countries like Antigua and Barbuda, Barbados and Trinidad and Tobago the main component influencing the informal economy is the tax burden. For example, for the period under consideration, Antigua and Barbuda has maximum marginal corporate and personal tax rates of 55 and 35 percent respectively.
- For others like St. Vincent and the Grenadines, St. Lucia and Belize the importance of the agriculture sector seems to be one of the most relevant factors, with approximately 75 percent of exports concentrated in agriculture and food products.
- For countries like Paraguay and Dominican Republic the significance of labor rigidities appears to be decisive, with minimum wages representing 170 percent and 90 percent of the corresponding GDP per capita.
- For most of the economies, inflation does not seem to be an

important factor determining the size of the informal economy, because of the price stability observed in the second part of the 1990s.

TABLE 5. RELATIVE CONTRIBUTION OF EACH CAUSAL VARIABLE TO THE SIZE OF INFORMAL ECONOMY

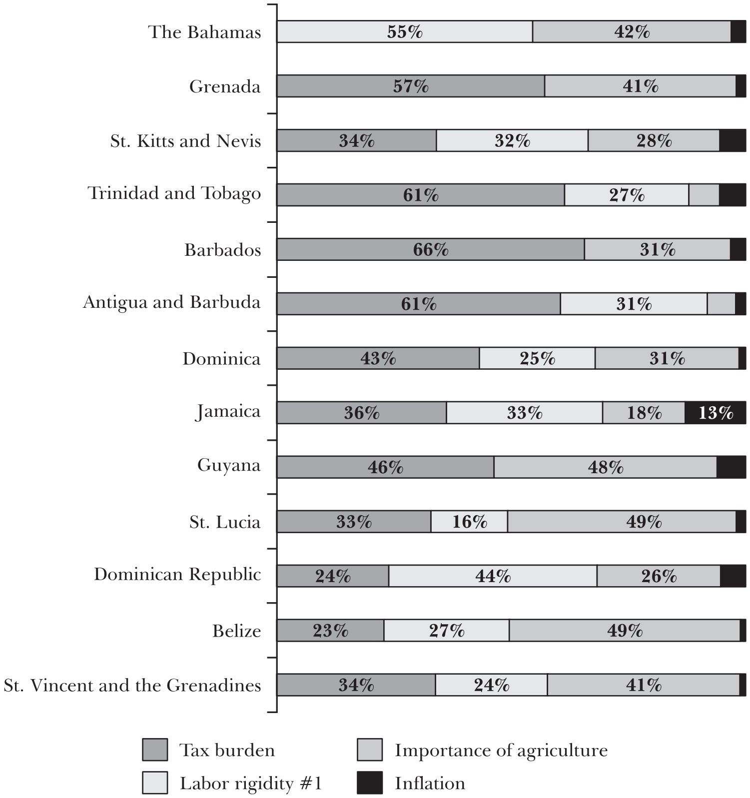
Country	*Tax burden*	*Labor rigidity index #1*	*Importance of agriculture*	*Inflation*
The Bahamas	0.0	54.6	42.3	3.1
Cyprus	32.2	0.0	63.5	4.3
Grenada	57.1	0.0	40.9	2.0
St. Kitts and Nevis	34.0	32.4	28.1	5.5
Trinidad and Tobago	61.4	26.5	6.5	5.6
Barbados	65.6	0.0	31.2	3.2
Mexico	52.4	14.4	5.4	27.8
Brazil	31.1	19.6	27.5	21.8
Malta	52.2	42.1	2.6	3.1
Antigua and Barbuda	60.5	31.3	6.1	2.1
Chile	36.1	27.6	30.2	6.0
Argentina	45.6	15.3	38.3	0.7
Dominica	43.2	24.7	30.7	1.4
Jamaica	36.2	33.3	17.6	12.9
Uruguay	22.8	15.4	43.0	18.9
El Salvador	32.1	30.3	32.8	4.8
Guyana	46.3	0.0	47.6	6.1
Peru	31.9	36.7	24.4	7.0
St. Lucia	32.9	16.4	48.7	2.0
Costa Rica	30.8	35.6	22.0	11.6
Guatemala	31.4	23.0	39.5	6.1
Venezuela	33.9	24.9	1.1	40.1
Colombia	36.4	35.3	15.2	13.1
Panama	29.0	23.1	47.1	0.8
Dominican Republic	23.9	44.4	26.3	5.4
Belize	22.9	26.7	49.3	1.1
St. Vincent and the Grenadines	33.8	23.9	41.0	1.2
Ecuador	21.1	35.7	22.2	21.0
Honduras	19.8	31.2	37.4	11.7
Fiji	22.8	29.6	45.8	1.7
Nicaragua	18.5	37.1	38.9	5.6
Paraguay	10.4	52.4	32.7	4.5
Mean	34.6	26.4	30.8	8.2

SOURCE: Author's calculation based on Model 1 MIMIC results.

V. CONCLUDING REMARKS

This paper estimates the size of the informal economy and the relative contribution of each underlying factor in the ECCU countries and 26 mainly Latin American countries in the early 2000s, being the first study to address this issue for the ECCU economies and many other Central American and Caribbean countries.

FIGURE 5. RELATIVE CONTRIBUTION OF EACH CAUSE VARIABLE TO THE INFORMAL ECONOMY



SOURCE: Author's calculation based on Model 1 MIMIC results.

NOTE: Because of graphical reasons only variables with contributions higher than 7% display the associated number.

Using a structural equation model approach that considers the informal economy as a latent variable with several causes and effects, we find that a stringent tax system and regulatory environment, higher inflation and dominance of the agriculture sector are the key factors in determining the informal economy, representing altogether around 79 percent of the informal economy variance. The results also confirm that a higher degree of informality reduces labor unionization, the number of contributors to social security schemes and enrolment rates in education.

The size of the informal economy differs considerably among countries. While in countries like Paraguay and Nicaragua the informal sector reaches values around 70 percent of total GDP, in economies like Bahamas, Cyprus, Grenada, St. Kitts and Nevis, Trinidad and Tobago, and Barbados the informal share has values below 25 percent. The average size of the informal economy for the ECCU and Caribbean countries is around 33 percent of GDP, while for Latin America the average share is 43 percent. Not only do many Caribbean economies have smaller levels of informality than the Latin American countries with the smallest informal economies, but also the Caribbean economies with the most informality have smaller informal economies than the Latin American countries with the biggest informal sector.

We also find that the relative contribution of each cause variable to the informal economy varies significantly across countries. For countries like Antigua and Barbuda and, Trinidad and Tobago the most important factor influencing the informal economy is the tax burden. For others like St. Vincent and the Grenadines, St. Lucia and Belize the relevance of the agriculture sector appears to be one of the most important elements, while for economies like Paraguay and Dominican Republic the significance of labor rigidities seems to be crucial.

The above analysis has important policy implications for authorities striving to reduce the degree of informality. For instance, in countries where the informal economy is related to a high tax burden, policy options include lowering and homogenizing effective tax rates across all sectors in the economy. In economies where labor market rigidities generate the informal economy, steps need to be taken to increase labor market flexibility. In countries where inflation is the key factor, priority should be given to tightening monetary policy and stabilizing prices, while in economies with an important agricultural sector, measures to improve the strength and expertise of government officials should be emphasized.

Appendix

I. DATA CONSTRUCTION AND SOURCES

Causal variables:

1. Tax burden: The proxy for tax pressure is the average of corporate and personal marginal income tax rate. The highest rate is used when there is more than one rate. This proxy measure is normalized between 0 and 100. The data correspond mostly for 2003 and is obtained from World Development Indicators 2006 and Bain and dos Santos (2004).

2. Labor rigidity indices: Two alternative measures of labor rigidity are constructed.

- Labor rigidity index #1 is represented by the ratio of minimum wage and GDP per capita normalized between 0 and 100. The minimum wage corresponds to the most general minimum wage regime. When minimum wages vary across sectors, the one for manufacturing (or for commerce, if manufacturing is not available) is reported. When minimum wages vary across regions, the value reported is either a simple average across regions or the minimum wage applicable in the main urban centers. A zero indicates that the country has no government set minimum wage, although minimum wages negotiated at the sectoral level may exist.
- Labor rigidity index #2 is the normalized average of two components divided by real GDP per capita. The first component captures minimum wages restrictions and corresponds to labor rigidity index #1, while the second element represents mandated benefits and it is measured by the contribution rates (as percentage of salaries) for all social security programs for both the employee and the employer. Only for Belize, where the contributions are flat-rate according to earning classes, the normalized legal number of days of maternity leave with full pay without complications is used. Following Loayza (1997) the normalized average of these components is divided by real GDP per capita in order to account for differences in labor productivity across countries.

The data for minimum wages correspond to 2002 and it is mainly obtained from the "Country Reports on Human Rights Practices" (2002). The Country Reports on Human Rights Practices are submitted annually by the U.S. Department of State to the U.S. Congress. The reports cover internationally recognized individual, civil, political, and worker rights, as set forth in the Universal Declaration of Human Rights. For Costa Rica and Mexico information from the respective ministries of labor is used. The social security contribution data correspond mostly to year 2003 and it is obtained from "Social Security Programs Throughout the World". Maternity leave information correspond to the average of the period 1999-2002 and it is obtained from several online publications from The Clearinghouse on International Developments in Child, Youth and Family Policies, Columbia University.

3. Importance of agriculture: It is measured by the agricultural raw material and food exports (as percentage of total exports) using World Development Indicators 2006 and correspond mainly for 2000. For Dominican Republic the year 2001 and for Fiji the year 2002 information is used.

4. Inflation: Annual average consumer prices inflation for the period 1995-1999. Aside for Antigua and Barbuda in which IMF data is used, the rest of the information is obtained from World Development Indicators 2006.

5. Strength of enforcement system: Following Loayza (1997) the strength of enforcement system is proxied by an average of three subjective indicators reported in the International Country Risk Guide (ICRG) for 2002. The three variables considered are quality of bureaucracy, corruption in government and rule of law. Quality of bureaucracy scores high under "autonomy from political pressure" and "strength and expertise to govern without drastic changes in policy or interruption in government services". Low scores in corruption in government indicate "high government officials are likely to demand special payments" and "illegal payments are generally expected throughout lower levels of government". The variable rule of law "reflects the degree to which the citizens of a country are willing to accept the established institutions to make and implement laws and adjudicate disputes". Higher values are associated with "sound political institutions, a strong court system, and provisions for an orderly succession of power". ICRG is a publication of Political Risk Services of Syracuse, NY.

Indicators:

1. Workers contributing to social security: Active contributors to old-age pension schemes, in percent of the labor force. It is based on social security agencies, household surveys and IMF country desks information predominantly for 2002.

2. Degree of unionization: Total union membership considering both public and the private sectors, in percent of the labor force. The data is mainly from "Country Reports on Human Rights Practices" (2002), but also country authority's information is used.

3. Gross enrolment ratio for secondary school: Total secondary enrolment as a percentage of the corresponding official school-age population, mostly for 2001. The sources of information are Human Development Report 2005 and "Organization of the Eastern Caribbean States. Towards a New Agenda for Growth" (2005).

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Price dynamics in the Eastern Caribbean

I. INTRODUCTION

Eastern Caribbean Currency Union (ECCU) member countries have generally enjoyed low inflation in the context of the regional quasi-currency board exchange rate arrangement, with a fixed peg to the US dollar. The currency union is one of only two currency unions in the world with a fixed exchange rate,[1] and is the only one in which member countries pool their foreign reserves.

[1] The other currency union is formed by the CFA franc zone consolidating the two economic unions in Africa, West African Economic and Monetary Union (WAEMU) and the Economic and Monetary Community of Central Africa (CEMAC). While the ECCU fixed exchange rate is supported by a quasi-currency board arrangement, in that the Eastern Caribbean Central Bank needs to cover only 60 percent of its domestic liabilities with foreign reserves, in actuality it operates like a full fledged currency board with almost full coverage of demand liabilities.

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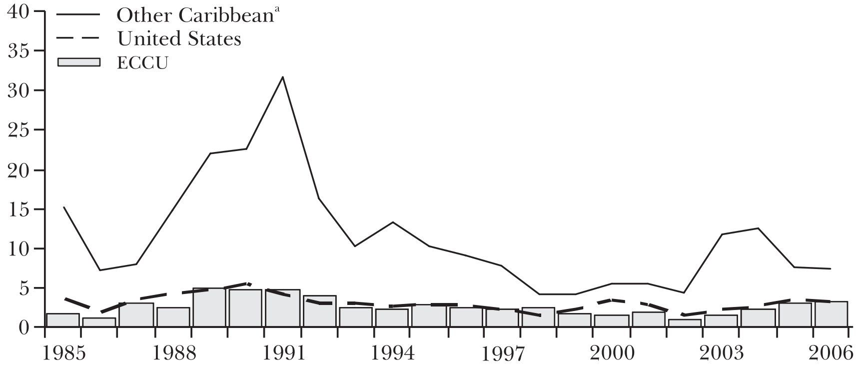
The convertibility of the common currency, the EC dollar, is fully self-supported; and the parity of the exchange rate has not been changed in more than three decades.

This paper formally examines the influence of the ECCU exchange rate arrangement on price dynamics in the six fund-member ECCU countries.[2] First, it examines to what extent the long-standing fixed peg with the US dollar has helped anchor price movements in the ECCU. Second, it analyzes whether the currency union has induced price convergence among its member countries and led to greater real exchange rate stability. Answers to these questions would shed light on whether price dynamics in the ECCU, both vis-à-vis the US and relative to each other, are entirely driven by external factors or have any domestic policy content.

INFLATION RATES, 1985-2006 (in percent)



SOURCES: WEO; and Fund staff estimates.

[a] Simple average of The Bahamas, Barbados, Belize, Dominican Republic, Guyana, Haiti, Jamaica, and Trinidad and Tobago.

The paper has two important findings. First, it establishes that the US price indeed helps anchor price stability at the ECCU, although inflation in the latter is not entirely imported from the US The failure of convergence to the US price is indeed not surprising, considering large structural differences between the two

[2] The countries are: Antigua and Barbuda (ATG), Dominica (DMA), Grenada (GRD), St. Kitts and Nevis (KNA), St. Lucia (LCA), and St. Vincent and the Grenadines (VCT). Anguilla and Montserrat, two other ECCU members, are U.K. territories and not members of the Fund.

economies, as well as differences in external environment and domestic policies. Second, even within the ECCU, absolute Purchasing Power Parity (PPP) does not hold, and real exchange rates are nonstationary.[3] These curious results reflect the fact that price movements in the ECCU countries are affected by persistent price dispersion of nontradables that account for a fairly large share of the consumer basket. The rest of the paper is organized as follows. Section II describes the data. Section III assesses the impact of US price movement on ECCU price dynamics, while Section IV analyzes real exchange rate stability within the ECCU countries. Section V concludes.

II. THE PRICE DATA

The sample comprises quarterly data of the broad disaggregated components of the consumer price index (CPI) of the six ECCU countries from 1990 to 2006. The data have a structural break in 2001 when most ECCU countries modified their CPI baskets to increase the level of disaggregation of some of the components of CPI. In order to ensure that the pre- and post- 2001 CPI data are compatible, the new components introduced after 2001 are absorbed back in the old ones using their corresponding weights. In other words, the analysis is based on the pre-2001 components in order to guarantee homogeneous components throughout the sample period.[4]

The weights of individual components of CPI baskets vary considerably across the ECCU countries (Table 1). For instance, food and beverages have the largest weight in the relatively less-developed Windward Islands, accounting for 35–55 percent of the total CPI basket.[5] Conversely, housing and transportation and

[3] This paper uses *real exchange rate stability* and *purchasing power parity* (PPP) interchangeably, as movements in real exchange rate may be viewed as a measure of the deviation from PPP. See Sarno and Taylor (2002) for a literature survey on the real exchange rate and PPP.

[4] For example, the post-2001 components of "food" and "alcoholic beverages and tobacco" are consolidated to one pre-2001 component of "food and beverages". See Cashin and others (2004) for details.

[5] Windward Island countries are Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines. Leeward Island countries are Antigua and Barbuda

communication carry more weight—in the order of 30–40 percent—in the relatively more-developed Leeward Islands.

Despite their small sizes and openness, the ECCU countries have a sizeable share of nontradables in their consumer baskets. The classification of CPI components into tradables and nontradables is somewhat subjective, although as a general rule of thumb all goods (usually imported) are classified as "tradable," while services (usually domestically produced) are classified as "nontradables."[6] Generally speaking, the higher the income level of a country, the higher is the share of nontradables—with the share of nontradables ranging from 27 percent in St. Vincent and the Grenadines to close to 50 percent in Antigua and Barbuda.

III. IMPACT OF US PRICE MOVEMENTS

As the ECCU countries have maintained a fixed peg to the US dollar for more than three decades, it is natural to ask how price levels in the ECCU have been affected by the US price movements. This section first describes the dynamics of overall CPI indexes in the ECCU countries vis-à-vis the US. It then examines their convergence to the US price using standard unit root tests, and establishes their relation with the US price using error correction techniques.

A close examination of the data reveals several stylized facts:

– Price indexes in the ECCU have generally moved closely with the US price index (Figure 1). Indeed, the ECCU countries have enjoyed remarkable price stability for decades, their average annual rate of inflation was about 3 percent during 1990–2006. Both tradable and nontradable prices display a large degree of co-movement with the US price level, although to a lesser degree for nontradables (Figures 2 and 3);

– Nevertheless, relative price indexes (i.e., bilateral real exchange rates) between individual ECCU countries and the US do not

and St. Kitts and Nevis.

[6] One caveat is that the production of nontradables would include tradable inputs, which we are unable to take into account in the absence of more disaggregated data of the ECCU CPI baskets.

TABLE 1. ECCU: CURRENT COMPOSITION OF CPI BASKET

	Category	*Antigua and Barbuda*	*Dominica*	*Grenada*	*St. Kitts and Nevis*	*St. Lucia*	*St. Vincent and Grenadines*
All items		1,000	1,000	1,000	1,000	1,000	1,000
Food	T	214	329	368	281	468	536
Alcoholic beverages and tobacco	T	2	10	9	7	28	10
Clothing and footwear	T	111	82	98	93	65	98
Housing	N	218	112	102	130	135	30
Fuel and light	T	64	59	55	44	45	89
Medical care and health expenses	N	28	32	47	37	23	62
Household furnishing	T	126	94	95	141	58	69
Transportation and communication	N	154	194	157	193	63	10
Education	N	23	29	37	21	-	34
Personal services	N	43	43	16	20	32	34
Miscellaneous	N	18	18	18	34	83	30
Memorandum items:							
Tradables	T	516	573	624	565	663	726
Nontradables	N	484	428	376	435	337	274

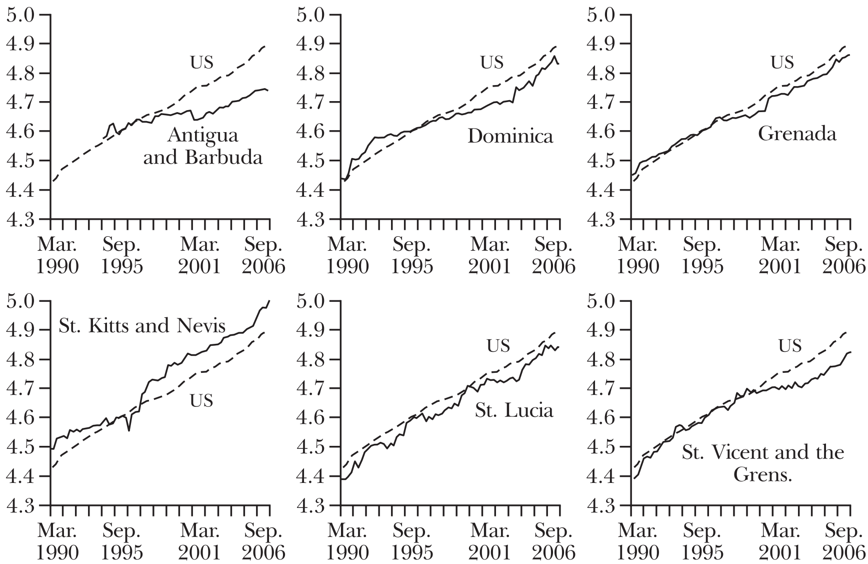
SOURCES: ECCU country authorities and Fund staff estimates.

NOTES: T = tradables; N = nontradables.

appear to be stationary, suggesting that inflation in the ECCU may not be entirely imported (Figure 4);

– Inflation volatility in the ECCU countries has been much higher than that of the US (Figure 5). As ECCU countries face more exogenous shocks in the context of a pegged exchange rate regime, their domestic prices have to adjust more frequently to absorb the shocks.

FIGURE 1. ECCU: CONSUMER PRICE INDEX MOVEMENT, MARCH 1990-DECEMBER 2006 (Logarithmic scale, index September 1995=100)



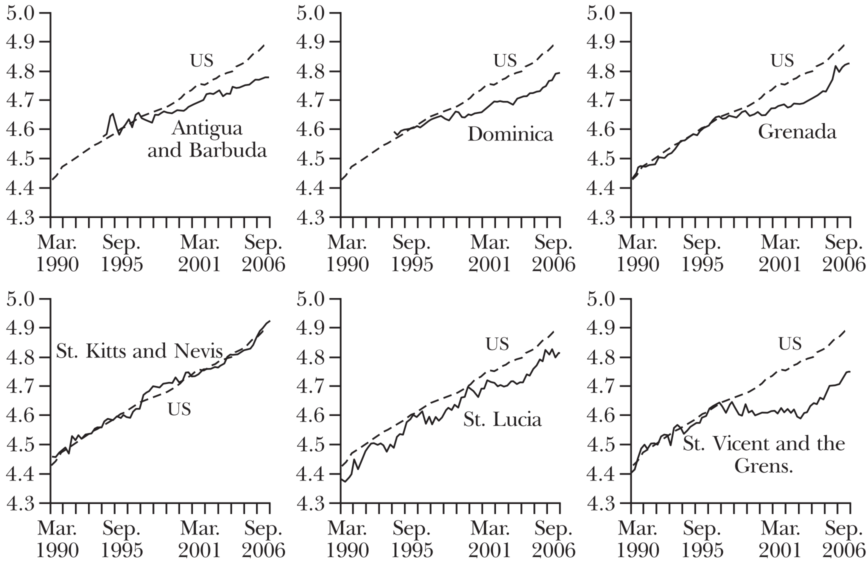
SOURCES: ECCB; and Fund staff estimates.

Panel unit root tests confirm that the ECCU price levels do not converge to the US price in the long run (Table 2). The nonstationarity of bilateral real exchange rates between ECCU countries and the US is not surprising, considering large structural differences between the two economies, as well as differences in external environment and domestic policies.

An error correction model is used to formally establish the link between the US and ECCU price indexes. The first step is to investigate whether there is a long-run equilibrium between the US and ECCU price indexes using cointegration techniques.[7] The second

[7] The optimal lag length of cointegration is chosen according to the Schwartz

FIGURE 2. ECCU: TRADABLE PRICE INDEX MOVEMENT, MARCH 1990-DECEMBER 2006 (Logarithmic scale, index September 1995=100)



SOURCES: ECCB; and Fund staff estimates.

second step is to examine short-run inflation dynamics and see how temporary deviations from the long-run equilibrium affect inflation. Results from both Trace test and Max-eigen value test suggest one cointegration vector at the 95 percent significance level (Table 3), with the long-run relationship between the ECCU price level[8] p and the US price level q given by (standard error in parentheses):

$$p = 0.785q + 1.067$$
$$(0.042) \quad (0.194)$$

The hypothesis that the coefficient on the US price is equal to one is rejected, indicating that absolute PPP does not hold vis-à-vis the US price, confirming again that inflation in the ECCU is not entirely imported from the US.

Moving next from the overall ECCU prices to country level price index data, cointegration analysis confirms the existence of

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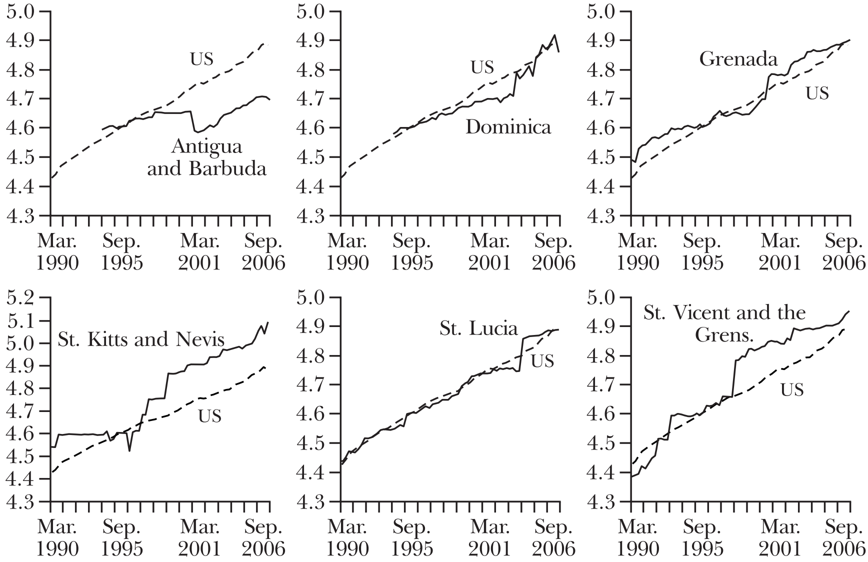
Information Criterion.

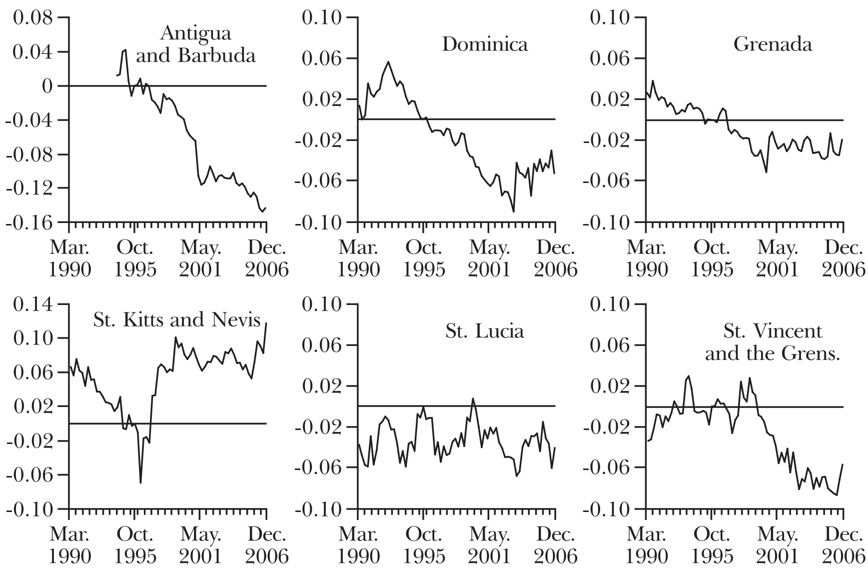
[8] Derived as a weighted average of prices in individual ECCU countries, using real GDP as the weight.

FIGURE 3. ECCU: NONTRADABLE PRICE INDEX MOVEMENT, MARCH 1990-DECEMBER 2006 (Logarithmic scale, index September 1995=100)



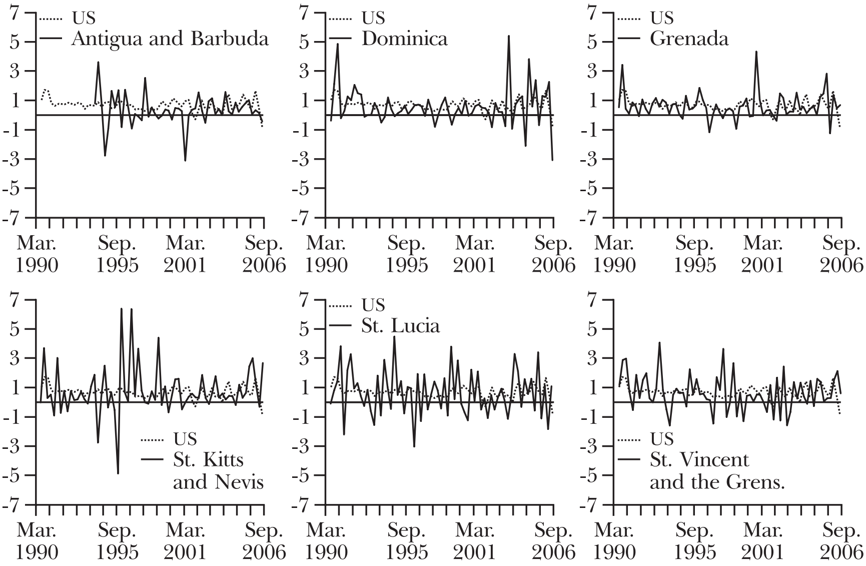
SOURCES: ECCB; and Fund staff estimates.

FIGURE 4. ECCU: RELATIVE PRICE INDEXES WITH THE UNITED STATES, MARCH 1990-DECEMBER 2006 (Logarithmic difference)



SOURCES: ECCB; and Fund staff estimates.

FIGURE 5. ECCU: QUARTERLY INFLATION, MARCH 1990-DECEMBER 2006 (in percent)



SOURCES: ECCB; and Fund staff estimates.

long-run equilibrium between the individual country price level and the US price level. However, cointegration equations differ across countries, likely reflecting structural and policy differences

TABLE 2. PANEL UNIT ROOT TESTS OF RELATIVE ECCU PRICES WITH THE US

Method	*Statistic*	*Prob.*	*Cross-sections*	*Obs*	*Test result*[a]
Null: Unit root (assumes common unit root process)					
Levin, Lin & Chu t	-1.10	0.13	6	377	No
Breitung t-stat	-0.70	0.24	6	371	No
Null: Unit root (assumes individual unit root process)					
Im, Pesaran and Shin W-stat	-0.49	0.31	6	377	No
ADF – Fisher Chi-square	16.54	0.17	6	377	No
PP – Fisher Chi-square	15.62	0.21	6	380	No
Null: No unit root (assumes common unit root process)					
Hadri Z-stat	10.45	0.00	6	386	Yes

SOURCE: Authors' calculations.
[a] Is the Null Rejected at 5% of significance.

TABLE 3. COINTEGRATION TEST BETWEEN ECCU AND US PRICES

Nº of CE(s)	*Eigenvalue*	*Trace Statistic*	*95% Critical Value*	*Max-eigen Statistic*	*95% Critical Value*
None	0.81	117.56	20.26	109.98	15.89
At most 1	0.11	7.58	9.16	7.58	9.16

SOURCE: Authors' calculations.

within the ECCU (Table 4). The hypothesis that the cointegration coefficient equals one can be rejected in all countries except Grenada and St. Lucia.

TABLE 4. ECCU: PRICE LEVELS—LONG-RUN EQUILIBRIUM RELATIONSHIPS[a]

Country	*Cointegration equation*[b]
ECCU average	0.785 (-0.042)
Antigua and Barbuda	0.326 (-0.089)
Dominica	0.679 (-0.083)
Grenada	0.934 (-0.074)
St. Kitts and Nevis	1.475 (-0.291)
St. Lucia	0.965 (-0.059)
St. Vincent an the Grenadines	0.704 (-0.06)

SOURCE: Authors' calculations.

[a] All variables are in logarithms. [b] Coefficient on US price level in cointegrating regression, with standard error in parentheses.

The short-run inflation dynamics are analyzed using a country-specific vector error correction model, which controls for country-specific factors. The general short-run equation has one country-specific error correction term to reflect deviation from the long-run equilibrium, with the coefficient on the error correction term providing the speed of adjustment for the system to return to its long-run equilibrium. Other independent variables include the US inflation Δq, inflation in other ECCU countries Δp^*, and past domestic inflation (to capture inflation inertia). Growth rates of ECCU-wide broad money m and real GDP y are also included to control for region-wide monetary aggregate and real aggregate demand, respectively.

$$\Delta p_t = c + \sum_{i=1}^{k} \alpha_{1i} \Delta p_{t-i} + \sum_{i=1}^{k} \alpha_{2i} \Delta q_{t-i} + \sum_{i=1}^{k} \alpha_{3i} \Delta m_{t-i} + \sum_{i=1}^{k} \alpha_{4i} \Delta y_{t-i} + \sum_{i=1}^{k} \alpha_{6i} \Delta p^*_{t-i} + \beta (ECT_{t-1}) + \upsilon_t + seasonal\ dummies + disaster\ dummies$$

The general model is estimated using OLS at both the country and regional level with four lags. A parsimonious inflation model is then derived using a general-to-specific model selection procedure, such that the model retains only those variables in the equation which are statistically significant.[9] Several results are noteworthy (Table 5):

- Short-run deviations are stationary in that a positive (negative) deviation from the equilibrium level reduces (increases) the rate of inflation, pushing the domestic price back to its equilibrium level. This result holds for the region as a whole and for all ECCU countries (excepting St. Kitts and Nevis), confirming that the peg with the US dollar has helped anchor price stability in the ECCU.
- The speed of adjustment to equilibrium is quite fast, with an estimated half life of about eight months for the ECCU as a whole.[10] Moreover, there is a large degree of heterogeneity within the ECCU when it comes to the speed of adjustment to long-run equilibrium.[11] The implied half life ranges from 1 quarter to 9 quarters, with Antigua and Barbuda adjusting the fastest, and Grenada the slowest.

In sum, the analysis in this section suggests that although the peg to US dollar has helped anchor price movement in the ECCU, ECCU prices do not converge to the US price, implying that inflation

[9] See Owen (2003) for a review on general-to-specific modeling using PcGets.

[10] The implied half life is calculated as $-\ln 2 / \ln(1+\beta)$.

[11] The error correction term for St. Kitts and Nevis is found to be statistically insignificant in explaining short-run inflation dynamics.

in ECCU countries is not entirely imported. The next objective is to analyze real exchange rate stability within the ECCU.

TABLE 5. RESTRICTED COEFFICIENT ESTIMATES OF SHORT-RUN INFLATION DYNAMICS MODEL

Regressor	*ECCU*	*ATG*	*DMA*	*GRD*	*KNA*	*LCA*	*VCT*
Error correction term	*-0.24*	*-0.72*	*-0.36*	*-0.07*		*-0.43*	*-0.41*
Implied half life (in quarters)	2.55	0.54	1.56	9.41		1.25	1.31
Dm (lagged change in M2)		0.30		0.42	-0.51		
Dq (lagged US inflation)	0.00			0.25		-1.15	-1.67
Dp (inflation inertia)	-0.28	-0.62			-0.31	0.68	
Dy (lagged change in real GDP)	0.63	1.60	1.02	0.03	0.72		1.18
R-square	0.42	0.61	0.48	0.51	0.33	0.43	0.33

SOURCE: Authors' calculations.

IV. REAL EXCHANGE RATES WITHIN THE ECCU

A. Literature Review

Whether PPP holds across international borders is a topic that has drawn significant academic interest for decades. An emerging consensus is that PPP might be viewed as a valid long-term international parity condition when applied to bilateral exchange rates among major industrialized countries, and that the pace of mean reversion is quite slow. Consensus estimates of the half life of deviation from PPP range between four and five years. A study on price dispersions among G7 industrial countries by Engel (1993) reveals that a strong empirical regularity, the consumer price of a good relative to a different good within a country tends to be much less variable than the price of that good relative to a similar good in a different country. Essentially, this result shows that nominal exchange rate fluctuations play a larger role in determining real exchange rate movements than relative consumer price movements within a country.

Some studies have looked at convergence toward PPP in the absence of trade barriers or nominal exchange rate fluctuations by analyzing price differences across cities within a country. Using 51 commodity prices across 48 cities in the US, Parsley and Wei (1996) found convergence rates substantially higher than typically uncovered in cross-country analysis. The rates of convergence occur faster for larger price differences and are slower for cities further apart. Engel and Rogers (1996) used disaggregated CPI data for the US and Canadian cities and found that price differentials are much larger for two cities across the two different countries relative to two equidistant cities within the same country. Engel and Rogers (2001) updated Engel's 1993 study using disaggregated CPI data for 29 US cities. They found that the strong cross-country empirical regularity uncovered by Engel (1993) does not hold as well across the US cities, implying that deviation from PPP is not as important for locations within the US as compared to deviation across countries.

The ECCU provides an interesting case study for analysis of the evolution of the real exchange rate. As discussed above, the literature on the real exchange rate has focused on either countries with different currencies or cities within the same country to which trade barriers or currency fluctuations do not apply. A currency union such as the ECCU is something in between these two polar cases. Nominal exchange rate variation, a standard factor underlying real exchange rate differences across countries, is not applicable in the ECCU countries, which share a common currency. However, many structural policies, related to trade barriers, factor market segmentation, and industry regulations, differ across the ECCU, making these countries less integrated than cities within the same country.

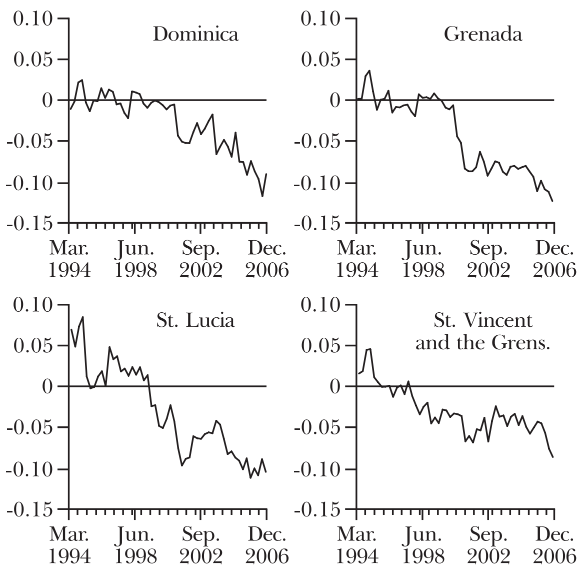
This section analyzes bilateral real exchange rates among ECCU countries. We address the following questions: Does PPP hold? If not, what can explain the deviation from PPP? How large is the deviation from PPP? While it may be difficult to draw any definitive conclusions given the relatively short sample period (1990–2006), we feel that it is important to analyze the above issues as a first step to understand inflation irregularities among these countries, which has not been done before.[12]

[12] Data on the components of CPI of the ECCU countries prior to 1990 were

B. Does PPP Hold?

A broad look at the data suggests that absolute PPP does not hold within the ECCU. Figure 6 depicts relative price indexes (i.e., the real exchange rate) using Antigua and Barbuda as the benchmark, and they do not appear to be stationary.[13]

FIGURE 6. ECCU: RELATIVE PRICES WITH ANTIGUA AND BARBUDA, MARCH 1994-DECEMBER 2006 (Logarithmic difference)



SOURCES: ECCB, and Fund staff estimates.

Unit root tests formally establish that bilateral real exchange rate among ECCU countries are indeed nonstationary. Standard ADF tests applied to the 15 bilateral real exchange rates among the six ECCU countries indicate that only one pair (GRD-LCA) is weakly stationary at the 10 percent significance level. In addition, the majority of the panel unit root tests also confirm the nonstationarity of bilateral real exchange rates among ECCU countries (Table 6).

C. What Explains the Deviation from PPP?

The absence of PPP among ECCU countries is quite surprising,

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not available at quarterly frequency.

[13] The above result holds regardless of the choice of benchmark ECCU country.

TABLE 6. PANEL UNIT ROOT TESTS OF RELATIVE PRICES WITHIN ECCU

Method	*Statistic*	*Prob.*	*Cross-sections*	*Obs*	*Test result*[a]
Null: Unit root (assumes common unit root process)					
Levin, Lin & Chu t	-1.40	0.08	15	918	No
Breitung t-stat	-3.08	0.00	15	903	Yes
Null: Unit root (assumes individual unit root process)					
Im, Pesaran and Shin W-stat	-0.08	0.47	15	918	No
ADF – Fisher Chi-square	26.95	0.63	15	918	No
PP – Fisher Chi-square	28.12	0.56	15	925	No
Null: No unit root (assumes common unit root process)					
Hadri Z-stat	16.11	0.00	15	940	Yes

SOURCE: Authors' calculations.
[a] Is the Null Rejected at 5% of significance.

considering that these countries have a common currency and share many economic similarities. To uncover the factors underlying the deviation from PPP within the ECCU, we next study the role of nontradables prices and transportation costs, as suggested in the literature (Engle, 1993; Parsley and Wei, 1996; Engel and Rogers, 2001; and Cecchetti, Mark, and Sonora, 2002).

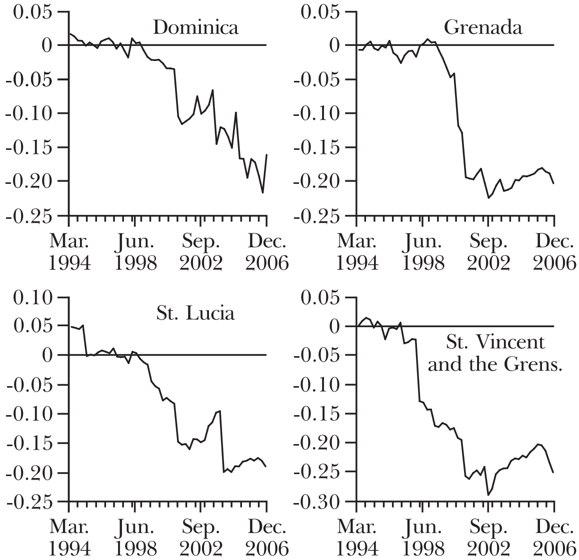
The presence of nontradables, which on average comprise about 40 percent of the CPI basket of ECCU countries, could give rise to deviation from PPP. To analyze the role of nontradables prices, we examine individual components of consumer price indexes to see if PPP would hold at disaggregated price levels, i.e., we analyze whether real exchange rates of tradables are more stationary than that of nontradables.

Barriers to trade such as transportation costs could also lead to failure of PPP. The geographical distance is used as a proxy for transportation costs (drawing on Engel and Rogers, 1996) and test if deviation from PPP is larger for countries which are further apart.

The role of nontradables prices

The data suggest that the deviation from PPP among ECCU countries is driven by persistent price differences in nontradables rather than tradables (Figures 7 and 8). We use two approaches to formally establish the role of nontradables in explaining the deviation of PPP. The first approach is to conduct panel unit root tests on disaggregated relative price indexes to assess whether relative tradable prices are indeed stationary while relative non-tradables prices are not. The second approach is to examine how the degree of tradability of a good affects the deviation from PPP. Other things equal, we expect deviation to be smaller for goods that have a smaller nontradable component.

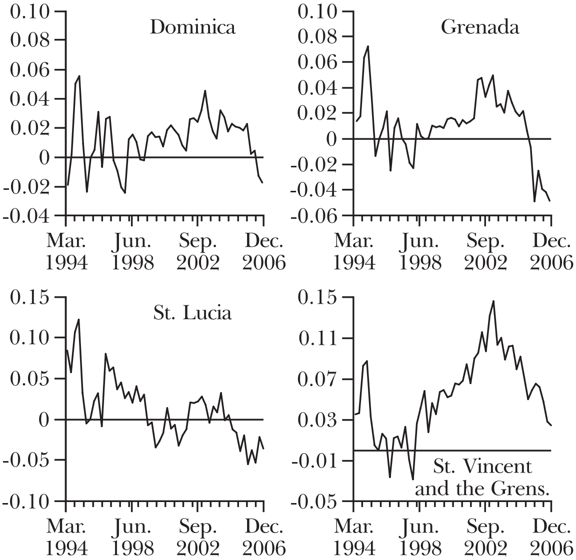
FIGURE 7. ECCU: RELATIVE NONTRADABLE PRICES WITH ANTIGUA AND BARBUDA, MARCH 1994-DECEMBER 2006 (Logarithmic difference)



SOURCES: ECCB, and Fund staff estimates.

The first approach is conducted in two steps. First, a number of panel unit root tests are used to determine if relative prices of individual CPI components are stationary. The relative prices are defined as the log price difference of CPI component k at time t between countries i and j; i.e., $q_{ij,k,t} = p^{i}_{k,t} - p^{j}_{k,t}$, where $p^{i}_{k,t}$ and $p^{j}_{k,t}$ are the log of the prices of good k at time t and in countries i and j, respectively. If alternative tests yield conflicting results, we take the result that is supported by a majority of the tests. Second, if stationarity is confirmed, the rate of convergence

FIGURE 8. ECCU: RELATIVE TRADABLE PRICES WITH ANTIGUA AND BARBUDA, MARCH 1994-DECEMBER 2006 (Logarithmic difference)



SOURCES: ECCB, and Fund staff estimates.

is estimated using a convergence regression where the change in relative prices is regressed on the lagged relative prices. Our regression is based on the Levin, Lin, and Chu (2002) specification.

The main results are summarized as follows (Table 7):

TABLE 7. PANEL UNIT ROOT TESTS OF RELATIVE DISAGGREGATED PRICES WITHIN ECCU

	Unit Root	*Convergence Coefficient*	*Max Lags*	*Half Life (Quarters)*
Tradables	No	-0.11	10	5.8
Food and beverages	No	-0.15	10	4.3
Clothing and footwear	No	-0.08	10	8.7
Household furnishing	No	-0.08	10	8.7
Fuel and light	Yes		10	
Nontradables	Yes		10	
Housing	Yes		10	
Transportation and communication	Yes		10	
Education	Yes		10	
Medical care and health expenses	Yes		10	

SOURCE: Authors' calculations.

Relative prices indexes are indeed stationary for most tradable goods (food and beverages, clothing and footwear, and household furnishing), except for fuel and light. The latter possibly reflects the fact, in the sample period under consideration, fuel prices have been administered in most ECCU countries, except Dominica.[14]

As for nontradables, relative price indexes are nonstationary, implying that country-specific structural and policy differences may have resulted in persistent differences in the national price of these nontradables.

For tradables, the speed of convergence to PPP, given by the estimated half life, ranges from four to nine quarters. It is much faster than the consensus estimates of four to five years using cross-country data, likely reflecting the fact that barriers to PPP such as currency and exchange rate volatility do not exist within the ECCU (see Parsley and Wei, 1996).

Also, among the tradables, the speed of convergence to PPP is faster for perishables (e.g., food and beverages) compared with nonperishables (e.g., household furnishing and clothing and footwear). This supports the findings of Parsley and Wei (1996) using disaggregated prices within the US.

The second approach tests whether deviation from PPP is larger for nontradables than tradables. Drawing on Engel and Rogers (2001), we use the standard deviation of changes in the log of the relative price index of good k across countries i and j, $\Delta p^{i}_{k,t} - \Delta p^{j}_{k,t}$ (where Δ stands for the first difference), as a measurement of degree of deviation from PPP, the higher the standard deviation, the larger the deviation. With only the exception of Antigua and Barbuda, the standard deviation for overall nontradables is always higher than for tradables in individual countries (Table 8). The cross-country average for nontradables is 4.2, as compared to 3.0 for tradables.

We perform pooled regression of the standard deviation of $\Delta p^{i}_{k,t} - \Delta p^{j}_{k,t}$ on a number of explanatory variables to identify factors behind the deviation from PPP. As noted by Engel and Rogers (2001), deviation from PPP could be larger when nominal

[14] Dominica has allowed full pass through from the world oil prices to domestic prices since late 2003. Grenada and St. Kitts and Nevis liberalized the determination of retail gasoline prices in late 2006.

TABLE 8. STANDARD DEVIATION OF LOGARITHMIC PRICE DIFFERENCES[a]

	ATG	*DMA*	*GRD*	*KNA*	*LCA*	*VCT*	*Average*
Food and beverages	3.2	2.2	2.3	2.7	3.4	2.8	2.8
Clothing and footwear	5.6	3.4	4.7	4.8	3.9	4.0	4.4
Household furhishing	2.4	1.8	2.1	2.3	2.2	2.3	2.2
Fuel and light	3.7	3.4	2.7	3.1	2.9	3.8	3.3
Housing	3.6	3.3	3.4	5.6	4.2	5.5	4.3
Transportation and communication	3.3	5.7	4.0	3.4	3.3	3.8	3.9
Education[b]	3.7		3.6		4.7		4.0
Medical care and health expenses[b]	3.0		3.4		3.7		3.4
Total	*3.5*	*3.3*	*3.0*	*3.5*	*3.5*	*3.1*	*3.3*
Tradables	*3.6*	*2.5*	*2.7*	*3.0*	*3.3*	*3.0*	*3.0*
Nontradables	*3.5*	*4.8*	*3.7*	*4.3*	*3.9*	*5.1*	*4.2*

SOURCES: Authors' calculations.
[a] Standard deviation x 100. [b] Data for three countries (DMA, KNA, and VCT) are unavailable.

prices are more volatile. To control for the effect of nominal price stickiness, the sum of the standard deviation of $\Delta p^{i}_{k,t}$ and $\Delta p^{j}_{k,t}$ is included in the regression as one independent variable. A dummy for nontradables is used to capture the effect of nontradability on price dispersion.

The results indicate that deviation from PPP is larger when nominal prices are more volatile (see Table 9, first column), consistent with the finding of Engel and Rogers (2001). More importantly, the coefficient of the dummy variable for nontradables is positive and statistically significant, confirming that the deviation from PPP is indeed larger for nontradables than for tradables.

TABLE 9. EXPLAINING PPP DEVIATION

	Specification 1		*Specification 2*	
	Coefficient	*t-statistics*	*Coefficient*	*t-statistics*
Nominal price stickiness	0.76	28.30	0.75	28.10
Dummy for nontradables	0.00	1.83	0.00	1.90
Distance			0.00	-1.17
Constant	0.00	-2.49	0.00	0.47
R-square	0.89		0.90	

SOURCE: Authors' calculations.

The role of distance

To assess the role of distance in explaining price dispersion, we add the log of distance between country i and j in the pooled regression of the standard deviation of $\Delta p^{i}_{k,t} - \Delta p^{j}_{k,t}$ (Table 9, second column). The coefficient on distance is statistically insignificant and also has the wrong sign. Hence, we conclude that distance does not explain price dispersion among ECCU countries. This result contrasts with other studies in the literature (such as Engel and Rogers, 1996 and 2001), and likely reflects the low level of intra-country trade within the ECCU.

D. Does Engel's Regularity Hold?

In this section we examine how deviation from PPP within the ECCU countries compares with findings of other studies. Specifically, we replicate Engel's (1993) study on price dispersion among G7 industrial countries for the ECCU countries. Using data at the national level, Engel compared the relative prices of similar good across countries to the relative price of different goods within a country, and found that the consumer price of a good relative to a different good within a country tends to be much less variable than the price of that good relative to a similar good in a different country. He attributed his finding to the fact that prices in domestic currencies are less variable than the nominal exchange rate. So as the nominal exchange rate varies, the common currency prices of the goods vary. We ask whether this empirical regularity holds within the ECCU in the absence of nominal exchange rate variability.

Following Engel (1993), we calculate the ratio r_{ki} for every good $k = 1, 2, \ldots, 8$, and every country $i = 1, 2, \ldots, 6$.

$$r_{ki} = \frac{\frac{1}{7}\sum_{n=1,n\neq k}^{7} std(\Delta p_{kt}^{i} - \Delta p_{nt}^{i})}{\frac{1}{5}\sum_{j=1,j\neq i}^{5} std(\Delta p_{kt}^{i} - \Delta p_{kt}^{j})}$$

The numerator of r_{ki} is the average of the standard deviations (*std*) of the first difference of the price of good k relative to the price of each different good in country i. It measures the volatility of relative prices of different goods in the same country. The denominator of r_{ki} represents the average standard deviation of the first difference of the price of good k in country i relative to the price of the same good in other countries. A small value of r_{ki} indicates that deviation from PPP across the ECCU countries is large.

Table 10 reports our calculation of the above ratio (r_{ki}) for each CPI component across ECCU countries. If Engel's empirical regularity holds for ECCU countries, the value of r_{ki} should be much smaller than one. However, the average ratio of ECCU countries (1.1) is much higher than the cross-country average (0.15) found by Engel (1993), but lower than the average of 29 US cities (2.03) found by Engel and Rogers (2001). This implies that the Engle's cross-country empirical regularity does not hold as well for ECCU countries. In other words, deviation from PPP within the ECCU is much smaller than that across countries, but larger than that among US cities. This likely reflects the absence of nominal exchange rate fluctuations under the currency union arrangement,

TABLE 10. RATIO OF RELATIVE PRICE VARIABILITY TO CROSS-COUNTRY PPP DEVIATION

	ATG	*DMA*	*GRD*	*KNA*	*LCA*	*VCT*	*Average*
Food and beverages	1.2	1.0	1.1	1.1	1.2	1.5	1.2
Clothing and footwear	0.9	0.7	0.8	0.9	0.8	1.0	0.9
Household furnishing	1.3	1.2	1.2	1.4	1.3	1.6	1.3
Fuel and light	1.2	1.0	1.0	1.0	1.3	1.2	1.1
Housing	0.9	0.8	0.4	0.7	0.6	0.9	0.7
Transportation and communication	1.0	0.9	0.9	1.0	1.0	1.2	1.0
Education[a]	0.9		0.8		0.9		0.9
Medical care and health expenses[a]	1.0		0.9		1.2		1.0
Total	*1.1*	1.0	*0.9*	*1.1*	*1.1*	*1.4*	*1.1*
Tradables	*1.2*	*1.0*	*1.0*	*1.2*	*1.1*	*1.4*	*1.2*
Nontradables	*0.9*	*0.9*	*0.7*	*0.9*	*0.8*	*1.0*	*0.9*

SOURCES: Authors' calculations.

[a] Data for three countries (DMA, KNA, and VCT) are unavailable.

as well as the existence of structural differences across ECCU countries (much more so than that across US cities).

Another interesting result generated by this exercise is that the value of r_{ki} tends to greater for tradables (1.2) than for nontradables (0.9), indicating that deviation from PPP is indeed larger for nontradables. This result reinforces our earlier finding on the role of nontradables in explaining deviations from PPP within the ECCU.

V. CONCLUDING REMARKS

This paper uncovers important peculiarities in the price dynamics of ECCU countries, which confirm that domestic policies and structural differences could have a persistent impact on prices in the ECCU. First, while US price stability has helped anchor price stability in the ECCU, inflation in the ECCU is not entirely imported from the US Second, purchasing power parity does not hold within the ECCU, due to the persistent price dispersion of nontradables. Thus, policy differences, related to the labor market and trade barriers, as well as differences in structural characteristics appear to have played a role in maintaining persistent inflation differences across ECCU countries. Looking ahead, these differences should decline over time as labor market segmentation and trade distortions are gradually removed, in the context of greater economic integration among ECCU countries.

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Jorge E. Galán
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Banknote printing at modern central banking: trends, costs and efficiency

I. INTRODUCTION

Banknote printing has been done customarily by central banks or, in some cases, by governments. However, with the development of financial markets and the consolidation of companies specialized in banknote production, a number of central banks have invited the private sector to participate in this function.

This change also has been motivated by a high increase in the demand for currency in recent years. As a matter of fact, the average

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growth in the amount of currency in circulation was 26.5% during the 2000–2005 period in the 56 countries studied. This situation generated, among other effects, an increase in banknote production and, consequently, in production costs.[1] In fact, central banks rely on a variety of strategies to enhance efficiency in the production and supply of banknotes to the economy.[2] These include, among others, creating subsidiary companies (e.g., Australia and Bulgaria), turning production over to the private sector (e.g., United Kingdom and Sweden), and combining currency printing and distribution under one roof, in a single complex (e.g., Portugal and Colombia).

In a broad study, the central bank of Colombia examined these methods and strategies for a sample of 133 central banks between 1993 and 2003. What it found was a tendency to turn over all or part of banknote production, primarily among the central banks of developed countries (Banco de la República, 2005). At the Central Bank of Japan, Nishihara (2006) found that changes in the banknote printing method used by the central banks attending the Executives' Meeting of East Asia and Pacific Central Banks (EMEAP)[3] depended on the bank's relationship with the government, the financial sector and private companies, as well as the modernization strategy adopted by each central bank.

Recently, Galán and Sarmiento (2007), using a panel data model for 68 central banks during the 2000-2004 period, found that the function of banknote printing is a very important determinant of the central bank's demand for labor. Moreover, they found that a change in the strategy used to perform this function has a relevant effect on staff.[4]

[1] Several studies suggest the recent increase in monetary aggregates is due to the decline in inflation and interest rates, coupled with the growth in real income (Hernández et al., 2006; De Gregorio, 2003).

[2] Baxter et al. (2005) examined how currency is distributed by central banks in Australia, Canada, England, Malaysia and Norway.

[3] The EMEAP includes the central banks of Australia, China, Hong Kong SAR, Indonesia, Japan, South Korea, Malaysia, New Zealand, Philippines, Singapore and Thailand.

[4] The case studies by Booth (1989) and Lacker (1993) for the United States are particularly important. Daltung and Ericson (2004) analyzed the banknote-printing and currency-management strategy adopted recently by the central bank of Sweden.

While the aforementioned studies shed light on the modernization strategies adopted recently by central banks to produce banknotes more efficiently, it is important to consider other aspects associated with that function, such as the denomination structure in each country, the features of its banknotes, and the production costs. These aspects are examined in detail herein, by identifying what determines banknote printing costs and how changes in strategies and production methods affect costs and efficiency.

This paper is divided into four sections, including this introduction. Section II provides an outline of the production methods, the denomination structure and the features of banknotes for 56 central banks during the 2000-2005 period. A set of comparative production-cost indicators is constructed in section III and a cost function is estimated as well, using a panel data model with random effects to identify the main production-cost determinants. Additionally, a non-parametric efficiency frontier model is used to identify the technical efficiency of central banks in banknote printing; changes in productivity are shown with the Malmquist Index. The main conclusions are presented in section IV.

II. TRENDS IN BANKNOTE PRINTING

1. Methods

In recent years, central banks have relied on different methods to produce banknotes. The most common include direct printing by the central bank, production through a subsidiary company, purchase from domestic suppliers (private companies and the government), and importation. The relative importance of these methods in 2005 is shown in Table 1. For the sake of comparison, central banks are classified into four groups: Eurozone, Other Advanced Economies, Latin America and Other Developing Countries.

As illustrated, in most of the Eurozone countries and in the group of Other Developing Countries, banknotes are produced by the central bank. Nonetheless, central banks that perform this function directly account for less than half of the sample analyzed. Table 1 also shows the purchase of banknotes from private

TABLE 1. METHODS USED BY CENTRAL BANKS TO PRODUCE BANKNOTES, 2005

	Eurozone		*Other Advanced Economies*		*Latin America*		*Other Developing Countries*	
Producer	*Country (12)*	*%*	*Country (14)*	*%*	*Country (14)*	*%*	*Country (16)*	*%*
Central Bank	Belgium France Greece Ireland Italy	41.7	Denmark Hong Kong Norway	21.4	Colombia Mexico Venezuela	21.4	Albania Armenia Bangladesh Romania Slovenia Thailand Turkey	43.8
Private Company	Finland Germany Netherlands	25.0	Canada England Sweden	21.4		0.0	Poland	6.3
Government	Spain	8.3	Japan United States South Korea	21.4	Argentina Brazil Chile	21.4	Czech Rep.	6.3
Subsidiary	Austria Portugal[a]	16.7	Australia	7.1		0.0	Bulgaria Hungary	12.5
Importation	Luxembourg	8.3	Cyprus Iceland Israel New Zealand	28.6	Bolivia Costa Rica Dominican Rep. Guatemala Nicaragua Paraguay Peru Uruguay	57.1	Bosnia Croatia Estonia Malaysia Slovakia	31.3

SOURCE: Central banks' annual reports (2000 – 2005). Authors' calculations.
[a] In Portugal, the central bank has relied on a joint venture with *De La Rue* since 1999.

companies is more common among central banks in the Advanced Economies and the Eurozone, than in other regions. The establishment of a subsidiary company is not a method used in Latin America, where more than half the countries in the sample import their banknotes. As to the importation of banknotes, most central banks rely on more than one supplier.[5]

Figure 1 shows the tendency in these methods during 2000-2005, when the number of central banks printing banknotes decreased, while the participation of private companies and importation increased. This tendency reflects the constant search for strategies to modernize banknote production, largely through the active involvement of third parties. The central banks that changed their method during the period under study were those of Bulgaria and Croatia in the group of Other Developing Countries, and England and Sweden in the group of Other Advanced Economies. The strategy adopted by the central bank of Bulgaria was to establish its currency printing works as an independent legal entity. It has been operating as a subsidiary of the central bank since January 2002.[6] In the 2002, the central bank of Croatia stopped producing banknotes directly and began to import them from OeBS, a subsidiary company of the Austrian central bank since 1998.

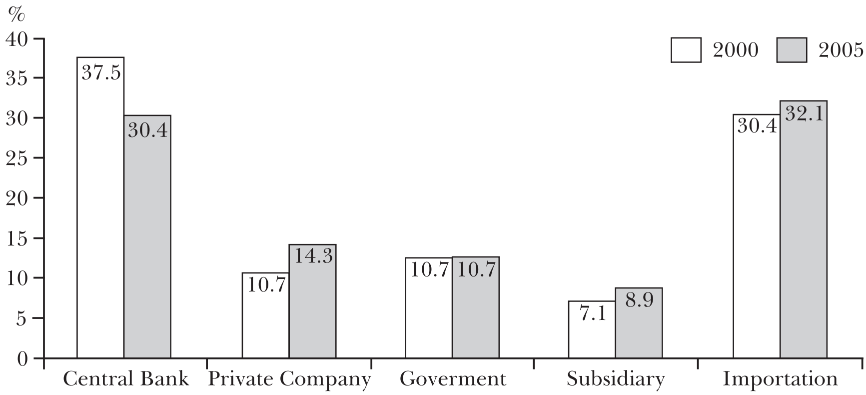
The strategy implemented by the central banks of Sweden and England was to sell their banknote printing works to private companies. In March 2003, the central bank of England sold its banknote printing works to De la Rue; the idea was to achieve certain cost and security objectives for the banknotes it offers.[7] Likewise,

[5] The central bank of Slovakia uses either the British company De la Rue, or the Canadian company Giesecke & Devrient GmbH. The central bank of Bosnia imports banknotes from two companies: Oesterreichische Banknoten und Sicherheitsdruck (OeBS) and Francois Charles Oberthur (FCO).

[6] The central bank of Bulgaria assumed full control of the company (100% stock ownership), with the authority to direct its financial and operating policies and to profit from its activities. The government has had an interest in the company since 2004. While dedicated primary to banknote production, this subsidiary also has been commissioned to produce certain types of paper and documents for the Finance Ministry of Bulgaria and other government agencies. See Bulgarian National Bank, Annual Report, 2002.

[7] Initially, the central bank transferred the capital and staff required for banknote production at its subsidiary, Debben Security Printing Ltd., which was sold eventually to De la Rue. The initial agreement called for De la Rue to

FIGURE 1. TRENDS IN BANKNOTE PRINTING METHODS, 2000-2005



SOURCES: Central banks' annual reports (2000-2005). Authors' calculations.

the central bank of Sweden sold its banknote printing facilities in 2001 to Crane & Co, Inc., a US company.[8] The aim, in this case, was to focus on the bank's core functions. Using a similar approach, the central bank of Norway decided, in 2003, to cease all direct banknote production by 2007.[9]

The transfer of banknote production from central banks to other agents is not the only strategy being used to make this activity more efficient. In 1995, the central bank of Portugal built the Carregado complex to house banknote production and cash distribution activities under one roof. De la Rue has been printing banknotes there since 1999, as part of a joint venture. In Colombia, the central bank began operating its Central de Efectivo in 2006, a complex that combines banknote production and currency distribution activities.

Since 2002, the central banks in the Eurozone have used a strategy based on joint and decentralized banknote production. With this approach, each nation's central bank is responsible for producing a portion of the banknotes, in a reduced number of denominations. However, each central bank may use a particular production method.[10]

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sell notes to the central bank for a seven-year period (Bank of England, 2003).

[8] This company was to develop additional printing techniques and to supply the production volume required for long-term benefits (Daltung and Ericson, 2004).

[9] On December 2006, the central bank of Norway signed an agreement with De La Rue and FCO to purchase banknotes from them during 2007-2012.

[10] The European Central Bank plans to institute a single bidding process in

2. Denomination structure

Central banks must define the structure of the denominations in circulation, regardless of the printing method used. This implies estimating the share of each denomination with respect to the total amount of currency the economy needs, and introducing a new denomination when they are required by the market. Therefore, when drafting a production plan, it is essential to analyze the production needs for each denomination. These are based essentially on three factors: change in the quantity of banknotes demanded by the public; restocking deteriorated banknotes; and the inventory needed to cover unexpected events.

Each of these factors differs from one denomination to another. Restocking deteriorated banknotes is more frequent with lower denominations. Because they are employed in a greater number of transactions, their useful life is shorter than that of other denominations.

Changes in the units required during an average year and in inventory needs depend on the public's preferences for each denomination. The quantity of denominations in circulation each year depends on a combination of economic circumstances that shapes the demand for currency. To illustrate this point, Table 2 shows that developed countries tend to use fewer denominations than developing countries, although a significant portion of the sample uses a structure that varies from five to seven denominations (See Attachment 1).

In countries with highly developed technological means of payment and currency distribution, and with advanced models for the distribution of goods and services (e.g., large department store chains and electronic payment networks integrated into commerce), the dynamics of currency are expected to be more stable, as is the composition of currency in circulation (Misas et al., 2004). Added to this is the fact that financial institutions can exert a significant influence on the demand for currency.[11] On the

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2012 to print banknotes for the Eurosystem. The goal is to make production more efficient by have only few suppliers (See the ECB Annual Report, 2002). For details on the role of central banks in the Eurozone, see Wellink et al. (2002).

[11] Financial institutions may influence the demand for currency, given their general bias towards high denominations for ATM's, which are a primary means of currency distribution.

TABLE 2. STRUCTURE OF THE DENOMINATIONS OF BANKNOTES IN CIRCULATION, 2005

Structure of Denominations	*Euro Zone*		*Other Advanced Economies*		*Latin America*		*Other Developing Countries*	
	Country (12)	*%*	*Country (14)*	*%*	*Country (14)*	*%*	*Country (16)*	*%*
Less than 5			Cyprus England Israel Japan South Korea	35.7	Costa Rica	7.1		
5			Australia Canada Denmark New Zealand Norway	35.7	Nicaragua Paraguay Peru	21.4	Albania Poland Thailand	18.8
6			Hong Kong	7.1	Argentina Chile Colombia Mexico Venezuela	35.7	Armenia Malaysia Romania Turkey	25.0

7	Austria Belgium France Finland Germany Greece Ireland Italy Luxembourg Netherlands Portugal Spain	100	Iceland Sweden United States	21.4	Bolivia Brazil Dominican Republic Guatemala	28.6	Bulgaria Hungary Slovakia	18.8
More than 7					Uruguay	7.1	Bangladesh Bosnia Estonia Croatia Czech Rep. Slovenia	37.5

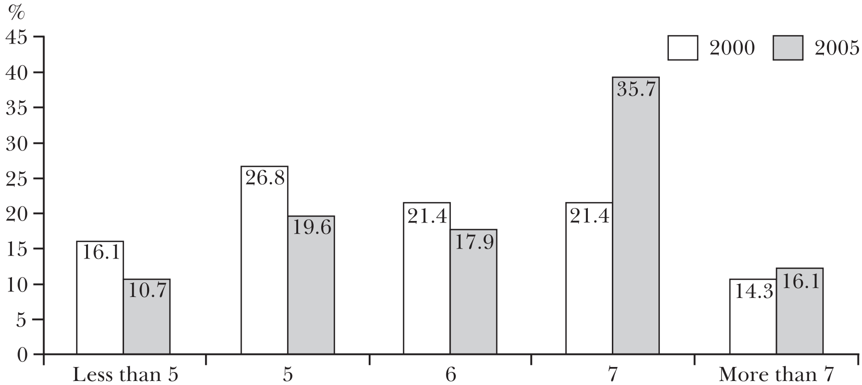
SOURCE: Central banks' annual reports (2000-2005), CEMLA (2005) and central banks' websites. Authors' calculations.

other hand, the considerable variability in the demand for currency in developing countries alters its composition. During periods of high inflation, the purchasing power of the denominations in circulation declines, making it necessary to introduce a denomination that adjusts to market conditions. In other words, an increase in the nominal value of daily transactions in the economy, due to inflation or economic growth, is regarded as a signal to introduce a new denomination.[12]

Figure 2 shows the changes in the denomination structure for the central banks in the sample. As illustrated, there is a tendency for the number of denominations to increase. Between 2000 and 2005, the percentage of countries using six denominations or less decreased and the portion of central banks issuing seven or more denominations increased. The most representative changes occurred in the Eurozone, after adoption of the Euro, in Latin America and in the group of Other Developing Countries (See Attachment 1).

There are different reasons for these changes. In some countries (e.g., Uruguay, Armenia and Hungary), the years when new

FIGURE 2. TRENDS IN THE STRUCTURE OF BANKNOTE DENOMINATIONS, 2000-2005



SOURCES: Central banks' annual reports (2000-2005). CEMLA (2005) and central banks' websites. Authors' calculations.

[12] This applies to countries where the Metric-D System is used. Developed by Payne and Morgan, it is employed to estimate the quantity of banknotes to be produced for each denomination and the predominant structure. The model relates average daily remuneration in the economy to the denominations of banknotes and coins to be issued. For details on models for currency issue, see Mushin (1998).

banknote denominations were introduced coincided with periods of high inflation. In Colombia, the changes in denomination structure were associated with the behavior of inflation, as well as the need to tackle counterfeiting. In Rumania, the adoption of an additional denomination was the result of a redenomination of the nation's currency in 2005.[13]

3. Banknote features

3.1. Security

Central banks include security features on banknotes to prevent counterfeiting. However, this implies the challenge of using security features that are on par with the latest printing, copying and engraving technology. There is considerable variation in the security features used on banknotes. Some are implicit in the paper manufacturing process (e.g., thickness, texture, inlays, etc.); others, such as the use of special inks, symbols, images, serial numbers and the like, are developed during the printing process. The materials used to manufacture banknotes determine some security features and the circulation life. Usually, banknotes are made of cotton paper; however, some countries issue polymer banknotes.[14]

Table 3 shows the percentage of countries that use the most common security features and those that issue polymer banknotes.[15] In general, watermarks and security thread are the security features used the most, because they come already printed in

[13] During the period, the central bank of Colombia issued a $50,000 peso banknote, given the trend in inflation, and a $1,000 peso banknote to discourage counterfeit coins of the same denomination.

[14] Several combinations are used. For example, Bulgaria issued a hybrid polymer-paper banknote in 2005; it is currently undergoing a test period. See Attachment 3 for details about the use of polymer banknotes.

[15] There are many other complimentary features used in certain countries, such as holographic bands (Brazil, Bulgaria, Canada, Hungary, Nicaragua and Norway), holographic patches (Denmark, England and Japan), a multiple redundant hologram (Cyprus and Paraguay), holographic security thread (Bangladesh, Honk Kong and Peru), windowed security thread (Argentina, Canada, Costa Rica, Korea and Paraguay), an iridescent band (Costa Rica, Mexico and Peru), multicolor planchettes (Canada and Colombia), and micro-perforations (Eurozone and Rumania).

cotton paper and polymer. They are, however, more common in paper notes. Security thread has some particular characteristics; it can be used complete, windowed or holographic. Other widely used security features are intaglio printing, micro-inscriptions and hidden images. Perfect register is not as common in the Other Advanced Economies group, and color-changing ink is used less in Latin America.

TABLE 3. SECURITY FEATURES MOST COMMONLY USED ON BANKNOTES AND POLYMER, 2005

	Eurozone	*Other Advanced Economies*	*Latin America*	*Other Developing Countries*
Features	*Countries (12)*	*Countries (14)*	*Countries (10)*	*Countries (13)*
Watermark (%)	100	85.7	100	92.3
Security threads (%)	100	78,6	100	92.3
Intaglio printing (%)	100	78.6	100	84.6
Micro-inscription (%)	100	85.7	90.0	100
Hidden image (%)	100	71.4	90.0	92.3
Perfectly matched drawing (%)	100	57.1	90.0	92.3
Color changing ink (%)	100	78.6	60.0	100
Observation under ultra violent light (%)	100	85.7	50.0	69.2
Hologram (contrasting elements) (%)	100	64.3	50.0	53.6
Average Number of Features	*9.0*	*6.7*	*7.1*	*7.4*
Polymer Banknotes (%)	*0*	*21.4*	*21.4*	*18.8*

SOURCE: Central banks' annual reports (2000-2005) and central banks' websites. Authors' calculations.

NOTE: Security features may vary from one denomination to another. Definitions of each security feature and a list of the countries using them are provided in Attachment 2.

On the other hand, observation under ultra violet light and holograms are not frequent features, except in developed countries.[16] As to holograms, there are some differences. For example,

[16] Most central banks that use observation under ultra violet light print their notes on non-fluorescent paper, which darkens when exposed to this light. Serial numbers, security threads, special characters and fibrils are some of the devices observed most often under ultraviolet light. The United States is known for not using florescent ink; however, the background colors on its banknotes are regarded as essential in the fight against counterfeiting.

Bulgaria, Canada and Hungary use holographic bands; Denmark, England and Japan use holographic patches; and the Euro notes feature bands for low denominations and patches for high denominations.

With respect to the total number of security features used, most of the countries use between seven and eight characteristics, although there are variations among denominations.[17] Only five central banks use less than six security features, while a significant group of countries, including those using the Euro, employ more than 10 features. However, less common elements are used in both groups. These include micro-perforations (Eurozone and Rumania), security backgrounds (Guatemala), Kinegram (Slovak Republic), invisible security fibers, intra-red ink and seal printing (Albania), and accentuated three-dimensional watermarks (Uruguay).[18] In short, not every central bank uses the features described in this section; they combine security features in different ways, depending on the denomination.

A trend towards the adoption of polymer banknotes was identified, mainly in low denomination notes, which have the shortest circulation life. Some of the countries that began issuing polymer notes during the period in question were Brazil (in 2000), Mexico (in 2002) and Chile (in 2004).

3.2. Size

Unlike security features, which are more the result of a decision to discourage counterfeiting, the size of banknotes is an aspect of the production process that central banks may control to reduce production resources (e.g., paper and ink). In many cases, the size of banknotes varies from one denomination to another. For example, the central bank of Denmark decided that all banknotes would be equal in height, but with a difference of 10 mm

[17] The higher denominations usually contain more features. For example, the highest denomination in Rumania has 10 security features; however, the lowest denomination has only three.

[18] The security background consists of fine designs in plane print on the background of the note. The designs form complex figures. Micro-perforations are very small perforations through paper that form figures when they are observed under light. A Kinegram is a half-moon-shaped metallic slip that permits the formation of images that change with the angle of the light.

TABLE 4. SIZE OF BANKNOTES IN CIRCULATION (2005)

Eurozone		*Other Advanced Economies*		*Latin America*		*Other Developing Countries*	
Country (12)	*(cm^2)*	*Country (14)*	*(cm^2)*	*Country (14)*	*(cm^2)*	*Country (16)*	*(cm^2)*
Austria		Australia	93.6	Brazil	91.0	Poland	87.5
Belgium		New Zealand	93.6	Peru	91.0	Bulgaria	89.2
France		Israel	98.0	Mexico	96.6	Malaysia	91.9
Finland		Iceland	100.5	Colombia	98.0	Croatia	92.1
Germany		Norway	101.6	Venezuela	98.5	Bosnia	94.6
Greece		United States	103.4	Dominican Rep.	99.2	Estonia	96.6
Ireland		Denmark	104.4	Nicaragua	100.5	Albania	100.7
Italy	105.6	Canada	106.5	Argentina	100.8	Romania	101.5
Luxembourg		Sweden	106.5	Guatemala	101.3	Slovenia	101.7
Netherlands		Cyprus	112.9	Chile	101.5	Hungary	103.5
Portugal		England	113.2	Bolivia	102.2	Czech Rep.	104.2
Spain		Hong Kong	117.3	Uruguay	102.3	Bangladesh	104.5
		Japan	117.8	Costa Rica	102.3	Armenia	106.1
		South Korea	118.6	Paraguay	105.2	Thailand	108.0
						Slovakia	108.5
						Turkey	123.2
Average	*105.6*		*106.3*		*99.3*		*100.9*

SOURCE: Central banks' annual reports (2000-2005) and central banks' websites. Authors' calculations.

between each denomination. This is done to facilitate classification and counting, as well as to help visually-impaired persons to distinguish the different denominations. This last objective served as justification for the Euro banknotes being designed in sizes that vary with the increase in denomination. The same is true for the British pound sterling and for the Mexican peso since 2006.[19]

Cost considerations also influence the size of banknotes. Larger banknotes are more expensive, because additional materials are used to produce them. For example, more sheets of paper are needed, which translates into more time spent to manufacture and verify the same quantity of banknotes.

The average size of the notes in circulation in each country is compared in Table 4. The developed countries have the largest banknotes. Latin America has the smallest, followed closely by the group of Other Developing Countries. However, this last group is more dispersed, as it includes countries with the smallest and largest banknotes in the entire sample (Poland with 87.48 cm^2 and Turkey with 123.17 cm^2). One strategy to reduce printing costs is to produce smaller banknotes for the lower denominations, because their circulation life is shorter. For example, the central bank of Colombia decided in 2006 to reduce the cost of banknote production by reducing the size of the two lowest denomination notes.[20]

III. PRINTING COSTS, COST FUNCTION, AND EFFICIENCY

1. Comparative Cost Analysis

A comparative analysis of banknote printing costs is provided only for the 28 central banks that supplied detailed information on costs. Printing costs are related to producing banknotes directly or being supplied with new banknotes, depending on the method used.[21]

[19] Mexico plans to begin circulating a complete new family of banknotes of different sizes before 2010.

[20] The size of the $1.000 and $2.000 peso banknotes was reduced by 14% (from 140mm x 70mm to 130mm x 65mm). As a result, the cost of producing those notes will be 15% and 20% less, respectively.

[21] When a central bank purchases banknotes from a private company, the

There are two aspects to consider when comparing the costs incurred by central banks. First, cost data for a central bank can vary considerably due to the different factors that alter production during the year. For example, there are periods when banknote production is low, since the inventory on hand is enough to supply production needs, and there are periods when a large quantity of banknotes must be produced because of deterioration or counterfeiting. This is why the cost figures are analyzed as an average for the years 2000-2005.

Secondly, costs vary widely among central banks, since the quantities of banknotes produced are very different, depending on the characteristics of the country and its economy. For example, while the central bank of Slovenia reports average printing costs of USD 0.5 millions a year, those costs in Japan are about USD 586 millions (See Attachment 3). This explains the need for comparisons linked to variables such as the country's population, the currency in circulation and per capita income.[22]

1.1. Printing costs and currency in circulation

The level of currency in circulation is a good measure of the quantity of banknotes a central bank must produce to satisfy the economy's currency needs. In fact, more currency in circulation implies more production and, consequently, higher costs. This is verified by the high correlation coefficient of the series in Figure 3. The central banks above the regression line have fewer costs in relation to the currency in circulation (e.g., Germany, Canada and Australia). Those below the line and furthest from it are the central banks of Armenia, South Korea, Colombia and Thailand.

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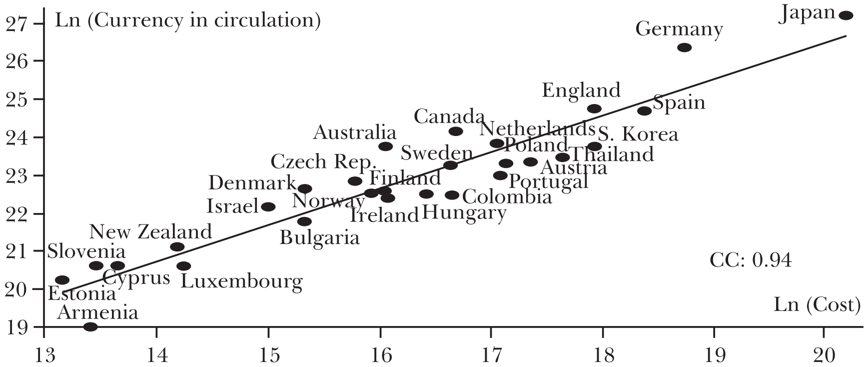
amount it pays includes the company's profit margin. When the government takes responsibility for production, the central bank usually recognizes only production costs, or part of them. When banknotes are produced by the central bank, the cost includes production materials, depreciation of machinery, and the cost of the staff involved directly in production. For the central banks in the Eurozone, data from 2002 to 2005 refer to the production costs of the denominations assigned by the European Central Bank.

[22] The most precise index is the cost per banknote produced; however, only 11 central banks reported detailed information in that respect. This index and two others comparing costs with GDP and operational costs are outlined in Attachment 3.

FIGURE 3. BANKNOTE PRODUCTION COSTS AND CURRENCY IN CIRCULATION, 2000-2005

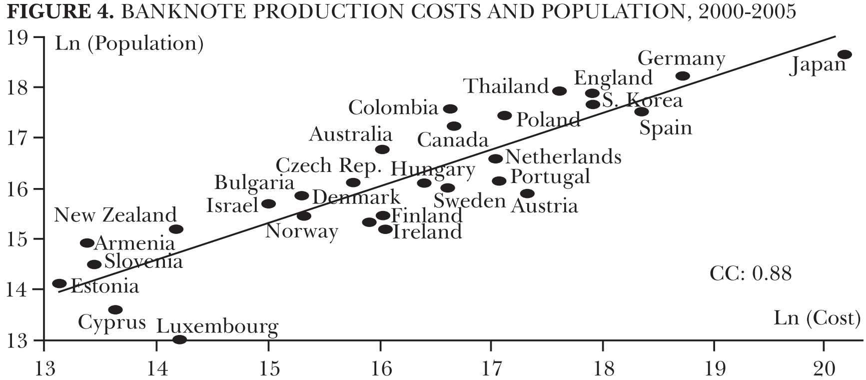


SOURCES: Central banks' annual reports (2000-2005). Authors' calculations.

1.2. Printing costs and population

The country's population also is considered a measure of the quantity of banknotes required for the economy. With this index, printing costs are compared to the population the central bank must supply with banknotes. The central banks situated above the regression line in Figure 4 have comparatively low costs, considering their population.

FIGURE 4. BANKNOTE PRODUCTION COSTS AND POPULATION, 2000-2005



SOURCES: Central banks' annual reports (2000-2005). Authors' calculations.

The central banks with the best results are those of Colombia, Australia, Canada and Armenia. In contrast, the central banks of Japan, Luxembourg and Austria are situated below the regression line. In the case of Japan, the central bank has costs four times higher than those of Germany, but with a population that is only 1.5 times larger.

2. A cost function for banknote printing

To suggest strategies to reduce printing costs and to enhance efficiency in the performance of this function, it is necessary to identify the variables that determine printing costs. For this purpose, a cost function is estimated using a panel data model with random effects for 28 central banks during the years 2000-2005.

2.1. The model

The printing cost function for central banks is assumed as a traditional Cobb-Douglas cost function, which is expressed as follows:

$$\ln C(y,w) = \beta_0 + \beta_1 \cdot \ln(Y) + \sum_{i=1}^{n} \beta_i \cdot \ln(w_i) \tag{1}$$

In the previous equation, (*Y*) represents the quantity in terms of the final service or goods produced and (*w*) the prices of *i* production factors. Using a Cobb-Douglas cost function is appropriate for this exercise as it allows for direct inference with respect to the elasticities of the independent variables. For the econometric estimation, this function can be expressed as a log-lineal equation, where a set of variables (*Z*) affecting production costs and those beyond the bank's control can be included (Battese and Coelli, 1995). Because efficiency measures are not estimated directly and there is no data on input prices, the variable (*w*) is omitted. Therefore, the following short-term cost function is used:

$$\ln(C_{it}) = \beta_0 + \beta_1 \cdot \ln(Y_{it}) + \sum_{j=1}^{m} \beta_j \cdot \ln(Zj_{it}) + u_{it} \tag{2}$$

Variables that reflect the output level, the characteristics of banknote production, and the production methods used by central banks are introduced into the model, based on equation (2). The econometric model is:

$$\begin{aligned} Ln(C_{it}) = B_0 + B_1.Ln(N_{it}) + B_2.Ln(Circ_{it}) + B_3.Ln(Y_{it}) + B_4.Ln(Den_{it}) + \\ + B_5.Ln(Sec_{it}) + B_6.Ln(Size_{it}) + B_7.Priv_{it} + B_8.Gov_{it} + u_{it} \end{aligned} \tag{3}$$

In equation (3), the banknote printing costs (*C*) are a function of the population of the country (*N*), the currency in circulation (*Circ*), per capita income (*Y*), the number of denominations produced and circulating in the economy (*Den*), the average number of security features (*Sec*), the average size of the banknotes (*Size*), and the method used by a central bank to produce banknotes (*Priv* and *Gov*).

The variable (*Priv)* refers to the method whereby private third parties participate in the printing process. This can include joint venture agreements, the various subsidiary methods or full delegation of the process to private companies, with the central bank purchasing their output. This is a dummy variable that takes the value of one in either of the aforementioned cases and zero in the other. Likewise, (*Gov)* is a dummy variable that specifically identifies the method in which the government is responsible for banknote printing; accordingly, it takes the value of one in that case and zero in the other.[23]

The relation between the first two explicative variables (*N* and *Circ*) and costs was identified in the previous indicators. These variables are introduced in the model as *proxies* of the amount of output the central bank must supply to the economy. They are expected to have a positive sign over them, inasmuch as the larger the country's population, the larger the quantity of banknotes required and, therefore, the higher the costs. By the same token, if there is a large amount of currency circulating within the economy, the country's need for currency will be greater and so will production costs.

Per capita income (*Y*) is a variable used to identify the extent to which an economy's level of financial development affects printing costs. Usually, in more developed economies, the use of noncash means of payment (e.g., electronic transfers and cards) is more prevalent; so, a negative sign is expected for this variable.[24] Moreover, the number of denominations (*Den*) is, to some extent, a measure of output, as the central bank has the obligation to supply banknotes of every denomination in circulation. A positive

[23] The method whereby the central bank is in charge of printing all banknotes is the base case model. In other words, it is identified because the (*Priv*) and (*Gov*) variables assume the zero value simultaneously.

[24] There has been evidence of this situation in recent years (BIS, 2007).

sign is expected, because the more denominations there are, the greater the need for different types of plates, paper, ink combinations and time.

The security features (*Sec*) and the size of the banknotes (*Size*) are particular aspects of the product and are defined by the central bank. However, the central bank exercises only indirect control over security features, which depend on factors such as counterfeiting. The bank is required to prevent counterfeiting through the introduction of security features. Positive signs are expected for both variables, because more security features and larger sized banknotes imply the use of more materials and production factors. This, in turn, raises costs. Lastly, the variables (*Priv* and *Gov*) are intended to discover if the methods used to produce banknotes determine their cost, and which of those methods may represent greater benefits in terms of cost.

2.2. Methodology and results

A random-effects panel data model was used to estimate equation (3), which is given as follows:

$$y_{it} = X_{it}\beta + u_{it} \tag{4}$$

Where: i = 1, ...,28 y t = 2000,...,2005.

Equation (4) represents a traditional panel data model where Y_{it} is the dependent variable that changes for each central bank i during each time period t; X_{it} is the set of explicative variables, and u_{it} is the error term, which is given as follows:

$$u_{it} = \mu_i + \varepsilon_{it} \tag{5}$$

In equation (5), μ_i represents the individual effect (either fixed or random) and ε_{it} is the observation error.[25] An estimator with dynamic effects allows for differences in minimal printing costs between central banks, by allocating different values to each observation.[26]

[25] As to the difference between a model with fixed effects and one with random effects, the latter adduces a random variable that changes for each individual, whereas the effect in the former is a fixed number. The selection of the model depends on the correlation between the individual effect and the explicative variables, which are reviewed using the Hausman test (Hsiao, 2003).

[26] An interesting exercise would be to obtain different coefficients for all the

Equation (3) above was estimated with the generalized least squares method (GLS), using the random effects obtained with the Hausman test. The results in Table 5 show a consistent model specification and high joint significance of variables. The population and circulation coefficients were positive and significant, with a 99% confidence level. This indicates they are good approximations to output and have a positive impact on costs.

TABLE 5. RESULTS OF THE PANEL DATA MODEL

	Dependent variable: Ln(*C*) Observations: 168, Random Effects – GLS Regression
Intercept	10.3371 (1.50)
Ln (*N*)	0.5894 (4.35)[c]
Ln (*Circ*)	0.7395 (5.21)[c]
Ln (*Y*)	-0.1085 (-2.03)[b]
Ln (*Den*)	0.6740 (1.87)[a]
Ln (*Sec*)	w.s. (-0.71)
Ln (*Size*)	1.9855 (3.09)[c]
Priv	-0.0895 (-2.17)[b]
Gov	0.3402 (2.11)[b]
Wald (*p-value)*	293.59 (0.00)
Hausman (*p-value)*	2.7103 (0.93)

SOURCE: Authors' calculations.

NOTES: w.s.: Wrong sign; Wald's test: Joint significance of the variables (Prob. > Chi 2); Hausman test: Differences in coefficients are not systematic (Prob. > Chi 2).

[a] Indicate the statistics are significantly different from zero at 1%. [b] Indicate the statistics are significantly different from zero at 5%. [c] Indicate the statistics are significantly different from zero at 10%.

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variables at each central bank, using a Swamy model. However, the number of years for which data were obtained is very limited and prevents the use of this type of model (Amemiya, 1978).

As to the per capita income variable, its coefficient is significant and its sign is negative, as was expected. This may suggest that more developed economies make more use of payment means other than currency, which is related to less need for currency and lower costs. The denomination structure used by central banks was significant, with a 90% confidence level and a positive sign. This suggests that a central bank with fewer denominations could have lower printing costs.

Contrary to expectations, the coefficient of the variable including the number of security features (*Sec*) is negative and not significant. So, the variable is not a relevant cost determinant. However, printing costs may be determined by the kind of security features used, as opposed to their number. Unfortunately, this detailed information is difficult to incorporate into the model.[27]

Banknote size, as a variable used to detect an important feature of the product, proved to be highly significant and had the expected sign. In other words, a central bank's decision about the size of banknotes has a major impact on production costs. Therefore, adopting smaller-sized banknotes is a valid strategy for reducing production costs. This largely supports the decisions taken recently by a number of central banks in that respect (e.g., Colombia and Mexico).

One of the model's most relevant results concerns the coefficients of the variables related to production methods. Those variables proved to be significant, confirming that the method a central bank selects to produce its banknotes does much to determine the cost of their production. The coefficients obtained and their signs allow for some important conclusions, considering that the base method used in the model is the case where production is the responsibility of the central bank. To begin with, the costs are higher when governments are responsible for banknote production than when production is done by the central bank. In fact, the difference is substantial. The coefficient suggests that, in countries where the government is responsible for production,

[27] Other characteristics such as the use of polymer may affect printing costs. However, this variable could not be included in the model, because only three central banks in the sample issue polymer banknotes (Australia, New Zealand and Thailand) and only Thailand registered changes during the period. This avoids a correct statistical inference over the variable.

the cost is 34% higher, on average, than when the central bank is in charge of production.

Secondly, the costs are less when a degree of private participation in banknote production is allowed, than when production is the exclusive responsibility of the central bank. These results confirm the decisions taken by some central banks to include private agents or companies that specialize in banknote production, be it through management agreements, the establishment of subsidiaries, the sale of the bank's entire printing works, etc. Elasticity calculated on the basis of the coefficient suggests that a central bank may be able to reduce its costs by almost 9% if it involves the private sector in the production process.

3. Efficiency and productivity change in banknote printing

To complement this analysis, measures of technical efficiency in banknote printing and changes in productivity during the period are identified. These measures are obtained by estimating an efficient production frontier and by constructing the Malmquist Index. The latter makes it possible to decompose productivity changes into changes in efficiency and technology for the years under study.

An efficiency frontier can be estimated using the nonparametric approach known as Data Envelopment Analysis (DEA), or the parametric methodology known as the Stochastic Frontier Approach (SFA).[28] Among the most recent applications to central banking is the study by Wheelock and Wilson (2004), which used a DEA model to gauge check-processing efficiency at the offices of the US Federal Reserve Bank (Fed). With the SFA, Bohn et al. (2001) assessed the efficiency of currency processing at the Fed's 37 branch offices. The same function was assessed by Sarmiento

[28] The SFA presented by Aigner et al. (1977) is based on the estimation of a cost or a production function (*e.g.*, Cobb Douglas or Trans-log), where the parameters allow for characterizing the efficiency frontier. With this approach, the error term is divided into two components: random error and technical inefficiency (Kumbhakar and Lovell, 2000). On the other hand, the DEA methodology proposed by Charnes et al. (1978) models a set of variables (input and output) and the type of returns to scale by means of a linear programming model, which is optimized to obtain a technical efficiency index for each assessed unit (Cooper et al., 2000).

(2005), using a DEA model for 15 branch offices of the central bank of Colombia during the years 2000-2004. An international comparison was developed by McKinley and Banaian (2005) using the SFA to evaluate the efficiency of monetary policy and financial supervision at 32 central banks from OECD and developing countries.[29]

Productivity change may be estimated through production/cost functions or by constructing index numbers using non-parametric methods. As to this last approach, the Malmquist Index was presented initially by Caves et al. (1982) and widely developed by Färe et al. (1989), who decomposed variations in productivity into efficiency and technology changes in the course of time.[30]

A DEA input-oriented model is used to evaluate technical efficiency in banknote printing for 28 central banks in the years 2000-2005. The same approach is used to calculate the Malmquist Index and to estimate changes in productivity and its components during the period under study.

Using the non-parametric approach to estimate efficiency and productivity measures does not impose a specific functional form for the structure of production or technology (unknown in this case). This is contrary to the parametric approach. Moreover, the Malmquist Index does not require information about the quantity and price of input and output, or assumptions about profit maximization or cost minimization. These conditions are required to calculate the Törnqvist and Ficher indexes, which also are used to measure changes in productivity. These two features make the Malmquist Index a useful instrument for identifying productivity changes in the public sector and among central banks, where prices usually are not available (Coelli et al., 1998; Sarmiento, 2007)

3.1. Technical, global and scale efficiency

An enveloped and convex production possibilities set (PPS) with

[29] For a more detailed analysis of efficient frontier models and their application to central banking, see Mester (2003).

[30] The Malmquist Index has been applied widely to the financial system, mostly to analyze productivity changes in the wake of financial liberalization processes (Humphrey, 1993; Wheelock and Wilson, 1999; Park and Weber, 2006). A detailed review of the application of this methodology to the financial system is presented by Berger and Mester (1997).

considerable input and output availability is assumed with the DEA approach. The PPS or technology, which is referred to as Z, is comprised of vector M of input $x = (x_1,...,x_M)' \in R_+^M$, which is used to produce vector S of output $y = (y_1,...,y_S)' \in R_+^S$.

After the production technology is defined, we have N central banks that consume M input to produce S output.[31] Central bank j consumes X_{ji} of input i and produces Y_{jr} of output r, assuming that $X_{ji} \geq 0$ and $Y_{jr} \geq 0$. In fact, both X and Y are matrices MxN and SxN, which contain all input and output corresponding to the N-evaluated central banks. Accordingly, the model, which allows us to measure the technical efficiency of input for each central bank during period t, is (Charnes et al., 1978):

$$\begin{gathered} \underset{\theta,\lambda}{Min\theta} \\ r.t.\ \ \lambda X^t - \theta x_0^t \leq 0 \\ \lambda Y^t \geq y_0^t \\ \lambda \geq 0 \end{gathered} \tag{6}$$

The model stated in equation (6) is intended to minimize the quantity of input used by the assessed central bank; where θ is a scalar accompanying each item of input, and λ is an intensity vector (Nx1) weighting the input and output level of each assessed central bank. The process is the same for each central bank j, by introducing $(x_o, y_o) = (x_j, y_j)$ into the model. Therefore, a central bank is technically efficient if $\theta^* = 1$ and $\lambda^* = 0$; on the other hand, it is inefficient if $\theta^* < 1$ and $\lambda^* > 0$.[32]

The model assumes constant returns to scale (CRS), which implies that every central bank operates according to an optimal

[31] According to Färe (1988), that within the PPS of output $P(x)$ and the PPS of input $L(y)$ $(x,y) \in Z \Leftrightarrow y \in P(x) \Leftrightarrow x \in L(y)$. Given this relation, Z has strong input and output availability if, for a productive process, $(x,y) \in Z, \forall x' \geq x \Rightarrow (x', y) \in Z$ and $\forall y' \leq y \Rightarrow (x, y') \in Z$ or, alternatively if $x \in L(y), x' \in L(y), \forall x' \geq x$ and $y \in P(x), y' \in P(x), \forall 0 \leq y' \geq y$.

[32] Nevertheless, a central bank may show $\theta^* = 1$ and $\lambda^* > 0$. This is a frontier point located in the weak zone of the efficiency frontier. To distinguish between a frontier point and an efficient frontier point, Seiford and Thrall (1990) state that the radial projection $(x_o, y_o) \rightarrow (\theta^* x_o, y_o)$ always takes to a frontier point, but the technical efficiency is reached only if $\theta^* x_o = X\lambda^*$ and $y_o = Y\lambda^*$, for every λ^*. Therefore, to reach technical efficiency, restrictions must be met with equalities.

production scale. Nevertheless, market failures and variables not controlled by central banks (e.g., demand for currency) may result in banks that are not producing at optimal scales. In fact, Banker et al. (1984) studied variable returns to scale (VRS) by adding the restriction $e^T\lambda = 1$ (where e is a ones' vector of Nx1) to equation (6). This generates an additional convexity requirement, specifically one where the production possibilities on the efficient frontier must have segments joining the extreme points. Then, with a CRS model, a measurement of global technical efficiency (GTE), without scale efficiencies, is obtained. Using a VRS model, technical efficiency is found and a determination is made as to whether a central bank is producing in the increasing or decreasing returns-to-scale zone. The ratio of both models allows us to find a scale efficiency (SE) measurement for every central bank, as follows: $SE = \theta^{CRS} / \theta^{VRS}$.

3.2. Productivity change: a Malmquist Index approach

To estimate changes in productivity, the Malmquist Index approach presented by Färe et al. (1989) is used, where changes in productivity are determined by efficiency and technology changes in the course of time. The Malmquist Index is expressed as follows (see Appendix):

$$M_I(X^{t+1},Y^{t+1},X^t,Y^t) = \frac{D_I^{t+1}(X^{t+1},Y^{t+1})}{D_I^t(X^t,Y^t)}\left[\left(\frac{D_I^t(X^{t+1},Y^{t+1})}{D_I^{t+1}(X^{t+1},Y^{t+1})}\right)\left(\frac{D_I^t(X^t,Y^t)}{D_I^{t+1}(X^t,Y^t)}\right)\right]^{1/2} \quad (7)$$

The first component in (7) calculates changes in technical efficiency (catch-up) by comparing the distance from a central bank to the efficiency frontier each year. If the value of this ratio is above one, the central bank is more efficient in period $t+1$ than in period t (it is closer to the frontier in period $t+1$). The opposite is suggested if the ratio is below one. The second component in (7) calculates technical change or boundary shift in industry (in this case, all central banks comprise a set) by comparing the distance between the efficiency frontiers in t and the one in $t+1$. Therefore, if the result of this component is above one, the industry presented a positive technological shift, improving the central banks' relative efficiency.

The result of multiplying both components is the Malmquist

Index. If it is above one, the central bank increased its productivity during the period in question. The increase may be due to an increase in technical efficiency and/or a positive technological shift. When there are variable returns to scale (VRS), the change in efficiency may be divided into two separate components: pure technical efficiency and scale efficiency (Färe et al., 1994):

$$CE = \frac{D_I^{t+1}(X^{t+1},Y^{t+1})}{D_I^{t}(X^{t},Y^{t})} = \frac{D_{VRS}^{t+1}(X^{t+1},Y^{t+1})}{D_{VRS}^{t}(X^{t},Y^{t})} \times \frac{\dfrac{D_{CRS}^{t+1}(X^{t+1},Y^{t+1})}{D_{VRS}^{t+1}(X^{t+1},Y^{t+1})}}{\dfrac{D_{CRS}^{t}(X^{t},Y^{t})}{D_{VRS}^{t}(X^{t},Y^{t})}} \quad (8)$$

The non-parametric method (DEA) is used to calculate the Malmquist Index, assuming distance functions reciprocal to the input-oriented technical efficiency measure defined above in equation (6) (Seiford and Thrall, 1990).

3.3. Results on efficiency and productivity change

Printing costs and the size of banknotes were introduced into the model as input, so as to measure technical efficiency and changes in productivity. These elements are regarded as variables the central bank is able to control. Moreover, the number of denominations and the quantity of currency in circulation per inhabitant were introduced as output variables in the model. All of these variables showed high statistic significance as determinants of printing costs (Section 2). Estimations were calculated for the same 28 central banks used in the econometric model (see Attachment 4).

Table 6 shows the results of the three efficiency measures (technical, global and scale) calculated with the model in equation (6). The results of the variable returns-to-scale model (VRS) show that, during the period under study, 75% of central banks increased their technical efficiency (TE) in banknote printing, and the average technical efficiency index for the central banks in the sample was 0.93. It is remarkable that the central banks of Bulgaria, Estonia and Slovenia are located at the efficiency frontier in every assessed period. Those central banks use three different methods to produce banknotes: subsidiary company, central bank and importation, respectively.

TABLE 6. TECHNICAL, GLOBAL AND SCALE EFFICIENCY AT CENTRAL BANKS, 2000-2005

		Technical Efficiency (TE-VRS)						*Average (2000-2005)*		
Central Bank	*Method*[a]	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*TE (vrs)*	*GTE (crs)*	*SE*
Armenia	C.B	0.993	0.928	0.966	0.932	1.000	0.946	0.961	0.717	0.746 (irs)
Australia	S	0.940	0.961	0.972	0.990	0.996	0.995	0.976	0.790	0.810 (drs)
Austria	S	0.971	0.918	0.891	0.910	0.922	0.941	0.925	0.866	0.935 (drs)
Bulgaria	S	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.879	0.879 (irs)
Canada	P.C	0.912	0.878	0.874	0.880	0.878	0.881	0.884	0.689	0.780 (drs)
Colombia	C.B	0.878	0.867	0.888	0.913	0.921	0.927	0.899	0.714	0.794 (irs)
Cyprus	I	1.000	0.876	0.999	0.958	0.915	0.895	0.940	0.591	0.628 (drs)
Czech Rep.	G	0.927	0.926	0.925	0.928	0.932	0.941	0.930	0.906	0.975 (drs)
Denmark	C.B	0.938	0.937	0.918	0.925	0.930	0.931	0.930	0.732	0.788 (drs)
England	P.C	0.797	0.806	0.814	0.828	0.833	0.829	0.818	0.633	0.774 (drs)
Estonia	I	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.949	0.949 (drs)
Finland	P.C	0.896	0.891	0.968	0.958	0.966	0.949	0.938	0.841	0.897 (drs)
Germany	P.C	0.946	1.000	1.000	1.000	1.000	0.933	0.980	0.973	0.994 (drs)
Hungary	S	0.872	0.880	0.893	0.891	0.897	0.894	0.888	0.821	0.925 (irs)
Ireland	C.B	0.984	0.947	0.893	0.908	0.935	0.937	0.934	0.845	0.904 (irs)

Israel	I	0.996	0.937	0.922	0.969	0.959	0.953	0.956	0.623	0.651 (drs)
Japan	G	1.000	1.000	0.898	1.000	1.000	1.000	0.983	0.969	0.985 (drs)
Luxembourg	I	1.000	0.986	0.975	1.000	1.000	1.000	0.994	0.905	0.911 (drs)
Netherlands	P.C	0.899	0.854	0.897	0.892	0.915	0.938	0.899	0.844	0.938 (drs)
New Zealand	I	0.954	0.967	1.000	0.993	1.000	0.986	0.983	0.726	0.738 (irs)
Norway	C.B	0.939	0.931	0.922	0.939	0.940	0.946	0.936	0.770	0.823 (drs)
Poland	P.C	0.955	0.961	0.970	1.000	1.000	1.000	0.981	0.740	0.754 (drs)
Portugal	S	0.875	0.889	0.873	0.900	0.923	0.906	0.894	0.804	0.899 (irs)
Slovenia	C.B	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000 (crs)
South Korea	G	0.776	0.757	0.773	0.782	0.782	0.778	0.775	0.553	0.714 (drs)
Spain	G	0.904	0.887	0.871	0.871	0.886	0.903	0.887	0.832	0.938 (drs)
Sweden	P.C	0.905	0.879	0.877	0.902	0.911	0.904	0.896	0.725	0.809 (irs)
Thailand	C.B	0.815	0.794	0.816	0.838	0.846	0.845	0.826	0.663	0.803 (drs)
Average	..	*0.931*	*0.916*	*0.921*	*0.932*	*0.939*	*0.934*	*0.929*	*0.789*	*0.848*

SOURCE: Authors' calculations.

[a] The banknote production method used in 2005. P.C: private company; C.B: central bank; S: subsidiary; I: importation; G: government. T.E: technical efficiency (VRS model); ETG: global technical efficiency (CRS model); S.E: scale efficiency (S.E = GTE/TE); drs: decreasing returns to scale; irs: increasing returns to scale; crs: constant returns to scale.

A look at global technical efficiency (GTE), which is obtained by calculating the model with CRS, shows a relevant reduction in the efficiency index; it declined to 0.79, on average. This is a consequence of the CRS approach, where central banks are compared under the assumption that they operate at an optimal production scale. However, this is not a genuine situation for central banks, due to market failures, particularly differences in the demand for currency. This result is proved empirically with the scale-efficiency index (SE), which shows that 68% of the central banks are located in the decreasing returns-to-scale zone (DRS), while 28% are located in the increasing returns-to-scale zone (IRS). Only the central bank of Slovenia is in the constant returns-to-scale (CRS) or optimal zone, with an index equal to one.

Knowing the type of scale returns is very useful, because it allows us to identify aspects that are crucial to a central bank's performance. In fact, for central banks located in the increasing returns-to-scale zone (IRS), an increase in the input level will result in more than proportional increases in the output level. For example, in the case of the central bank of Colombia, a larger production scale would generate a more than proportional increase in the production level. This justifies the construction of the Central de Efectivo, which is the banknote printing and cash processing complex in Colombia. It initiated operations in 2006.

The results of the Malmquist Index and its components are presented in Table 7, which shows the central banks moderately increased their productivity, especially during the 2004-2005 period, when they registered an increase of 1.7%.

The larger increases in productivity were registered by the central banks of Portugal, Bulgaria, Austria, Australia, Colombia and Sweden, with increases above 10%. The average productivity increase for the sample was 0.2%. It is important to point out that the five central banks producing banknotes through a subsidiary company are among the 13 central banks with average productivity increases (38.5%). In terms of production methods, they are followed by central banks producing through private companies and by those producing banknotes with their own resources, with three central banks each of these categories.

In general, productivity increases are primarily a consequence of increased efficiency. Technical change is also a factor, but less so. In most cases, a positive change in efficiency is largely the result of higher scale efficiency; another factor, but not as important, is the added proximity of central banks to the reference frontier efficiency (pure efficiency). This could be due to the sharp increase in demand for currency, which led to an important increase of banknote production for most central banks. In Colombia, for example, the growth in banknote production between 2000 and 2005 was about 45%, due to the high demand for currency motivated by the financial transaction tax, which has reduced the use of checks and electronic payment methods.[33]

IV. CONCLUSIONS

The main modernization strategies implemented recently by central banks to deal with the growing demand for currency are identified in this paper. The period under study witnessed a decline in the number of central banks producing banknotes and an increase in partial or full private involvement in the banknote production process (e.g., Croatia, England, Sweden and Bulgaria). The central banks of Portugal and Colombia apply a strategy that combines currency production, processing and distribution activities under one roof, in a single complex.

It was found that most Latin American central banks import their banknotes, which becomes a marketing opportunity for the region's central banks that are involved in the printing process. As to denominations, the central banks of developed countries were found to have fewer denominations than the developing countries, which have issued new denominations in recent years (e.g., Bulgaria and Uruguay).

There are important differences in the use of security features on banknotes, which vary by country and denomination, and are associated with the material used to print banknotes (cotton paper or polymer). In fact, a tendency towards the production of polymer banknotes was identified, especially for low denomination banknotes, which are those with the shortest circulation life (e.g., Brazil, Mexico and Chile). Regarding the size of banknotes, the average size is smaller in Latin America and in other developing

[33] Arango et al. (2006) showed the hidden economy also has an important effect on the demand for currency in Colombia.

TABLE 7. MALMQUIST INDEX. TECHNICAL AND EFFICIENCY CHANGES. 2000-2005

		Malmquist Index					*Average (2000-2005)*				
Central Bank	*Method*[a]	*2000-2001*	*2001-2002*	*2002-2003*	*2003-2004*	*2004-2005*	*Malmquist Index*	*Technical Change*	*Efficiency Change*	*Pure Efficiency*	*Scale Efficiency*
Armenia	C.B	0.974	1.018	1.033	0.997	0.966	0.998	0.961	1.037	0.992	1.048
Australia	S	0.994	0.986	1.023	1.018	1.051	1.014	1.039	0.975	1.011	0.965
Austria	S	0.986	1.002	1.000	1.047	1.031	1.013	1.015	0.999	0.994	1.003
Bulgaria	S	0.995	1.033	1.024	0.997	1.019	1.014	1.013	1.001	1.000	1.001
Canada	P.C	0.975	0.935	1.010	0.994	1.039	0.991	0.999	0.990	1.007	0.996
Colombia	C.B	0.995	1.002	1.003	1.056	1.005	1.012	0.937	1.069	1.011	1.057
Cyprus	I	0.994	1.031	1.033	0.997	0.971	1.005	1.015	0.991	0.982	1.011
Czech Rep.	G	0.981	1.004	0.999	0.995	1.018	0.999	0.990	1.006	1.003	1.003
Denmark	C.B	0.966	0.950	1.015	1.003	1.046	0.996	0.988	0.993	0.998	0.994
England	P.C	0.971	0.987	1.000	0.995	1.042	0.999	0.998	0.994	1.008	0.986
Estonia	I	0.976	1.009	1.004	0.999	1.003	0.998	0.984	1.010	1.000	1.010
Finland	P.C	0.977	0.994	1.022	1.010	1.007	1.002	0.934	1.072	1.012	1.056
Germany	P.C	0.996	1.000	1.000	1.000	0.960	0.991	1.002	0.992	0.998	0.993
Hungary	S	0.985	1.013	0.999	0.996	1.010	1.001	0.970	1.032	1.005	1.027

Ireland	C.B	0.963	1.005	0.999	1.023	1.029	1.004	0.983	1.021	0.991	1.032
Israel	I	0.973	0.955	1.000	0.995	1.025	0.990	1.001	0.989	0.992	0.998
Japan	G	1.000	0.988	1.009	0.977	1.006	0.996	0.990	1.002	1.002	1.001
Luxembourg	I	0.976	1.007	1.024	0.995	1.005	1.001	0.959	1.049	1.000	1.049
N. Zealand	I	0.998	0.995	1.003	0.996	1.005	1.000	0.998	1.002	1.007	0.996
Netherlands	P.C	0.972	0.988	0.992	1.014	1.049	1.003	0.977	1.026	1.009	1.015
Norway	C.B	0.974	0.986	1.000	1.031	1.055	1.009	1.015	0.994	1.007	0.989
Poland	P.C	0.988	0.994	0.998	0.996	1.010	0.997	0.996	1.002	1.009	0.993
Portugal	S	0.986	1.057	1.005	1.016	1.027	1.018	0.968	1.051	1.007	1.044
S. Korea	G	0.985	0.976	1.000	1.036	1.013	1.002	1.033	0.994	1.001	0.993
Slovenia	C.B	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Spain	G	0.961	0.971	0.999	0.995	1.029	0.991	0.950	1.048	1.000	1.048
Sweden	P.C	0.987	1.003	1.017	0.990	1.060	1.011	1.024	0.988	1.000	0.988
Thailand	C.B	0.994	1.002	1.001	0.999	0.997	0.998	0.999	0.999	1.007	0.992
Average	..	*0.983*	*0.996*	*1.008*	*1.006*	*1.017*	*1.002*	*0.991*	*1.012*	*1.002*	*1.010*

Source: Authors' calculations
[a] The banknote production method used in 2005. P.C: private company; C.B: central bank; S: subsidiary; I: importation; G: government.

countries than in advanced economies. There also is a tendency to reduce the size of banknotes, which usually results in differences among the denominations (e.g., Colombia and Mexico).

On the other hand, our comparative analysis of banknote printing costs showed major differences among central banks, primarily due to the size of the country's population and the amount of currency in circulation. The cost function estimate showed the number of denominations and the size of banknotes are important factors that affect printing costs. Consequently, reductions in these characteristics lead to major cost savings. The method a central bank uses to produce banknotes was found to be another determinant of printing costs. In fact, government printing was shown to be the most costly method, while involving the private sector in the production process (e.g., through joint ventures, subsidiaries or specialized companies) substantially reduces costs.

The efficient frontier model showed that most central banks increased their technical efficiency during the period under study, especially in cases where the private sector is involved. Likewise, our Malmquist Index calculation indicates that central banks have seen a moderate increase in productivity, primarily due to greater efficiency. Technical change is also a contributing factor, but less so. In most cases, a positive change in efficiency is mainly the result of higher scale efficiency, which could be due to the sharp increase in demand for currency.

This study identifies possible strategies to reduce banknote printing costs and to produce banknotes more efficiently. Decreasing the number of denominations in circulation, reducing the size of banknotes, and involving the private sector to some extent in the production process are among the most important strategies. However, in some countries, there are economic and institutional conditions (e.g., counterfeiting or a hidden economy) that should be assessed carefully before any strategy is adopted.

Appendix

The Malmquist Index Approach

The starting point for this approach is the definition of set Z^t (production technology), within which input $X^t \in R_+^M$ is transformed into output $Y^t \in R_+^S$. This process is done for each time period $t = 1,\ldots,T$, where $Z^t = [(X^t,Y^t)$: X^t can produce $Y^t]$. The Malmquist Index is founded with the distance functions introduced by Shephard. Input orientation, it is represented as follows (Färe et al. (1989):

$$D_I^t(X^t,Y^t) = \max\left[\theta \geq 1 : (X^t/\theta, Y^t) \in Z^t\right] \tag{9}$$

Equation (9) seeks to maximize the radial input contraction to reach a given output level in period t. Likewise, in period $t+$, the distance function is determined by $D_I^{t+1}(X^{t+1},Y^{t+1})$. For intra period comparison, it is necessary to define a distance function $D_I^t(X^{t+1},Y^{t+1})$, where the (X^{t+1},Y^{t+1}) combination is viable in relation to technology in t. A distance function $D_I^{t+1}(X^t,Y^t)$ is required as well, where the (X^t,Y^t) combination is possible under technology in period $t+1$. Once the distance functions have been defined, it is possible to define the Malmquist index as:

$$M_I(X^{t+1},Y^{t+1},X^t,Y^t) = \left[\frac{D_I^t(X^{t+1},Y^{t+1})}{D_I^t(X^t,Y^t)} \times \frac{D_I^{t+1}(X^{t+1},Y^{t+1})}{D_I^{t+1}(X^t,Y^t)}\right]^{1/2} \tag{10}$$

Equation (10) shows the Malmquist Index is the geometric mean of two indexes, which use technology in t and $t+1$ as a reference. This equation can be formulated to obtain changes in productivity, which are determined by changes in efficiency and technological changes in the course of time, as it is expressed in Chapter III, equation (7).

Measuring changes in productivity for central banks between t and $t+1$ requires solving four linear programming problems using the non-parametric method (DEA): $D_I^t(X^t,Y^t)$, $D_I^{t+1}(X^t,Y^t)$, $D_I^t(X^{t+1},Y^{t+1})$, $D_I^{t+1}(X^{t+1},Y^{t+1})$. To do so, it is assumed that each central bank $j = 1,2,\ldots, N$, employs $m = 1,2,\ldots,M$ input $x_m^{t,j}$ to produce $s = 1, 2,\ldots,S$ output $y_s^{t,j}$. Solving the first problem, including technology and observations in period t, implies solving the following problem for the j' central bank:

$$D_I^t(X^{t,j'},Y^{t,j'}) \ = \ \min \theta^{j'} \tag{11}$$

$$r.t. \ \sum_{j=1}^{N} \lambda^{t,j} x_m^{t,j} = \theta^{j'} x_m^{t,j'}$$

$$\sum_{j=1}^{N} \lambda^{t,j} y_s^{t,j} = y_s^{t,j'}, \ \lambda^{t,j} \geq 0$$

Likewise, the distance function $D_I^{t+1}(X^{t+1}, Y^{t+1})$ is calculated by replacing *t* for *t+1* in equation (11). When distance functions require information from both periods simultaneously, the problem is:

$$D_I^t(X^{t+1,j'}, Y^{t+1,j'}) = \min \theta^{j'} \qquad (12)$$

$$r.t. \ \sum_{j=1}^{N} \lambda^{t,j} x_m^{t,j} = \theta^{j'} x_m^{t+1,j'}$$

$$\sum_{j=1}^{N} \lambda^{t,j} y_s^{t,j} = y_s^{t+1,j'}, \ \lambda^{t,j} \geq 0$$

In equation (12), the reference technology for the assessed central bank $(X^{t+1,j'}, Y^{t+1,j'})$ is that of period *t*. Therefore, $D_I^t(X^{t+1,j'}, Y^{t+1,j'})$ may take values above 1; this is contrary to the situation in equation (11), where $(X^{t,j'}, Y^{t,j'}) \in Z^t$ and $D_I^t(X^{t,j'}, Y^{t,j'}) \leq 1$. In the case of distance function $D_I^{t+1}(X^t, Y^t)$, the problem to solve is the one in equation (12), but the time periods are exchanged. In order to decompose the shift in efficiency into pure and scale efficiency, the distance functions using (VRS) are calculated by including the restriction $\sum_{j=1}^{N} \lambda^{t,j} = 1$ to the previous problems.

Attachment 1

TABLE A.1. COUNTRIES CHANGING THEIR DENOMINATION STRUCTURE, 2000 AND 2005

Country	*Denominations* 2000	*Denominations* 2005
Armenia	5	6
Austria	6	7
Belgium	6	7
Bosnia	7	8
Bulgaria	6	7
Colombia	4	6
Costa Rica	7	4
Finland	5	7
France	5	7
Germany	8	7
Greece	6	7
Hungary	6	7
Ireland	5	7
Luxembourg	3	7
Mexico	5	6
Netherlands	6	7

Portugal	5	7
Romania	5	6
Spain	4	7
Uruguay	8	9

SOURCES: Central banks' annual reports (2000-2005) and central bank's websites. Authors' calculations.

Attachment 2

TABLE A.2. COUNTRIES WITH POLYMER BANKNOTES

Country	*Introducing year of polymer bank-notes*	*Denominations of polymer notes in circulation (2005)*
Australia[a]	1992	5
Brunei[b]	1996	3
Thailand[c]	1997	0
Sri Lanka	1998	1
Indonesia[d]	1999	0
New Zealand[e]	1999	5
Romania[f]	1999	7
Brazil[g]	2000	1
Bangladesh	2001	1
Salomon Island[h]	2001	1
Mexico[i]	2002	1
Papua - New Guinea[j]	2003	6
Vietnam[k]	2003	6
Zambia[l]	2003	2
Chile[n]	2004	1
Malaysia	2004	1
Singapore	2004	1
Nepal	2005	1
Nigeria[ñ]	2007	0
Hong Kong[o]	2007	0
Guatemala[p]	2007	0

SOURCES: Central banks' annual reports (2000-2005) and central bank's websites.

NOTE: In 2005, Bulgaria issued a hybrid paper, polymer note that is now in a trial period. Also, some countries have issued only commemoratives notes (Samoa, Kuwait, Northern Ireland, Taiwan and China).

[a] In 1996, it was the first country to issue all denominations in polymer. [b] The one, five and 10 ringgit notes were the first notes to be issued after Australia. [c] The 50 baht note was issued. Nevertheless, it returned to paper notes in 2004. [d] The 100,000 rupee note was issued for circulation. However, Indonesia returned to paper notes in 2004. [e] Banknotes are imported from Australia. In 1999, all denominations began to be issued in polymer. [f] In 1999, it was the first European country to issue all denominations in polymer. [g] Brazil was the first Latin American country to issue a polymer note. [h] The $2 polymer note was issued. [i] Mexico issued the $20 peso polymer note in 2002, and issued a new $20 note and a $50 note in polymer in 2006. [j] The 20 kina polymer note was issued. By 2007, 6 denominations in circulation were polymer. [k] It has issued all denominations in polymer. [l] It was the first African country to issue a polymer note in 2003. [n] The $2000 peso note was issued for general circulation. [ñ] In 2008, it will be the first African country to issue all denominations in polymer. [o] The 10 dollar polymer note was issued for a two-year trial period. [p] Guatemala will issue the one quetzal note in polymer at the end of 2007.

TABLE A.3. MOST COMMON BANKNOTE SECURITY FEATURES, 2005

Country	*Polymer*	*WM*	*ST*	*IP*	*PMD*	*Hol*	*HI*	*UV*	*MI*	*CCI*	*Total*
Eurozone		x	x	x	x	x	x	x	x	x	*9*
Other Adv. Econ.											
Australia	x			x	x		x	x	x	x	*6*
Canada		x	x	x	x	x	x	x	x	x	*9*
Cyprus		x	x	x	x	x	x	x		x	*8*
Denmark		x	x	x		x	x	x	x	x	*8*
England		x	x	x		x		x	x		*6*
Hong Kong	x	x	x	x	x	x	x	x		x	*8*
Iceland		x	x	x				x	x		*5*
Israel		x	x	x	x	x		x	x	x	*8*
Japan		x		x		x	x	x	x	x	*7*
New Zealand	x			x	x		x	x	x		*5*
Norway		x	x		x	x	x	x	x	x	*8*
South Korea		x	x				x		x	x	*5*
Sweden		x	x	x	x	x	x	x	x	x	*9*
United States		x	x						x	x	*4*
Latin America											
Argentina		x	x	x	x		x		x	x	*7*
Bolivia		x	x	x	x		x	x	x		*7*
Brazil	x	x	x	x	x		x		x		*6*
Chile	x	x	x	x	x		x			x	*6*
Colombia		x	x	x	x		x	x	x	x	*8*
Costa Rica		x	x	x	x		x		x		*6*
Dominican Rep.		x	x	x				x	x	x	*6*
Guatemala[a]		x	x	x	x	x		x	x		*7*

Mexico	x	x	x	x	x			x	x	x	*7*
Nicaragua		x	x	x	x	x		x	x	x	*8*
Paraguay		x	x	x	x	x	x	x	x		*8*
Peru		x	x	x			x		x	x	*6*
Uruguay		x	x	x	x	x	x	x	x		*8*
Venezuela		x	x	x	x	x	x	x	x	x	*9*
Other Develop. C.											
Albania		x	x	x	x	x	x	x	x	x	*9*
Armenia		x	x	x	x				x		*5*
Bangladesh	x	x	x	x	x	x	x		x	x	*8*
Bosnia		x	x	x	x		x		x		*6*
Bulgaria		x	x	x	x	x		x	x	x	*8*
Croatia		x	x	x	x		x	x	x	x	*8*
Czech Rep.		x	x		x			x	x	x	*6*
Estonia		x	x	x		x	x	x	x	x	*8*
Hungary		x	x	x	x	x	x	x	x	x	*9*
Malaysia	x	x	x	x	x		x		x		*6*
Poland		x	x		x	x	x	x	x	x	*8*
Romania	x		x	x	x			x	x	x	*6*
Slovakia		x	x	x	x		x	x	x	x	*8*
Slovenia		x	x	x	x			x	x	x	*7*
Thailand[b]		x	x	x	x	x	x	x	x	x	*9*
Turkey		x	x	x	x		x	x	x	x	*8*
Total	*9*	*41*	*41*	*39*	*35*	*21*	*31*	*33*	*41*	*32*	

SOURCES: Central banks' annual reports (2000-2005) and central bank's websites. Authors' calculations.

NOTE: WM: watermark; ST: security thread; IP: Intaglio printing; PMD: Perfect matched drawing; Hol: holograms; HI: hidden image; UV: observation under ultraviolet rays; MI: micro-inscriptions; CCI: color changing ink.

[a] Guatemala is due to issue a polymer note shortly. [b] Thailand returned to paper in 2004, after using polymer.

Attachment 3

TABLE A.4. BANKNOTE PRINTING COSTS (AVERAGE 2000–2005)

Central Bank	*Average printing costs per year*[a] *(USD)*	*Printing costs vs. GDP*[b] *(USD)*	*Printing costs as a percentage of operational costs*[c] *(%)*	*Cost per produced banknote*[d] *(USD)*
Estonia	509,885	0.5880	3.95	..
Armenia	650,835	2.2071	8.97	..
Slovenia	694,686	0.2672	2.20	0.039
Cyprus	834,281	0.6845	2.86	..
New Zealand	1,429,484	0.1897	6.73	..
Luxembourg	1,490,411	0.5827	4.10	..
Israel	3,292,655	0.2887	1.71	..
Bulgaria	4,462,928	2.3769	14.22	0.055
Denmark	4,491,171	0.2254	4.78	..
Czech Rep.	7,090,582	0.8325	1.82	0.079
Norway	8,182,138	0.3830	3.67	0.113
Finland	9,221,025	0.6053	8.64	..
Australia	9,232,025	0.1825	7.49	..
Ireland	9,436,190	0.6669	12.95	0.055
Hungary	13,376,340	1.7526	15.95	..
Sweden	16,649,807	0.5866	12.09	..
Colombia	16,884,348	1.8570	10.61	0.027
Canada	17,508,515	0.2061	12.73	..
Netherlands	25,281,483	0.5303	8.13	..
Portugal	26,148,199	1.9014	9.20	..
Poland	27,361,343	1.2364	9.40	0.100
Austria	33,828,479	1.4028	12.58	..
Thailand	45,002,927	3.1903	44.01	0.023
England	60,551,726	0.3443	18.73	0.070
South Korea	61,136,159	1.0144	19.62	0.052
Spain	95,034,242	1.1590	22.90	..
Germany	135,992,422	0.5921	7.28	..
Japan	586,364,623	1.3377	27.09	0.166

SOURCES: Central banks' annual reports (2000-2005). Authors' calculations.

[a] Annual average cost in 2005 constant dollars. [b] Cost per USD 10,000 in GDP, in 2005 constant dollars. [c] Printing cost as a percentage of a central bank's total operating costs. [d] Average cost per banknote produced, in 2005 constant dollars.

Attachment 4

TABLE A.5. VARIABLES USED IN THE PANEL DATA MODEL (Sample: 28 Countries; Years: 2000–2005; Observations: 168)

Variable	*Average*	*Maximum*	*Minimum*	*Standard Dev.*
C[a]	43.72	665.14	0.18	118.10
N[a]	24,269.8	127,956.0	438.0	29,401.5
Circ[a]	45,286	722,159	138.38	131,596
Y	22,482	75,189	571.21	15,844
Den[a]	5.7	9.0	3.0	1.5
Seg.	7.0	11.9	3.0	2.1
Ta[a]	103.6	119.1	84.8	7.7

SOURCE: Central banks' annual reports (2000-2005). Authors' calculations.

[a] Variables used to estimate the efficient frontier model and the Malmquist Index. C: Printing costs in millions of 2005 constant dollars; N: Population in thousands of inhabitants; Circ: Currency in circulation in millions of 2005 constant dollars; Y: GDP per capita in 2005 constant dollars; Den.: Number of denomination in circulation; Sec: Average number of security features on circulating banknotes; Size: Average size of circulating banknotes in cm2.

TABLE A.6. BANKNOTE PRODUCTION METHODS USED BY CENTRAL BANKS, 2000-2005

	Central Bank		*Private Company*		*Government*		*Subsidiary*[a]		*Importation*	
Country	*2000*	*2005*	*2000*	*2005*	*2000*	*2005*	*2000*	*2005*	*2000*	*2005*
Armenia	x	x	..	..	..	..	..	..	..	..
Australia	..	..	..	..	..	..	x	x	..	..
Austria	..	..	..	..	..	..	x	x	..	..
Bulgaria	x	..	..	..	..	..	..	x	..	..
Canada	..	..	x	x	..	..	..	..	..	..
Colombia	x	x	..	..	..	..	..	..	..	..
Cyprus	..	..	..	..	..	..	..	..	x	x
Czech Rep.	..	..	..	..	x	x	..	..	..	..
Denmark	x	x	..	..	..	..	..	..	..	..
England	x	..	..	x	..	..	..	..	..	..
Estonia	..	..	..	..	..	..	..	..	x	x
Finland	..	..	x	x	..	..	..	..	..	..
Germany	..	..	x	x	..	..	..	..	..	..
Hungary	..	..	..	..	..	..	x	x	..	..
Ireland	x	x	..	..	..	..	..	..	..	..
Israel	..	..	..	..	..	..	..	..	x	x
Japan	..	..	..	..	x	x	..	..	..	..
Luxembourg	..	..	..	..	..	..	..	..	x	x
Netherlands	..	..	x	x	..	..	..	..	..	..
New Zealand	..	..	..	..	..	..	..	..	x	x
Norway	x	x	..	..	..	..	..	..	..	..
Poland	..	..	x	x	..	..	..	..	..	..
Portugal	..	..	..	..	..	..	x	x	..	..
Slovenia	x	x	..	..	..	..	..	..	..	..
South Korea	..	..	..	..	x	x	..	..	..	..
Spain	..	..	..	..	x	x	..	..	..	..
Sweden	x	..	..	x	..	..	..	..	..	..
Thailand	x	x	..	..	..	..	..	..	..	..

SOURCES: Central banks' annual reports (2000-2005). Authors' calculations.
[a] Including joint ventures.

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