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Capital Mobility and the Output-Inflation Tradeoff

Prakash Loungani, Assaf Razin, and Chi-Wa Yuen

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Prepared by Prakash Loungani, Assaf Razin, and Chi-Wa Yuen[1]

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Abstract

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Identifying determinants of the output-inflation tradeoff has long been a key issue in business cycle research. We provide evidence that in countries with greater restrictions on capital mobility, a given reduction in the inflation rate is associated with a smaller loss in output. This result is shown to be consistent with theoretical presumption from a version of the Mundell-Fleming model. Restrictions on capital mobility are measured using the IMF's Annual Report on Exchange Rate Arrangements and Exchange Restrictions. Estimates of the output-inflation tradeoff are taken from previous studies, viz., Lucas (1973) and Ball, Mankiw and Romer (1988).

JEL Classification Numbers: E3, F41

Keywords: Output-inflation tradeoff, capital mobility, capital controls, openness

Authors' E-Mail addresses: ploungani@imf.org; razin@post.tau.ac.il; cwyuen@hkusub.hku.hk

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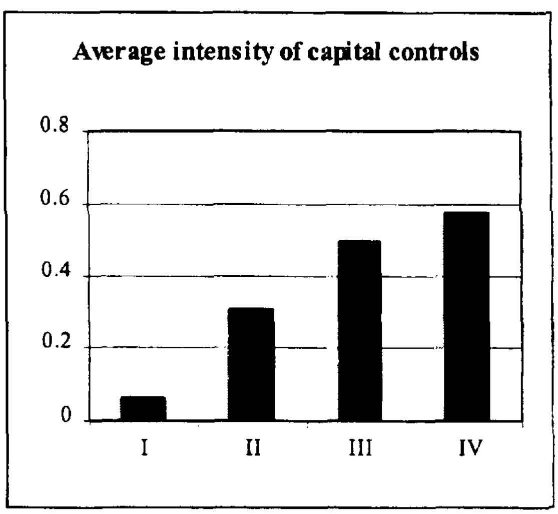
Contents

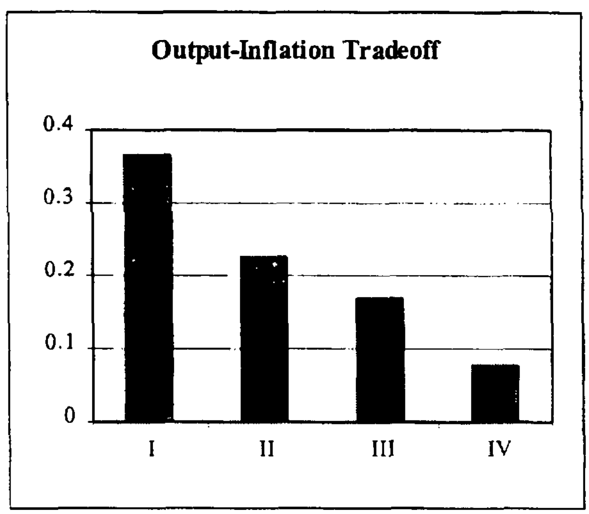
I. Introduction

Understanding the determinants of the output-inflation tradeoff (or the "sacrifice ratio") has been a key area of research in business cycle theory. The new classical approach [Lucas (1972, 1973)] and the new Keynesian approach [Ball, Mankiw and Romer (1988), Ball (1993)] offer competing explanations for the determinants of the tradeoff. Though these studies use cross-country data to test their models, both approaches are based on closed economy considerations.

In contrast, our paper analyses the determinants of the output-inflation tradeoff in an open-economy setting. In particular, we show that countries with greater restrictions on capital mobility have smaller tradeoff parameters (i.e. steeper Phillips curves). As a prelude to the empirical results in the paper, consider the evidence in the figure below.

In the left panel, we measure the extent to which countries restrict capital movements using an index constructed from the IMF's *Annual Report on Exchange Rate Arrangements and Exchange Restrictions*. We have divided the sample of 35 countries used in Ball, Mankiw and Romer into four groups based on the average value of our capital controls index over the period 1950 to 1986. Group I consists of countries, such as the United States and Singapore, which have had essentially no capital controls over this period, whereas countries with the most restrictions on capital mobility are in Group IV. In the panel on the left, the height of the bar shows the average value (across countries) of the capital controls index for each group. In the panel on the right, the average value of Ball, Mankiw and Romer's estimated output-inflation tradeoff parameter for the four groups is shown. It is evident that there is an inverse relationship: the greater the intensity of capital controls, the smaller is the tradeoff parameter (i.e., the steeper is the Phillips curve). The use of Ball's sacrifice ratio estimates--instead of Ball, Mankiw and Romer's estimates--yields similar results.





To develop some intuition for why capital mobility might matter, consider the two polar cases of zero mobility and perfect mobility of capital, respectively. In the zero mobility case, interest rate parity does not have to hold, and this leaves more scope for adjustment in the domestic interest rate in response to shocks; at the same time, however, closed capital accounts require that net trade be balanced, and this limits the flexibility of the real exchange rate. In the perfect mobility case, the adjustment of the domestic interest rate is limited by the interest parity condition, whereas the real exchange rate has greater room to adjust. Thus the degree of capital mobility influences how responsive aggregate demand is to real interest rate and real exchange rate movements, and this in turn, as shown in section 2, affects the output-inflation tradeoff. In this section of the paper, we also establish a theoretical presumption that for reasonable parameter values, an increase in restrictions on capital mobility should make the output-inflation tradeoff parameter smaller, that is, a given change in inflation rates should be associated with smaller movements in output. In Ball's terminology, the sacrifice ratio should be smaller, the greater the restrictions on capital mobility.

In section 3, we provide empirical evidence that an index measuring the restrictiveness of capital controls is a significant determinant of the output-inflation tradeoff. The correlation holds after controlling for the determinants suggested by the new classical and new Keynesian approaches, namely, the variability of aggregate demand and the expected inflation rate.

II. Open Economy Macroeconomic Framework

In this section, we provide a model of the relation between international capital mobility and the output-inflation tradeoff. We use the familiar Mundell-Fleming model cast in a stochastic framework.[2] Such a framework assumes a set of exogenous stochastic processes (e.g., money supply) which drives the dynamics of the equilibrium system. Since economic agents are forward looking, each short term equilibrium is based on expectations about future shocks and the resulting future short term equilibria.

We can write the structural form of the aggregate demand equation as:

$$y_t^d = (\tilde{d}_t^A + A_y y_t^d + A_r r_t) + (d_t^X + X_y y_t^d + X_q q_t). \qquad (*)$$

[2]See Frenkel, Razin, and Yuen (1996), Chapters 3 and 4 for details.

where y_t^d stands for aggregate demand, r_t for the domestic real rate of interest, and q_t for the real exchange rate. The first parenthetical expression refers to domestic absorption (A), and the second to net trade balance (X). The autonomous component of absorption is denoted by $\bar{d}_t^A$, the income elasticity of absorption by A_y (> 0), and interest elasticity of absorption by A_r (< 0). Similarly, d_t^X denotes the autonomous component of trade balance, X_y (< 0) the income elasticity of trade balance, and X_q (> 0) the real exchange rate elasticity of trade balance. Defining the sum of marginal propensities to save and import, $1-A_y-X_y$, as α, d_t as $(\bar{d}_t^A+d_t^X)/\alpha$, η as X_q/α (> 0), and σ as $-A_r/\alpha$ (> 0), we can express y_t^d as a function of r_t and q_t as follows:

$$y_t^d = d_t + \eta q_t - \sigma r_t. \tag{1}$$

where η and σ are positive elasticities. As is usual, the real variables are derived from the following nominal variables: s_t, the spot exchange rate (the domestic value of foreign currency); p^*, the foreign price level; p_t, the domestic price level; and i_t, the domestic nominal rate of interest. More specifically, $q_t = s_t + p^* - p_t$ and $r_t = i_t - E_t(p_{t+1}-p_t)$. For simplicity, we assume the foreign price level, p^*, to be constant over time.

Aggregate demand is positively related to the exogenous demand shock, capturing external, fiscal, and other internal shocks. The real exchange rate affects positively aggregate demand by stimulating the traded sector (exportables and domestic production of importables). The real interest rate affects negatively aggregate demand by discouraging investment and consumption.

In the presence of closed capital accounts, the net trade balance (X) is zero. Hence, $d_t^X + X_y y_t^d + X_q q_t = 0$, which can be rewritten as

$$d_t^X - \mu y_t^d + \alpha\eta q_t = 0, \tag{1'}$$

where $\mu = -X_y$ and $\alpha\eta = X_q$. Substituting this into the structural equation for aggregate demand, we can modify the final form as

$$y_t^d = d_t^A - \sigma\gamma r_t, \tag{1''}$$

where $d_t^A = \bar{d}_t^A/(1-A_y)$ and $\gamma = (1-A_y-X_y)/(1-A_y) > 1$. Money market equilibrium is specified as:

$$m_t^s - p_t = y_t - \lambda i_t, \tag{2}$$

where m_t^s is the money supply at time t, and λ (> 0) the interest semi-elasticity of the demand for money. As usual, the domestic nominal rate of interest (i_t) has a negative effect on the demand for money, while domestic output (y_t) has a positive effect. To simplify matters, the output demand elasticity is assumed to be unity.

Price setting is based on a mix of auction markets and long term contract markets. The market clearing price in the auction market is p^e_t. The price in the long term contract market is set one period in advance according to expectations of the future market clearing price in that market, $E_{t-1}p^e_t$. Accordingly, the general price level in the domestic economy, p_t, is given by a weighted average of these two prices:

$$p_t = (1-\theta)E_{t-1}p_t^e + \theta p_t^e, \tag{3}$$

where $0 < \theta < 1$ is the share of the auction market in domestic output. The long term contract element is akin to Taylor (1981) and Fischer (1981). This introduces an element of price rigidity into the system.

Under free capital mobility, interest parity prevails. Assuming risk neutrality, uncovered interest parity should hold. That is,

$$i_t = i^* + E_t(s_{t+1} - s_t), \tag{4}$$

where I^* is the world rate of interest, assumed for simplicity to be constant over time. Through costless arbitrage, the return on investing one unit of domestic currency in domestic security, i_t, is made equal to the expected value of the domestic currency return on investing the same amount in foreign security, which yields a foreign currency return, I^*, plus an expected depreciation of domestic currency, $E_t(s_{t+1} - s_t)$. This parity condition will no longer hold in the absence of capital mobility.

The equilibrium system under free capital mobility consists of the four equations (1)-(4) at each point in time. Observe that domestic output is demand-determined, as in all models with price rigidity. In the case without capital mobility, equation (1) is replaced by equations (1)' and (1)".

In the free capital mobility case, the shock (or forcing stochastic) processes that drive the dynamics of the equilibrium system are:

$$y_t^s = g_y + y_{t-1}^s + \epsilon_{yt}, \tag{5a}$$

$$d_t = g_y + d_{t-1} + \epsilon_{dt}, \tag{5b}$$

$$m_t^s = g_m + m_{t-1}^s + \epsilon_{mt}, \tag{5c}$$

where g_y and g_m are the deterministic growth rates of output and money, and ϵ_{yt}, ϵ_{dt}, ϵ_{mt} are independently and identically distributed (i.i.d.) *supply*, *demand*, and *money* shocks with zero means and constant variances.[3] Accordingly, our specification assumes that the system is bombarded by permanent shocks (in a random walk fashion). As an analogue to (5b), we specify the stochastic process for d_t^A in the case without capital mobility as

$$d_t^A = g_y + d_{t-1}^A + \epsilon_{dt}^A, \tag{5b'}$$

where ϵ_{dt}^A is assumed to have similar properties as ϵ_{dt}.

A. The Phillips Curve

Since our stochastic framework is both forward and backward looking, a systematic procedure is required to obtain a solution. We apply a two-stage procedure for solving the equilibrium system (1)-(5). In the first stage, we solve for a flexible price equilibrium that corresponds to this system. In the second stage, we use the flex-price equilibrium to arrive at a full-fledged solution for the mixed fix-flex-price system. Similar solution procedure is followed in the case of capital immobility.

Define excess output capacity, $y_t^e - y_t$, (which is directly related to the rate of cyclical unemployment) by ut. Then we can obtain an expectations-augmented Phillips curve relation between inflation (π_t) and excess capacity (u_t) as follows:

$$\pi_t = \pi_t^e - \left(\frac{1}{1+\lambda}\right)\left(\frac{\lambda}{\sigma+\eta} + 1\right) u_t. \tag{6}$$

where the superscript 'e' denotes the flex-price equilibrium value. Equation (6) shows that the Phillips curve is flatter when the aggregate demand elasticities η (with respect to the real exchange rate) and σ (with respect to the domestic real rate of interest) are larger. The effect of the interest semi-elasticity of money demand (λ) on the slope of the Phillips curve is, however, ambiguous, depending on whether $\sigma+\eta$ exceeds or falls short of unity. The source of this ambiguity is derived from the same fundamental ambiguous effects of excess capacity innovations on the domestic nominal interest rate and spot exchange rates.

In the capital immobility case, we can express the Phillips curve as follows:

$$\pi_t = \pi_t^e - \left(\frac{1}{1+\lambda}\right)\left(\frac{\lambda}{\sigma\gamma} + 1\right) u_t. \tag{6'}$$

---

[3]To guarantee the existence of a long run (steady state) equilibrium for our system, the deterministic growth rates of output on both the supply and demand sides (g_y) are assumed to be identical.

The steepest (flattest) line in Figure 2 portrays the open-economy Phillips curve under capital controls when $\sigma\gamma <(>) \sigma+\eta$ while the line with intermediate slope depicts the Phillips curve under perfect capital mobility. In other words, fluctuations in inflation rates will be associated with smaller or bigger variations in unemployment depending on whether $\sigma\gamma <$ or $> \sigma+\eta$.

The intuition behind the changing slopes of the Phillips curve has to do with the effect of capital controls on aggregate demand. Comparing the aggregate demand functions under capital controls (1)" and under free capital mobility (1), we observe that in the former case the interest semi-elasticity becomes bigger ($\sigma\gamma > \sigma$ since $\gamma > 1$) and the real exchange rate effect disappears ($0 < \eta$) from the reduced form equation for aggregate demand. This is because, under capital controls, the interest rate parity need not hold, leaving more room for adjustment in the domestic interest rate to shocks (the "r-effect"); while the zero net trade balance restriction (given that the capital account is closed) limits the flexibility of the real exchange rate (the "q-effect"). On the other hand, capital controls do not alter the mechanisms underlying the determination of prices (i.e., the price setting equation (3) and the money market equation (2)).

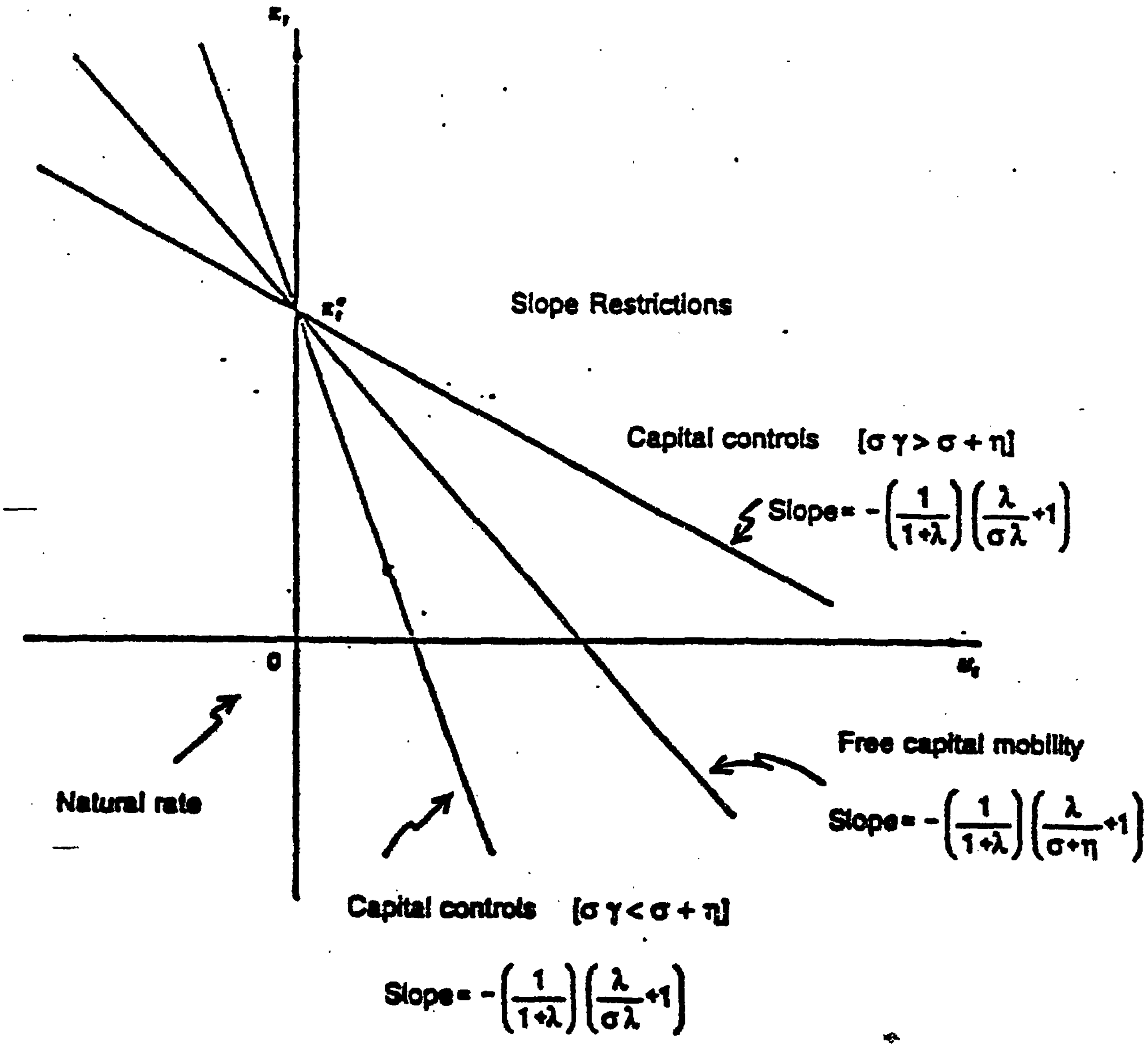
Indeed, a comparison between equations (6) and (6)' reveals that the difference in the slopes of the Phillips curve under free capital mobility and capital controls depends solely on the aggregate demand parameters $\sigma+\eta$ versus $\sigma\gamma$, and not on the money market parameter λ and the price setting parameter θ. In particular, when the q-effect dominates the r-effect ($\sigma\gamma < \sigma+\eta$), the overall output effect due to, say, any policy change that moves the economy along its Phillips curve will be smaller with than without capital controls while the price (or inflation) effect remains unchanged. In other words, restrictions on capital flows will generate less variations in unemployment rates (excess output capacity) at the expense of more variations in inflation rates. The reverse is true when the r-effect dominates the q-effect (i.e, when $\sigma\gamma > \sigma+\eta$).

Presumably, the natural rate of unemployment (= 0 in our case) and the expected rate of inflation (π^e) are unaffected by capital controls. This is reflected by the intersection of the two Phillips curves at the point $(0,\pi^e)$. While the various shocks will move the economy away from this point along the respective Phillips curve (depending on the capital mobility regime), changes in the expected rate of inflation due to permanent changes in the relative money-output growth rates ($g_m - g_y$) will shift the Phillips curve around.

B. Some Evidence on the Aggregate Demand Effects of the Interest Rate and Real Exchange Rate

To get a feel for the relative size of the r-effect and q-effect on aggregate demand and consequently the relative output-inflation tradeoffs with and without capital mobility, we cite evidence from the literature that bears on this issue. (Section 3.5 and the Annex report on an alternate attempt to provide evidence on this issue.)

FIGURE 2: OPEN-ECONOMY PHILLIPS CURVE



Papell (1988) estimated a Mundell-Fleming model, similar in spirit to the one discussed above, for Germany, Japan, the United Kingdom, and the United States for the period 1973-84 (the flexible exchange rate period). He was able to capture the exchange rate dynamics and interest rate effects by using constrained maximum likelihood methods with the cross-equation restrictions implied by rational expectations imposed. Table 1 reports a selection of his estimates useful for our purpose.

Table 1. Papell's Estimates of η and σ

	Germany		United States		Japan	
	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
η (q-effect)	0.87	3.83	0.54	4.94	0.45	2.44
σ (r-effect)	0.40	1.88	0.34	3.25	2.11	2.64

For the slope comparison, we also need estimates of γ, which is the ratio of the marginal propensities to save and import to the marginal propensity to save. While we do not have an estimate of γ, a reasonable conjecture is that it should lie somewhere between 1 and 2. The reader can easily check to see that $\gamma\sigma < \sigma+\eta$ over this range of values for γ in the German and U.S. case, and also in the Japanese case if γ is the neighbourhood of 1. Given reasonable values of the saving and import propensities in these countries, the value of Germany is likely to be closer to 2 and that for Japan closer to 1, with the U.S. an intermediate case. In sum, the presumption from the theoretical work is that the output-inflation tradeoff is smaller under capital immobility than under free capital mobility.[4]

III. Capital Controls and the Output-Inflation Tradeoff

A. Literature Review: Measures of Output-Inflation Tradeoffs

There is by now a large literature on the estimation of output-inflation tradeoffs; some of the important studies are summarized in Table 2. Lucas (1973) conjectured that the tradeoff, which we will denote by τ, should depend on the variability of nominal GNP growth. In countries where the variability is high, the Phillips curve should be steep, which in

[4]The parameter estimates for the United Kingdom also satisfy this condition. However, the estimates are not statistically insignificant, and therefore not considered here.

Table 2. Literature Review

Author(s)	Sample Period [Sub-Periods]	No. of Countries [No. for Which We Have Data on Capital Controls]	Determinant (s) of Output-Inflation Tradeoff	Innovations in Study
Lucas (1973)	1951-67 [No sub-periods considered]	18 [12]	Variance of nominal GNP growth	First of its kind
Alberro (1981)	1953-69 [No sub-periods considered]	49 [21]	Variance of nominal GNP growth	Extended Lucas's study to a wider set of countries.
Kormendi and Meguire (1984)	1949-77 [No sub-periods considered]	47 [21]	Variance of unanticipated component of money growth	Combined "Barro's (1977) idea of estimating the effects of unanticipated money supply changes on real output with Lucas's idea of drawing inferences from a cross-section of policy regimes."
Ball, Mankiw and Romer (1988)	1949-86 [1949-72, 1973-86]	43 [35]	(I) Mean inflation (ii) Mean inflation squared (iii) Variance of nominal GNP growth	Offered "New Keynesian" alternative to Lucas's theory.

our notation corresponds to a low value for τ. The theoretical argument for expecting such an effect was that in countries with high variability of nominal GNP, agents will be more likely to treat a particular shock, whether nominal or real, as nominal and hence there will be less of an output response to the shock. Alberro (1981) extended Lucas's empirical work to a larger set of countries. In Kormendi and Meguire's (1984) study, the independent variable was the variability of the unanticipated component of monetary growth, instead of the variability of nominal GNP growth used by Lucas and Alberro.[5]

[5] Another study in the new classical tradition was by Addison, Chappell and Castro (1986). Their empirical work incorporated some theoretical and econometric modifications to Lucas's analysis that were suggested by Froyen and Waud (1980). The results using their estimates of the tradeoff parameter are quite similar to those for the other new classical

(continued...)

Ball, Mankiw and Romer (1988) offered a new Keynesian alternative to the new classical studies discussed above. Their work relies on the presence of menu costs, that is fixed costs associated with changing prices. They show that an implication of their theory is that the Phillips curve should be steeper, the higher is the mean inflation rate. The intuition is that "an increase in the average rate of inflation causes firms to adjust price more frequently...In turn, more frequent price changes imply that prices adjust more quickly to nominal shocks and thus that shocks have smaller real effects."[6]

B. Measures of Capital Controls

The data on restrictions to international capital mobility used in this paper come from the International Monetary Fund's publication *Annual Report on Exchange Arrangements and Exchange Restrictions*. The report, which has been issued since 1950, states whether or not a particular IMF member country had in place that year "restrictions on payments for capital transactions" and whether the country had "separate exchange rates for some or all capital transactions and/or some or all invisibles." Following Grilli and Milesi-Ferretti (1995), we interpret these restrictions "as a form of control on capital flows." [7]

This information on restrictions is used to construct three (0,1) variables. The first variable, CAP1, takes the value 1 if there was a restriction on payments for capital transactions in a given year in a given country, and zero otherwise. Likewise, the second variable, CAP2, takes the value 1 if there were separate exchange rates for capital transactions, and zero otherwise. The third variable, CAP, is the simple average of CAP1 and CAP2.

Even though this procedure gives us a time-series on CAP for each country, year-to-year fluctuations in CAP are fairly rare. Hence, almost all of the variation in the data comes from cross-country differences. In light of this, we use the average value of CAP over the period 1950 to 1986 as our measure of the intensity of capital controls for a country. By also constructing CAP over a different interval of time--1973 to 1986--we do investigate to some extent whether or not there is structural stability in the relationships that we report.

(...continued)
studies, and are omitted in the interests of brevity.

[6] Ball, Mankiw and Romer (1988, p. 3). Another study in the new Keynesian tradition is by Defina (1991).

[7] Grilli and Milesi-Ferretti (1995, p. 525). Other papers that also interpret these restrictions as capital controls include Bartolini and Drazen (1995). Earlier studies tended to use alternate measures such as onshore-offshore interest rate differentials, the size of the black market exchange rate premium and deviations from covered interest rate parity.

All of the studies mentioned in the literature review report their data for both the output-inflation tradeoff parameter as well as the independent variable(s) used.[8] Hence, our empirical strategy is quite simple: first we re-estimate the regressions reported in these studies and then augment them with the variable CAP to see if the intensity of capital controls over the period affects the estimated output-inflation tradeoff. As noted in Table 2, we do not always have data on CAP for all the countries used in these studies; this restricts the sample quite a bit in the case of the new classical studies; however we do have data on CAP for 35 out of the 43 countries used in Ball, Mankiw and Romer.

Our basic empirical results are presented in Tables 3 and 4, which have the following general format. The regressions reported in the odd-numbered columns are similar to those reported by the authors of the studies discussed above, and the regressions in the even-numbered columns augment each regression with the measure CAP. The sample period and the list of countries are given in the table (or in the notes at the bottom of the table).

C. Revisiting Lucas (1973) and Other "New Classical Studies"

In the regression reported in column (1) of Table 3, the dependent variable is Lucas's estimate of the output-inflation tradeoff. The independent variable---the variability of nominal GNP--has the expected negative impact on the tradeoff, but the coefficient estimate is not very precise. This result is not surprising because we have had to leave out, because of missing data on CAP, countries such as Argentina and Paraguay which have very high variability of nominal GNP.[9] When the measure of capital controls is added to the regression, as in column (2), its coefficient estimate turns out to be negative; that is the greater the degree of restrictions on capital mobility, the smaller is the output-inflation tradeoff, which is consistent with our theoretical presumption. The estimate is significantly different from zero, with a t-statistic exceeding 3. The addition of CAP also lifts the coefficient estimate on the variability of nominal GNP closer to statistical significance.

In columns (3) and (4), the dependent variable consists of Alberro's estimates of τ; they differ somewhat from Lucas's estimates because of slight differences in sample period and econometric method, and data revisions. In addition, Alberro's estimates are for a larger set of countries. It is evident that the results in this case have a similar flavor to those just discussed. The variability of nominal GNP has a negative but imprecisely measured impact, whereas CAP has a significant negative impact. The addition of CAP boosts the adjusted R-square from 0.09 to 0.22.

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[8] Typically, these estimates are obtained from a regressing of the log-level of real GDP on nominal GDP growth.

[9] It was noted by Lucas himself that his sample essentially provided "only two points," the "highly volatile and expansive policies of Argentina and Paraguay, and the relatively smooth and moderately expansive policies of the remaining sixteen countries." [Lucas (1973, p. 331).

Table 3. Determinants of the Output-Inflation Tradeoff: Revisiting the "New Classical" Studies

		(1)	(2)	(3)	(4)	(5)	(6)
	Author (s)	Lucas (1973)		Alberro (1981)		Kormendi & Meguire (1984)	
Row No	Independent Variables ↓	Without Capital Controls Measure	With Capital Controls Measure	Without Capital Controls Measure	With Capital Controls Measure	Without Capital Controls Measure	With Capital Controls Measure
(1)	Variability of "aggregate demand"	-64.9 (161.0)	-174.6 (117.5)	-54.3 (32.5)	-42.9 (30.5)	-25.1 (14.3)	-19.6 (12.5)
(2)	Intensity of capital controls	.	-0.69 (0.21)	.	-0.39 (0.19)	.	-0.51 (0.18)
(3)	Intercept	0.63 (0.14)	0.97 (0.14)	0.67 (0.05)	0.82 (0.09)	0.32 (0.06)	0.53 (0.09)
(4)	Adjusted R^2	-0.08	0.47	0.09	0.22	0.09	0.33
(5)	Number of countries	12		21		21	
	List of countries	USA, UK, Austria, Belgium, Denmark, Germany, Italy, Netherlands, Norway, Sweden, Canada, Ireland		Lucas's sample plus Japan, Finland, Greece, Iceland, Ireland, Portugal, Turkey, Australia, Israel		Same as Alberro's sample	
(6)	Sample period	1951 to 1967		1953 to 1969		1949 to 1977	

Table 4. Determinants of the Output-inflation Tradeoff: Revisiting the "New Keynesian" Study

		(1)	(2)	(3)	(4)	(5)	(6)
		Basic Specification		Squared Inflation Included as Additional Regressor		New Keynesian vs. New Classical Specification	
Row No.	Independent Variables	Without Capital Controls Measure	With Capital Controls Measure	Without Capital Controls Measure	With Capital Controls Measure	Without Capital Controls Measure	With Capital Controls Measure
(1)	Mean inflation	-1.20 (0.39)	-1.08 (0.37)	-4.46 (1.17)	-3.87 (1.17)	-0.71 (1.03)	0.86 (1.05)
(2)	Mean inflation squared	.	.	6.56 (2.25)	5.55 (2.23)	.	.
(3)	Standard deviation of nominal GNP growth	.	.	.	.	-0.68 (1.32)	-2.62 (1.33)
(4)	Intensity of capital controls	.	-0.52 (0.22)	.	-0.40 (0.21)	.	-0.74 (0.24)
(5)	Intercept	0.34 (0.06)	0.52 (0.09)	0.55 (0.09)	0.66 (0.10)	0.35 (0.06)	0.62 (0.10)
(6)	Adjusted R^2	0.20	0.30	0.35	0.40	0.18	0.36
(7)	Number of countries	35	35	35	35	35	35

Notes: (I) For all countries, data for capital controls are averages over the period 1950 to 1989. (ii) List of countries consists of OECD members over this period plus S. Africa, Argentina, Bolivia, Brazil, Colombia, Costa Rica, Mexico, Nicaragua, Panama, Peru, Venezuela, Israel, Philippines, Singapore, Zaire.

Kormendi and Meguire's estimates of the output-inflation tradeoff are based on an econometric methodology that corrects for some deficiencies in Lucas's formulation; in addition, the independent variable is the variability of the unanticipated component of money growth. The list of countries is identical to that of Alberro's, but the sample period is different. Here again, we find a strong negative impact from capital controls, and a weaker negative impact from money growth variability. The improvement in adjusted R-square is from 0.09 to 0.33.

D. Revisiting Ball, Mankiw and Romer (1988)

The regression reported in the first column of Table 4 is the basic specification reported by Ball, Mankiw and Romer (henceforth, BMR)[10] and the parameter estimates we obtain are essentially identical to the ones they report. An increase in the mean inflation rate lowers the output-inflation tradeoff; the coefficient estimate is statistically significantly different from zero. When we add the measure of capital controls, it continues to have a significant negative impact on τ [column (2)]. In the regressions in columns (3) and (4), where the square of the mean inflation rate is included as an additional regressor, CAP continues to be significant.

BMR attempt to distinguish between their theory and the new classical studies by including both the mean inflation and the variability of nominal GNP growth in the same regression. When this is done, as shown in column (5), neither variable is significant; as BMR point out, this may be because the correlation between the two variables is as high as 0.92. In any event, as shown in column (6), CAP once again has a significant negative impact on the tradeoff.

E. Robustness Checks

Having presented the basic results, we now present results for sub-samples and also report 2SLS estimates to correct for the possible endogeneity of the capital controls measure. First, we distinguish between OECD and non-OECD countries, and then present results for the 1973-86 period. As shown in column (1) of Table 5, for the 20-country OECD sample, the impact of mean inflation on the output-inflation tradeoff is negative but very imprecisely estimated. The impact of CAP is negative and very significant. For the 15-country non-OECD sample [column (2)], both variables have a negative impact, but the t-statistics in each case are around 1.2. In column (3), the dependent variable is BMR's estimates of tau using data over the period 1973 to 1986. Mean inflation has a negative impact, with the t-statistic just a little under 2. Capital controls, which are now measured as before but only using data over the period 1973 to 1986, again have a very significant negative impact.

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[10] See equation (5.1) on p. 41 of their paper.

Table 5. Determinants of the Output-Inflation Tradeoff: Further Tests

Row No.	Column No. / Independent Variables	(1) OECD Countries	(2) Non-OECD Countries	(3) 1973-86 Sub-Sample	(4) 2SLS Estimates
(1)	Mean inflation	-0.75	-0.67	-0.27	-0.94
		(1.68)	(0.48)	(0.14)	(0.40)
(2)	Intensity of capital controls	-0.83	-0.55	-0.53	-0.92
		(0.31)	(0.43)	(0.20)	(0.54)
(3)	Intercept	0.68	0.39	0.60	0.65
		(0.14)	(0.13)	(0.11)	(0.20)
(4)	Adjusted R^2	0.32	0.23	0.25	0.23
(5)	No. of countries	20	15	35	35

In column (4), we report 2SLS estimates using as instruments the ratio of imports to GDP and a measure of land area. Grilli and Milesi-Ferretti suggest that when an economy is open, it is difficult to monitor capital controls and hence they are less likely to be imposed. They also suggest that the imposition of capital controls can be influenced by public finance considerations; our use of land area is based on the conjecture that larger countries may have access to more sources of revenue than smaller countries.[11] The estimate of the capital controls index remains significantly negative.

We carried out two additional robustness checks.[12] First, the model presented in section 2 has a dual testable implication: If (a) the correct configuration of parameters holds and (b) the model is correct, then the use of stronger capital controls will affect the tradeoff. We presented evidence from the literature suggesting that (a) holds. However, one can also try to control for (a) directly in our regressions. In particular, η and σ should vary across countries and, therefore, so should the strength of the effect of the capital controls on the

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[11] Grilli and Milesi-Ferretti suggest a much longer list of potential measures of openness and public finance considerations than the two considered here. However, we found that the R-square of the "first-stage" regressions using alternate measures is generally in the range of 0.20, and the t-statistics on the instruments are between 1.2 and 2.0.

[12] We are grateful to an anonymous referee for suggesting these tests.

tradeoff. We conjecture that η should be affected by the degree of trade openness and σ by the depth of the financial sector. We then augment our regressions with two interaction terms, one measuring the interaction between capital controls and trade openness and the other between capital controls and financial sector depth. In practice, these interaction terms do not end up being statistically significant; the t-ratios range between 0.4 and 1.2, depending on the particular measure of trade openness used and other variables included in the specification.[13] On the other hand, the coefficient of the capital controls index consistently remains negative and highly significant, as before. The regressions are reported in the Annex; it may be that with greater refinement of the measures of capital controls, trade openness and financial sector depth, this may ultimately prove to be a useful way of testing our entire model.

Second, the association between the capital controls index and the output-inflation tradeoff appears so strong that one is tempted to think that capital controls are acting as a proxy for some other determinants of the tradeoff. While we have controlled for the two key variables suggested by the literature (the variability of aggregate demand and mean inflation), it may still be the case that other determinants are being left out. In particular, if central bank credibility is correlated with the use of controls, our results would overestimate the importance of controls in determining the tradeoff. One way to evaluate whether this issue is important is to include a measure of central bank independence (CBI) [see Cukierman (1992)] as an additional determinant of the tradeoff. As reported in the Annex, in practice the coefficient on CBI is insignificant (t-statistic of about 0.4), while the coefficient on the capital controls index is virtually unchanged.[14]

F. An Extension to Panel Data

The empirical analysis presented thus far closely follows the tradition of earlier work in this literature. We did this deliberately in order to show the importance of our capital controls variable in a setting in which "other things were held constant," that is the data and the econometric procedure used were identical to those in previous studies. Nevertheless, the econometric procedure used in the literature has the limitation that potentially important time-series information is discarded because the independent variables are constructed by

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[13] We used trade (i.e exports+imports) as a share of GDP, imports as a share of GDP and the Sachs-Warner openness index as alternate measures of trade openness. Only the regressions using the Sachs-Warner index are reported in the Annex.

[14] As is well-known, measures of CBI tend to have greater explanatory power for industrialized country inflation than for developing country inflation. Hence, we also tested whether CBI was an important determinant of the tradeoff for the OECD sample. The coefficient on CBI remained insignificant, while the coefficient on the capital controls index was negative and significant.

averaging over long periods of time. In this sub-section we implement a more flexible approach, following Defina (1991), that allows much greater time-series variation in the independent variables.

The following notation is used. Let y_{it} denote the log-level of real GDP in country I at time t, Δx_{it} denote the growth rate of nominal GDP, and let α_i and β_t denote country-specific and year-specific fixed effects, respectively.[15] Then, consider the following panel equation:

$$y_{it} = \alpha_i + \beta_t + \gamma_0 * \Delta x_{it} + \delta y_{i,t-1} \qquad (7)$$

In the equation above, γ_0 is the slope of the Phillips curve; that is, as in the earlier studies by Lucas and Ball & Mankiw, it is obtained by regressing the log-level of real GDP on nominal GDP growth. We then assume that the slope of the Phillips curve depends on mean inflation at time t, capital controls at time t, and the interaction of these two variables:

$$\gamma_0 = b_0 + b_1 * AINF_{it} + b_2 * ACAP_{it} + b_3 * (\pi_t * CAPC_{it}) \qquad (8)$$

where, AINF and ACAP are the average inflation rate and the average intensity of capital controls, respectively, over a certain interval of time. In our previous empirical work, AINF and ACAP were constructed as averages over the entire sample period (or, in one case, over the period 1973-86). Now, we attempt to minimize the loss of time-series information by constructing AINF and ACAP as averages over shorter intervals. We tried intervals ranging from three-years to seven-years, and found that the results to be discussed below were not sensitive to the choice of interval within this range; the results below are for the intermediate case of a five-year interval.

The form of the panel regression that we estimate is obtained by substituting equation (8) in (7). To be consistent with our previous results, the estimates of b_1 and b_2 should be negative; since the interaction between inflation and capital controls was not considered earlier, we do not any conjecture about the sign of this estimate. Table 6 shows the estimates of these three coefficients for the OECD and non-OECD countries separately. As shown, we once again find that the estimates of b_1 and b_2 are negative.

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[15] In other words, the country-fixed effects are (0,1) dummy variables that take on the value 1 for country I and 0 otherwise. Likewise, the year-fixed effects are (0,1) dummy variables that take on the value 1 for year t and 0 otherwise.

Table 6. Panel Estimation

	Estimate of b_1	Estimate of b_2	Estimate of b_3
OECD	-2.02	-0.13	0.97
	(0.78)	(0.06)	(0.76)
Non-OECD	-0.43	-0.19	0.45
	(0.08)	(0.06)	(0.16)

IV. Conclusions

While previous studies of the determinants of the output-inflation tradeoff have been confined to a closed economy setting, our paper establishes that the degree of capital mobility is an important determinant of the tradeoff. In the present study we used data from the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions* to construct indicators of the intensity of capital controls. We found that countries with stricter capital controls had a smaller output-inflation tradeoff parameter, i.e, a steeper Phillips curve. Taken literally, an implication of this finding is that the loss in output from reducing inflation is lower in countries that impose some restrictions on capital mobility. Of course, this "gain" has to be balanced against several costs of imposing capital controls, which are not considered here.

The empirical results here are meant to be suggestive; a more refined measure of the degree of capital mobility would be needed to establish it more conclusively as a determinant of the output-inflation tradeoff. In future work, it would also be necessary to account for linkages between the choice of a monetary policy framework (which implicitly influences the output-inflation tradeoff) and the decision on whether or not to impose controls. In particular, it would be interesting to test whether countries that imposed controls already had a vertical Phillips curve.

DETERMINANTS OF THE OUTPUT-INFLATION TRADEOFF: FURTHER ROBUSTNESS CHECKS

Row No.	Independent Variables ↓	(1) Basic Regression (Table 4, Column 2)	(2) With two Interaction Terms	(3) With One Interaction Term	(4) With CBI
(1)	Mean inflation	-1.08 (0.37)	-0.66 (0.48)	-0.72 (0.46)	-1.10 (0.40)
(2)	Intensity of capital controls	-0.52 (0.22)	-0.99 (0.42)	-0.96 (0.40)	-0.49 (0.24)
(3)	Capital controls interacted with Sachs-Warner openness measure	.	0.016 (0.015)	0.018 (0.013)	.
(4)	Capital controls interacted with financial depth (M2/GDP)	.	0.07 (0.33)	.	.
(5)	Index of central bank independence				0.15 (0.35)
(6)	Intercept	0.52 (0.09)	0.52 (0.10)	0.53 (0.09)	0.65 (0.20)
(7)	Adjusted R^2	0.30	0.29	0.31	0.27
(8)	Number of countries	35	35	35	35

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