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Balance of Payments Anti-Crises

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Abstract

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published to elicit comments and to further debate.

Several emerging economies have, until recently, experienced large government surpluses
and accelerating foreign exchange reserve accumulation. This has been accompanied by
economic booms, exchange rate appreciations and in some cases increases in domestic
inflation. We show that one way to understand these episodes is as manifestations of balance
of payments anti-crises, as reflecting the perception that the government intends to
discontinue its accumulation of reserves in the near future. The end-phase of such crises is
characterized by nominal interest rates approaching their zero lower bound in accelerating
fashion and, if the government targets CPI inflation, by fast increasing domestic inflation.

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I. Introduction

On March 20, 2007 China's central bank governor announced that his country would stop accumulating foreign exchange reserves. He was quoted in Reuters (2007) as stating "foreign exchange reserves in China are large enough. We do not intend to go further and accumulate reserves." As shown in Figure 1, this statement followed several years of very large and accelerating Chinese reserve gains. The central bank did not follow through on the statement and kept accumulating reserves throughout 2007. But in all subsequent debates this option has never been completely off the table. The remainder of the year 2007 was characterized by accelerating Chinese currency appreciation and by a significant increase in domestic inflation.

Similarly, during 2007 Colombia experienced a period of large central bank foreign exchange purchases to stem the appreciation of its real exchange rate due to capital inflows. As reported in Kamil (2008), financial markets perceived this intervention as unsustainable and bet heavily against the central bank. As a result of its rapid accumulation of foreign currency denominated assets, the central bank soon ran out of domestic currency treasury bills, and its net creditor position vis-a-vis the financial sector turned into a net debtor position. This made it very difficult to control the interbank nominal interest rate, which started to significantly undershoot the policy interest rate. As shown in Figure 1, exchange rate appreciation continued unchecked. The intervention policy was soon abandoned.[1]

What these episodes have in common is a concern, either on the part of the central bank or of financial markets, that an existing monetary regime may not be sustainable because it involves the accumulation of *too much* foreign exchange. This problem is relatively new, and its theoretical implications have therefore, to our knowledge, not yet been studied by the literature. In this paper, we suggest that it is very useful to examine it through the lens of a familiar literature - the literature on first-generation balance of payments crises following Krugman (1979), Calvo (1987), the survey in Calvo and Vegh (1999), and Kumhof, Li and Yan (2007), which studies balance of payments crises under inflation targeting regimes. The critical difference is that in that literature the concern is with countries that experience the consequences of a central bank owning *too little* foreign exchange. While many emerging markets continue to have that concern, there is now also a large group of countries with very large and growing foreign exchange reserves who may be unwilling or unable to let them grow without bound. What these countries could then experience is what we will refer to as a balance of payments *anti-crisis*.

In this paper we focus on the effects of such anti-crises on the domestic economy. We therefore study this problem in the context of a small open economy, without emphasizing the global repercussions that might arise if the central bank of a larger player, like China, should discontinue foreign exchange purchases. We assume that a central bank, similar to the Chinese announcement of 2007, declares that it will continue accumulating reserves only up to an upper limit that is not too far above the existing level.[2] To account for the

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[1]The last period shown in Figure 1 (and Figure 2) is 2007Q4, because 2008 data were dominated by the world financial crisis.

[2]In terms of describing pre-crisis dynamics, it is in fact sufficient to assume that markets, as in the Colombian case, perceive this intention or necessity on the part of the central bank.

fact that the countries concerned may be pursuing a variety of different monetary regimes, we examine the cases of exchange rate targeting, CPI inflation targeting and domestic (nontradables) inflation targeting.

We assume that the event that ultimately leads to an anti-crisis is a favorable shock to the government budget. Specifically, we assume that the government starts to receive an additional tradables endowment equal to 1% of GDP. As illustrated in Figure 2, this may be a good stylized description of the situation experienced by several strongly performing economies prior to the recent financial crisis. Chile saw a rapid improvement in its fiscal balance starting in 2003, mainly due to a large increase in the world copper price. In Chile half of the copper sector is state-owned, while the privately-owned remainder generates higher taxes and royalties when prices rise. Norway and Russia, around the same time, saw a big fiscal improvement due to higher world prices for hydrocarbons. State ownership in this sector is large in both countries. In each of these three cases it was this improvement in the fiscal balance that was mainly responsible for the simultaneous improvement in the current account balance, and therefore a rapid accumulation of foreign exchange reserves.[3] In 2007 all three countries experienced exchange rate appreciation accompanied by stable or even increasing aggregate inflation, which implies that domestic inflation was increasing. Unlike for China and Colombia, for these countries we are not aware of public information that would have suggested an imminent end to the continuation of reserve accumulation. But in each case the countries concerned did experience a tension, in that there was for several years little reason to expect the high raw materials prices and therefore the surpluses to discontinue, while the growth in reserves was exponential and, absent other budgetary changes, indicative of unstable government *asset* dynamics.[4] The question is therefore what those budgetary changes could be. There are three possibilities. The first two are obvious, the government could increase spending or decrease taxation. The third possibility is what concerns us here - the government could announce that it will stop reserve accumulation, or markets could force the government into doing so.

We show that this is enough to balance the budget endogenously if reserves are not already too large. The announcement causes downward pressure on exchange rate depreciation, with goods and money demand increasing in an accelerating fashion due to the resulting reduction in inflationary distortions. The increase in real money demand, to the extent that it is accommodated by nominal money issuance in exchange for foreign currency, causes a final burst of reserve accumulation, the anti-crisis. Under inflation targeting this crisis is continuous while under exchange rate targeting it is instantaneous. The reserve gains are fastest, and the anti-crisis therefore happens earliest, under monetary regimes that imply the strongest commitment to intervene in foreign exchange markets by issuing money against foreign exchange, and therefore the strongest commitment against letting the nominal exchange rate appreciate. The ranking of regimes

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[3]In the case of Colombia, as discussed above, fiscal surpluses were not the main driver of reserve accumulation. According to the official data, the same is true for China. However, the official data may be misleading due to, for example, the manner in which they account for public enterprises. In a World Bank empirical study, Kuijs (2005) finds that "(The Chinese) Government saving is remarkably high compared to other countries, and is much higher than suggested by the headline fiscal data." It is for this reason that we do not show the official Chinese fiscal surplus data in Figure 1.

[4]In 2006/7, the Chinese gross/net reserves equalled approximately 40%/25% of GDP. The corresponding Russian figures were 30%/20%. Norwegian reserves reached almost 100% of GDP, while in Chile and Colombia they equalled around 15% of GDP.

in terms of reserve gains is therefore, from fastest to slowest, exchange rate targeting followed by CPI inflation targeting and domestic inflation targeting.

For the government the effect of lower exchange rate depreciation is a reduction in seigniorage income that balances the budget. The point at which this happens is not arbitrary, because by uncovered interest parity exchange rate depreciation cannot drop arbitrarily low without violating the zero lower bound on nominal interest rates. Because this limits the extent to which lower seigniorage can balance the budget, it ensures that the anti-crisis happens before reserves go beyond a certain maximum.

The rest of the paper is organized as follows. Section 2 develops the model. Section 3 discusses model calibration and the solution algorithm. Section 4 discusses the dynamics of balance of payments anti-crises. Section 5 concludes. Technical details and a description of the solution algorithm are contained in the Technical Appendix accompanying the paper.

II. The Model

The economy consists of a government, a representative household, and representative tradables and nontradables producing firms. Real interest rates and international goods prices are exogenous and constant, and the latter are normalized to one. Purchasing power parity holds for tradable goods, while nontradables prices are flexible.

A. Households

Households maximize lifetime utility derived from their consumption of tradable goods c_t^T, nontradable goods c_t^N, and leisure $1 - h_t$, where 1 is the time endowment and h_t is hours worked or labor supply. The CES consumption aggregator is c_t, the elasticity of substitution between c_t^T and c_t^N is denoted by σ, and the quasi-share parameter of tradables is η. The personal discount rate is assumed to equal the constant real international interest rate r. We have the optimization problem

$$Max \quad \int_0^\infty \left[\gamma \ln c_t + (1 - \gamma) \ln(1 - h_t) \right] e^{-rt} dt \, , \tag{1}$$

$$c_t = \left(\eta^{\frac{1}{\sigma}} (c_t^T)^{\frac{\sigma-1}{\sigma}} + (1 - \eta)^{\frac{1}{\sigma}} (c_t^N)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \, . \tag{2}$$

Labor is remunerated at the real wage rate $w_t = W_t / E_t$, where W_t is the nominal wage rate and E_t is the nominal exchange rate. Wages are equalized across the two sectors. Households own fixed capital stocks k^T and k^N with real returns $r_t^{k^T}$ and $r_t^{k^N}$. They also receive lump-sum transfers g_t from the government. Financial assets include nominal domestic currency money balances M_t, real international bonds b_t with constant real return r, and domestic currency government bonds Q_t, for which there is complete home bias, with nominal return i_t. The no-arbitrage condition between domestic and foreign currency denominated bonds, or uncovered interest parity, is given by

$$i_t = r + \varepsilon_t \, , \tag{3}$$

where $\varepsilon_t = \dot{E}_t/E_t$. Foreign and domestic currency denominated bonds are therefore perfect substitutes, and we can simplify further by assuming that domestic government bonds are in zero net supply at all times. Total real financial assets are then given by $a_t = b_t + m_t$, where $m_t = M_t/E_t$. After imposing the transversality condition $\lim_{t\to\infty} a_t e^{-rt} \geq 0$, households' lifetime budget constraint can be written as

$$a_0 + \int_0^\infty \left(w_t h_t + r_t^{k^T} k^T + r_t^{k^N} k^N + g_t \right) e^{-rt} dt \geq \int_0^\infty \left(c_t^T + \frac{c_t^N}{e_t} + i_t m_t \right) e^{-rt} dt , \quad (4)$$

where $e_t = E_t/P_t^N$ is the relative price of tradables, and P_t^N is the nominal price of nontradables. There is a cash-in-advance constraint on consumption

$$m_t \geq \alpha \left(c_t^T + \frac{c_t^N}{e_t} \right) . \quad (5)$$

We will assume and later verify that this constraint holds with equality at all times, which must be true as long as $i_t > 0 \; \forall t$. The household maximizes (1) and (2) subject to (4) and (5), taking as given $\left\{ w_t, r_t^{k^T}, r_t^{k^N}, g_t, E_t, P_t^N \right\}_{t=0}^\infty$. The multiplier of the lifetime budget constraint (4) is given by λ. Then the optimality conditions are (4) and (5) holding with equality, and the following first-order conditions:

$$c_t^T = \left(\frac{\eta}{1-\eta} \right) \left(\frac{c_t^N}{e_t^\sigma} \right) , \quad (6)$$

$$\frac{1-\gamma}{1-h_t} = \lambda w_t . \quad (7)$$

We can also derive the following condition relating aggregate consumption to aggregate labor supply (see the Technical Appendix):

$$w_t^{cpi} = \frac{W_t}{P_t} = \frac{1-\gamma}{\gamma} \frac{C_t(1+\alpha i_t)}{1-h_t} . \quad (8)$$

The consumption based price index P_t is given by

$$P_t = \left(\eta \left(E_t \right)^{1-\sigma} + (1-\eta) \left(P_t^N \right)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} . \quad (9)$$

Letting $\pi_t = \dot{P}_t/P_t$ and $\pi_t^N = \dot{P}_t^N/P_t^N$ we also have the following relationship between inflation rates:

$$\pi_t \left(\eta e_t^{1-\sigma} + (1-\eta) \right) = \eta e_t^{1-\sigma} \varepsilon_t + (1-\eta)\pi_t^N . \quad (10)$$

B. Firms

The production functions of tradables and nontradables manufacturing firms are given by

$$y_t^T = \left(k^T \right)^{\rho^T} \left(h_t^T \right)^{1-\rho^T} , \quad (11)$$

$$y_t^N = \left(k^N \right)^{\rho^N} \left(h_t^N \right)^{1-\rho^N} , \quad (12)$$

where h_t^T and h_t^N are the respective labor inputs. Profit maximization implies standard first order conditions for labor.

C. Government

The government receives a flow endowment of tradable goods $\{d_t\}_{t=0}^{\infty}$ that is normalized to zero in the initial steady state. Government policy consists of a specification of the path of lump-sum transfers $\{g_t\}_{t=0}^{\infty}$ and of a monetary policy rule. For the latter we consider exchange rate targeting, CPI inflation targeting and domestic inflation targeting. The initial target inflation rates under the respective regimes are denoted by $\bar{\varepsilon}$, $\bar{\pi}$ and $\bar{\pi}^N$. These target growth rates are assumed to have been consistent with fiscal solvency under a previous path of endowments and transfers. However, after the arrival of information at time 0 about a more favorable path of transfers $\{d_t\}_{t=0}^{\infty}$, they become too high to prevent ongoing foreign exchange reserve accumulation that would be unbounded without an ultimate change of policy. The eventual steady state target nominal growth rates will be determined by a balanced budget requirement for the government.

For each of the three monetary regimes, we assume that central bank accommodation of changes in real money demand at time 0 ensures a smooth path of the targeted price variable. Exchange rate targeting is therefore fully defined by a continuous target path for the nominal anchor:

$$E_t = E_0 e^{\bar{\varepsilon} t} \ . \tag{13}$$

For inflation targeting, we follow the literature in assuming that the central bank follows a nominal interest rate rule that responds to deviations of inflation from its target. But we replace inflation deviations with deviations of the price path from its targeted path. This avoids indeterminacy under flexible prices. The target price paths $\tilde{P}_t$ and $\tilde{P}_t^N$ are formulated as in (13). Furthermore, the nominal interest rate is raised one for one with the current rate of exchange rate depreciation. For CPI inflation targeting, we therefore have the rule

$$i_t^P = r + \varepsilon_t + \xi^P (P_t - \tilde{P}_t) \ , \ \xi^P > 0 \ , \tag{14}$$

$$\tilde{P}_t = P_0 e^{\bar{\pi} t} \ , \tag{15}$$

and similarly for domestic inflation targeting

$$i_t^{P_N} = r + \varepsilon_t + \xi^{P_N} (P_t^N - \tilde{P}_t^N) \ , \ \xi^{P_N} > 0 \ , \tag{16}$$

$$\tilde{P}_t^N = P_0^N e^{\bar{\pi}^N t} \ . \tag{17}$$

Let x_t be the government's foreign exchange reserves. Then its budget constraint is

$$\dot{x}_t = r x_t + \dot{m}_t + \varepsilon_t m_t + d_t - g_t = r x_t + \mu_t m_t + d_t - g_t \ , \tag{18}$$

where $\mu_t m_t$ is the amount of seigniorage collected by the central bank. At times of discrete upward jumps in real money balances between t^- and t, we can decompose that jump as $\Delta m_t = \Delta m_t^M + \Delta m_t^E > 0$. Here Δm_t^M are jumps in real money balances that are due to jumps in nominal money balances, that is, $\Delta m_t^M = (M_t - M_{t-})/E_t$, while Δm_t^E are jumps in real money balances that are due to downward jumps in the nominal exchange rate, that is, $\Delta m_t^E = M_{t-} (1/E_t - 1/E_{t-})$. The former are associated with central bank acquisition of foreign exchange, so that $x_t - x_{t-} = \Delta m_t^M$, but the latter are not associated with changes in foreign exchange reserves. There is a similar decomposition for continuous increases in real money balances $\dot{m}_t = \mu_t m_t - \varepsilon_t m_t > 0$ around the time of the anti-crisis.

Real money balances can increase either through an increase of the nominal money supply ($\mu_t m_t > 0$) or through nominal exchange rate appreciation alone ($\varepsilon_t m_t < 0$). These two effects can be shown to be substitutes – ceteris paribus, a faster expansion in nominal money balances slows down the appreciation of the nominal exchange rate.

The government may at any time announce a maximum level of foreign exchange reserves beyond which it will stop reserve accumulation and instead allow the rate of exchange rate depreciation to adjust. This maximum level is not relevant before time 0, when the government budget is balanced. But when the fiscal revenue shock hits at time 0 we assume that an upper limit for reserves $\bar{x}$ is part of the announced government policy package. We have

$$x_t \le \bar{x} \quad \forall t . \tag{19}$$

In addition we impose the transversality condition $\lim\limits_{t\to\infty} (x_t - m_t)\, e^{-rt} = 0$ to obtain the government's infinite horizon budget constraint from (18) as follows:

$$x_0 + \int_0^\infty \left(i_t m_t + d_t - g_t\right) e^{-rt} dt = m_0 . \tag{20}$$

D.   Equilibrium

In equilibrium, households and firms maximize their objective functions, the government follows the policy rules set out in the previous subsection, and labor and goods markets clear:

$$h_t = h_t^T + h_t^N , \tag{21}$$

$$c_t^N = y_t^N . \tag{22}$$

Combining (4) and (20), and denoting the economy's overall net foreign assets by $f_t = b_t + x_t$, the economy's overall resource constraint can then be derived as

$$f_0 + \int_0^\infty \left(y_t^T + d_t\right) e^{-rt} dt = \int_0^\infty c_t^T e^{-rt} dt , \tag{23}$$

with current account

$$\dot{f}_t = r f_t + y_t^T + d_t - c_t^T . \tag{24}$$

Furthermore, for the two inflation targeting regimes, in equilibrium it must be true that $i_t^P = i_t$ and $i_t^{P_N} = i_t$. Together with the uncovered interest parity condition (3) this implies

$$P_t = P_0 e^{\bar{\pi} t} , \tag{25}$$

$$P_t^N = P_0^N e^{\bar{\pi}^N t} . \tag{26}$$

These are analogous to equation (13) for exchange rate targeting, and amount to exact price level targeting.

E. Government Revenue Shock

Assume that the economy is in an initial steady state (subscript ss) with constant net foreign assets f_{ss}, foreign exchange reserves x_{ss}, endowment flow d_{ss}, and with a balanced budget. In this steady state all rates of price change are equal to the initial target growth rate of the nominal anchor. We assume that $f_{ss} = 0$, $d_{ss} = 0$ and $\varepsilon_{ss} = \pi_{ss} = \pi^N_{ss} = 0$. Therefore the budget is simply

$$g_{ss} - d_{ss} = rx_{ss} \ . \tag{27}$$

For simplicity we assume that $d_{ss} = 0$. Now assume that the government experiences a permanent increase in its endowment flow from d_{ss} to $\bar{d}$ at time 0, with $\bar{g} = g_{ss}$, but that it keeps the target growth rate of its nominal anchor at 0 under all three monetary regimes. We therefore have $\bar{g} - \bar{d} < rx_{ss}$. By (18) this generates an accumulation of foreign exchange reserves that would ultimately be unbounded in the absence of the constraint (19). The constraint therefore becomes binding within finite time τ. At that time the monetary regime collapses in an anti-crisis, and the economy reaches its final (subscript τ) steady state. The time τ is endogenous. Given that the constraint (19) is binding for all $t \geq \tau$, the budget must be balanced through lower seigniorage income from that time onwards,

$$\bar{g} - \bar{d} = r\bar{x} + \varepsilon_\tau m_\tau \ , \tag{28}$$

where $\varepsilon_\tau < 0$. It is shown in the Technical Appendix that under CPI and domestic inflation targeting ε_t must be continuous for all $t > 0$ including τ.

III. Model Solution

A. Parameter Values

Where available, parameters are calibrated based on Chinese data. Other parameter values are assigned based on the literature for developing countries. The time unit for calibration of stock-flow ratios is a quarter.

As is common in the monetary business cycle literature, we assume a value of 3% per annum (p.a.) for the real international interest rate r. Given our assumption of zero initial inflation, the nominal interest rate i_{ss} therefore also equals 3% p.a. The inverse velocity α is set equal to the average ratio of the real monetary base to quarterly output in China over the period 2000Q1 through 2007Q4, implying $\alpha = 1.55$. The quasi-share parameter for tradables consumption η is set equal to $\eta = 0.5$, while the elasticity of substitution between tradables and nontradables is $\sigma = 0.5$, based on the evidence discussed in Mendoza (2005). Several of the remaining parameters are calibrated based on a normalization of output and asset stocks in the initial steady state. We normalize $f_{ss} = 0$, $y^*_{ss} = c^*_{ss} = 1$ and $y_{ss} = c_{ss} = 1$. By (6), and given our choice of $\eta = 0.5$, this implies an initial relative price of tradables $e_{ss} = 1$. This in turn implies that the initial share of tradables in consumption is equal to 0.5 in our baseline. The proportion of time spent working in the initial steady state is $h_{ss} = 1/3$. Labor income shares are assumed to equal 60%, by setting $\rho^T = \rho^N = 0.4$. As for the price variables, the initial CPI price level is normalized to one, $P_{ss} = 1$. Then the formula for the CPI determines the price levels

P_N and E, and the cash-in-advance constraint determines the levels of real and nominal balances.

Initial inflation rates are set to zero, and initial central bank net foreign exchange reserves x_{ss} are set equal to China's average ratio of net foreign exchange reserves to annual output in 2006, which equals 22%. Because initial annual output equals 8, this implies $x_{ss} = 0.22 \times 8 = 1.76$. Government transfers are set equal to the interest earnings on these reserves so as to balance the budget by (27), which requires $g_{ss} = 0.0132$. The new and permanently higher government tradables endowment is assumed to be $\bar{d} = 0.02$, which equals 1% of overall output and 2% of tradables output. Finally, the upper limit on foreign exchange reserves is fixed at 24% of initial annual output, or $\bar{x} = 1.92$. This means that the higher endowment alone would take reserves to their upper limit within eight quarters. In practice the limit will be reached faster because of a combination of compound interest and increases in money demand at time 0 and during the anti-crisis.

B. Solution Method

To compute the paths of all variables we adopt a nested shooting algorithm for the CPI and domestic inflation targeting cases, because these cases involve complicated transitions to a new steady state. The general strategy is to iterate over the marginal value of lifetime wealth λ and the initial exchange rate jump ε_0 to ensure that, given the policy announced at time 0, equilibrium paths satisfy both the economy's overall resource constraint (23) and the government's lifetime budget constraint (20), the latter combined with the upper bound on foreign exchange reserves (19). The steps of the algorithm are described in detail in the Technical Appendix.[5]

IV.   Anti-Crises

Figure 3 presents solution paths for our policy experiment, with broken lines denoting exchange rate targeting (ET), solid lines denoting CPI inflation targeting (CPIT), and dotted lines denoting domestic inflation targeting (DIT).

The three monetary regimes share a number of features. At time 0, households learn that the government will receive a permanently higher endowment of tradables equal to 1% of the initial GDP. They know through the policy announcement that this windfall will not be shared with them immediately by way of higher transfers, but instead will be shared over their lifetimes by way of lower inflation, after an initial period in which the government saves the extra revenue without a significant reduction in inflation.

This pattern, as seen in Figure 3a, has two effects on household behavior. First, there is an immediate positive wealth effect as households anticipate future benefits by consuming more and working less today. Second, when inflation eventually does decline, households increase consumption even further. But this is due to a reduction in inflationary

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[5]Computation of the exchange rate targeting case is much simpler, as it involves simple step paths for all variables. Details are also provided in the Technical Appendix.

distortions rather than a further wealth effect. This means that at that time, to satisfy the extra demand, labor supply actually rises to slightly above its original level. In the long run, both consumption and labor are therefore above their initial steady state values. This reflects not only the positive endowment shock and the foreign asset accumulation experienced during the transition, but also the smaller inflationary distortions in the new steady state.

The details of the dynamics of anti-crises under the three monetary regimes differ in that they happen instantaneously under exchange rate targeting, while under inflation targeting they happen continuously over a period of one to two quarters. This difference is best understood in terms of the time profiles of the inflationary distortions. By equations (8) and (3), the key variable is the rate of exchange rate depreciation ε_t. Under exchange rate targeting this is held constant by the central bank, both before and, at a different level, after τ. There is therefore a discrete reduction in distortions and thus an increase in real variables at time τ. Under inflation targeting, ε_t becomes endogenous and, as shown in the Technical Appendix, continuous after time 0. Inflationary distortions are therefore allowed to increase in a gradual fashion before time τ. As a result, all real variables approach their post-crisis values in a continuous fashion.

Both consumption and production patterns depend on the evolution of the relative price of tradables e, which falls both initially and again later during the anti-crisis. The reason is that households now demand more of all goods, but unlike tradables, nontradables are not in perfectly elastic supply. This drives up their relative price, which helps to stimulate additional production as real wages fall in terms of nontradables and rise in terms of tradables. This causes employment to move to the nontradables sector, as illustrated in Figure 3b. The final outcome is a Dutch disease phenomenon, as tradables output falls by about one third of the increase in the tradables endowment (0.7% versus 2% of initial tradables output).

Comparing tradables consumption and output in Figure 3a, we observe that the initial gap between the two equals less than half of the increase in the endowment. This is because prior to the anti-crisis the endowment supports mostly additional reserve accumulation rather than additional consumption. As a result the country at this stage starts to run a current account surplus equal to around 0.4% of GDP. But during the anti-crisis consumption increases sharply as inflationary distortions are eliminated, and in the final steady state the current account is again balanced. At this stage the gap between tradables consumption and output equals slightly over 2% of GDP, the size of the endowment increase plus interest on the accumulated reserves.

Figure 3c shows how this pattern is reflected in the government budget and in its stock of foreign exchange reserves. The government gains reserves that ultimately hit the upper bound for several reasons. Firstly, there is of course the increase in endowment income. But secondly, money demand also increases, both on impact and then again during the anti-crisis. By the cash-in-advance constraint this is due to an increase in consumption, and the amount of that increase is nearly independent of the monetary regime.

The extent to which this causes reserves to increase is however a function of the monetary regime, as discussed above in the paragraph following equation (18). The main differences between regimes consist of the degree of commitment to let the money supply expand, or

of the degree of commitment against letting the exchange rate appreciate, in order to defend the target of monetary policy. A monetary regime that intervenes less, and lets the exchange rate appreciate earlier and more, thereby collecting a lower inflation tax before the anti-crisis, experiences smaller reserve gains during the entire transition to the eventual collapse. Its anti-crisis therefore takes place later. The differences between nominal money issuance versus nominal exchange rate appreciation between the three monetary regimes can be seen clearly in Figure 3d. We observe that intervention is weakest under domestic inflation targeting, intermediate under CPI inflation targeting, and strongest under exchange rate targeting.

We start our discussion with domestic inflation targeting. Here the commitment against letting the exchange rate appreciate is weakest. The successive reductions in the relative price of tradables are therefore accomplished by an appreciation of the nominal exchange rate rather than by an increase in the nontradables price. This raises the real value of existing money balances sufficiently to require much smaller additional money issuance and therefore reserve gains to satisfy the successive increases in money demand. This is true both at the outset and during the anti-crisis.

Under CPI inflation targeting, the commitment to intervene is stronger and reserve gains are larger. The reason is that, while permitting exchange rate appreciation under domestic inflation targeting does not directly affect the targeted inflation rate, the same appreciation does lead to a negative deviation from a CPI inflation target. A further increase of the money supply, via central bank purchases of foreign exchange, is therefore required to induce nontradables inflation and to limit exchange rate appreciation.

Under exchange rate targeting, the central bank's commitment to intervene is strongest, given its complete commitment against letting the exchange rate appreciate. Therefore the entire increase in money demand, both initially and during the anti-crisis, leads to instantaneous stock money issuance against a stock acquisition of foreign exchange reserves, $\Delta m = \Delta m^M$. As a result, the upper limit on reserves is reached most quickly, after 5.5 quarters, a full 1.5 quarters earlier than under domestic inflation targeting.

The bottom half of Figure 3c shows the flow budgetary implications of anti-crises. We note that the seigniorage gains under domestic inflation targeting are indeed very much smaller than under CPI inflation targeting, because additional money issuance $\dot{m}$ is barely sufficient to offset the drop in the inflation tax εm. But more importantly, the final steady state is characterized by a reduction in the seigniorage to GDP ratio by slightly more than one percentage point. This is of course precisely what is required to offset the one percentage point (of initial GDP) higher endowment income and the increased interest income on a two percentage point (of initial GDP) larger stock of reserves.

Finally we turn to Figure 3d for a closer look at the dynamics of inflation. The first observation is that exchange rate depreciation comes to a halt at -2.7%, meaning that the nominal interest rate, shown in Figure 3a, reaches a new steady state of 0.3%, just above its zero lower bound. This emphasizes that the upper reserve limit announced by the government cannot be arbitrarily large. If the endowment shock is not accompanied by other budgetary changes such as spending increases or tax cuts, the zero lower bound on nominal interest rates will impose an upper limit on foreign exchange reserves, because once reserves get beyond that limit, even the largest feasible reduction in seigniorage will

not stabilize government asset dynamics. We have calibrated the example on the realistic premise that a monetary authority would not want to drive its nominal interest rate all the way down to zero.

The second observation pertaining to Figure 3d concerns the behavior of nontradables inflation under CPI inflation targeting. In the monetary business cycle literature it is generally argued that nontradables inflation targeting has advantages over CPI inflation targeting in terms of stabilizing the business cycle. But in practice some version of CPI inflation targeting is still the most widely used monetary regime. As discussed above, under this regime the central bank fights exchange rate appreciation prior to time τ through higher money growth that induces nontradables inflation. Therefore, as long as the central banks of the countries discussed in Figures 1 and 2 could be described as following, at least implicitly, a version of CPI inflation targeting, an increase in the domestic component of inflation would be fully consistent with an incipient balance of payments anti-crisis.[6]

V.   Conclusion

This paper addresses a relatively new phenomenon for emerging markets, a concern either by the government or by financial markets with excessive rather than insufficient government foreign exchange reserves, often accompanied by exchange rate appreciation and higher domestic inflation. While such episodes may often turn out to be nothing more than a natural resource cycle, they can also have a critical fiscal dimension, particularly if government assets look to be on an unstable, explosive trajectory. This paper explores the nature of that fiscal problem and its dependence on the monetary regime.

We show that one way to understand these episodes is by looking at them through the lens of the literature on balance-of-payments crises. The major difference is that the crises, or rather the anti-crises, that concern us feature an upper rather than a lower limit on foreign exchange reserves. Moreover, this upper limit is not arbitrary but rather depends on the ability of seigniorage adjustments to stabilize asset dynamics. That ability encounters its natural limit in the desire of the monetary authority to stay away from the zero lower bound on nominal interest rates.

We have shown that the end-phase of such anti-crises is characterized by an economic boom accompanied by a further acceleration in the accumulation of foreign exchange reserves, and by nominal interest rates approaching their zero lower bound. While exchange rate depreciation drops sharply at that time, domestic inflation can rise sharply if the government targets CPI inflation. Monetary regimes that imply the strongest commitment to intervene in the foreign exchange market to prevent exchange rate appreciation, such as exchange rate targeting and to a lesser extent CPI inflation targeting, experience the most rapid reserve accumulation and therefore the quickest onset of the anti-crisis.

The financial crisis of 2008/9 has dramatically changed the asset dynamics of many governments around the world, as several countries including China and Russia have

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[6]In fact our discussion of Colombia seems perfectly consistent with this story.

started to use some of their reserves to stimulate their domestic economies. But global current account imbalances are still a major issue, and governments are major participants in those imbalances. Furthermore, a resumption in high energy prices over the medium term, a distinct possibility under the demand-supply forecast scenarios developed by the International Energy Agency (2008), could lead to renewed explosive asset dynamics among hydrocarbons exporters. The relevance of the phenomenon analyzed in this paper has therefore by no means disappeared.

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Figure 1. China and Colombia – Reserves and Inflation
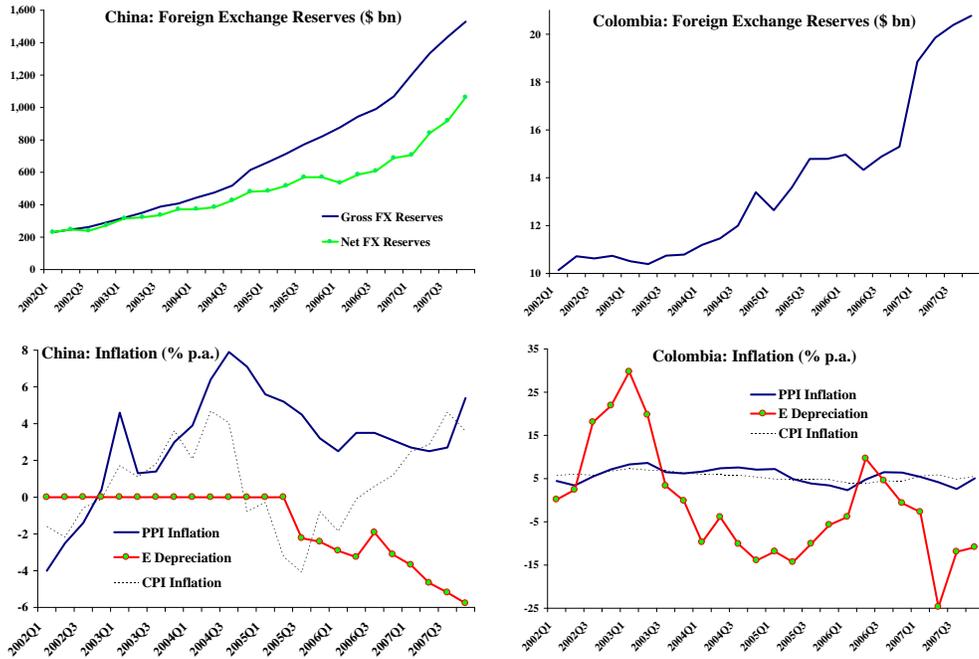
Note: For China, both gross and net foreign exchange reserves are shown. The latter deduct from gross reserves the central bank bond liabilities issued for the purpose of sterilizing reserve accumulation. The model treats such bonds as perfect substitutes for international bonds.

Figure 2. Chile, Norway and Russia – Reserves and Inflation
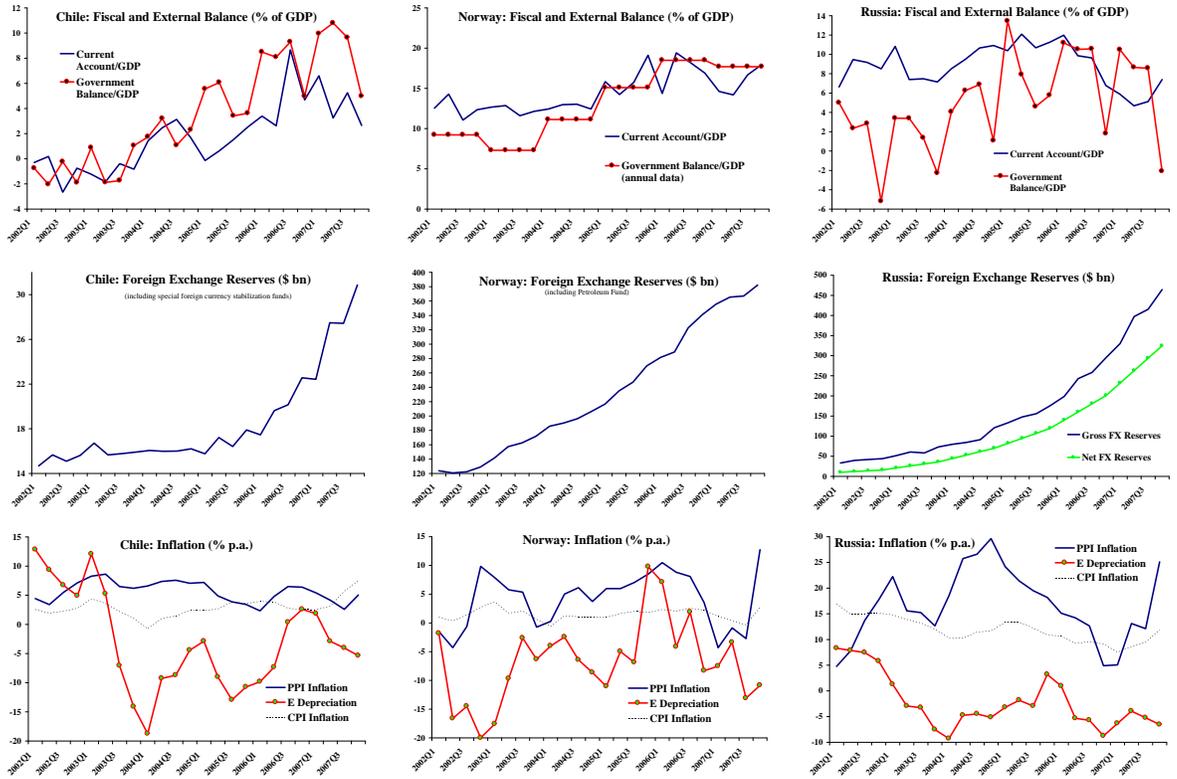
Figure 3. (a) Anti-Crisis — Overview
ET = --, CPIT = —, DIT = …

Nominal Interest Rate (i)

Relative Tradables Price ($e = E / P^N$)

Nontradables Consumption (c^N)

Tradables Consumption (c^T)

Nontradables Output (y^N)

Tradables Output (y^T)

Aggregate Consumption (c)
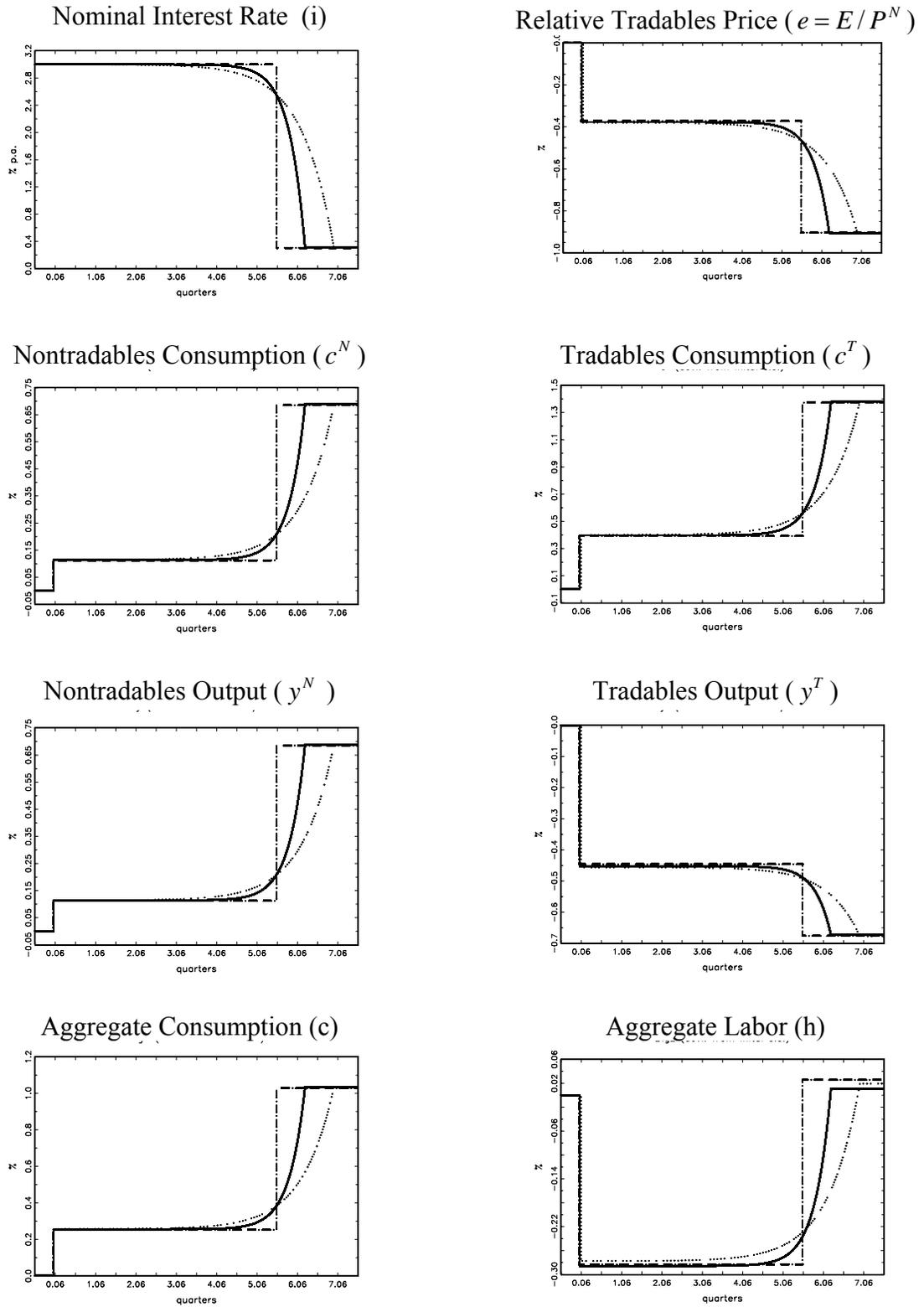
Aggregate Labor (h)

Figure 3. (b) Anti-Crisis ─ Labor Market
ET = --, CPIT = ──, DIT = …

Nontradables Labor Demand (h^N)
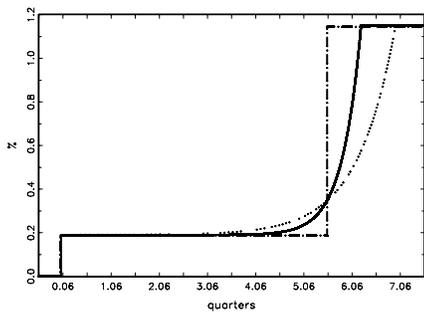
Real Wage in Nontradables ($w^N = W / P^N$)
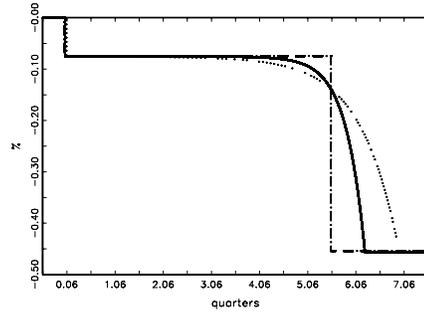
Tradables Labor Demand (h^T)
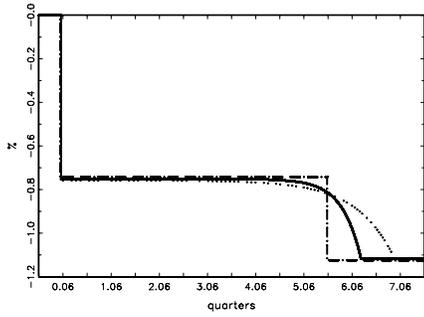
Real Wage in Tradables ($w = W / E$)
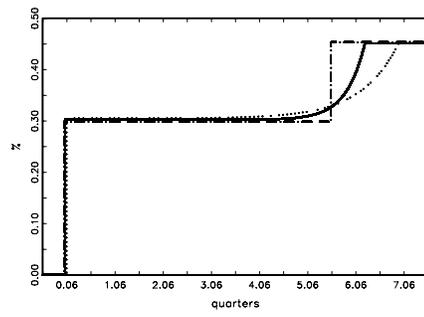
Aggregate Labor (h)
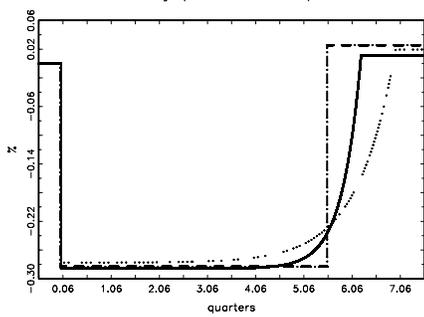
Real Wage in terms of CPI ($w^{cpi} = W / P$)
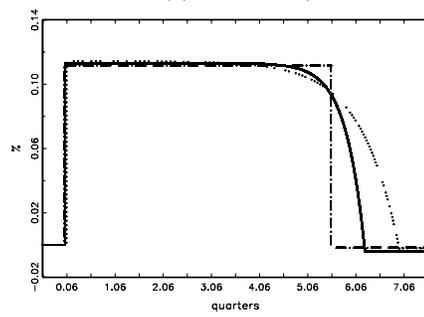
Nominal Wage Level (W)
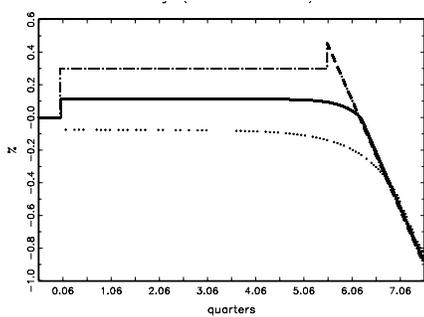
Nominal Wage Inflation (π^w)
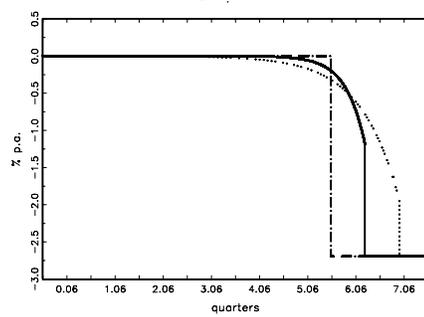
Figure 3. (c) Anti-Crisis ― Government Budget
ET = --, CPIT = ―, DIT = …

Real Money Balances (m)

Foreign Exchange Reserves (x)

Current Account / GDP (ca/gdp)

Net Foreign Assets / GDP (f/gdp)

Endowment / GDP (d/gdp)

Seigniorage / GDP (μm/gdp)

Inflation Tax / GDP (εm/gdp)

Real Money Growth / GDP ($\dot{m}$ /gdp)
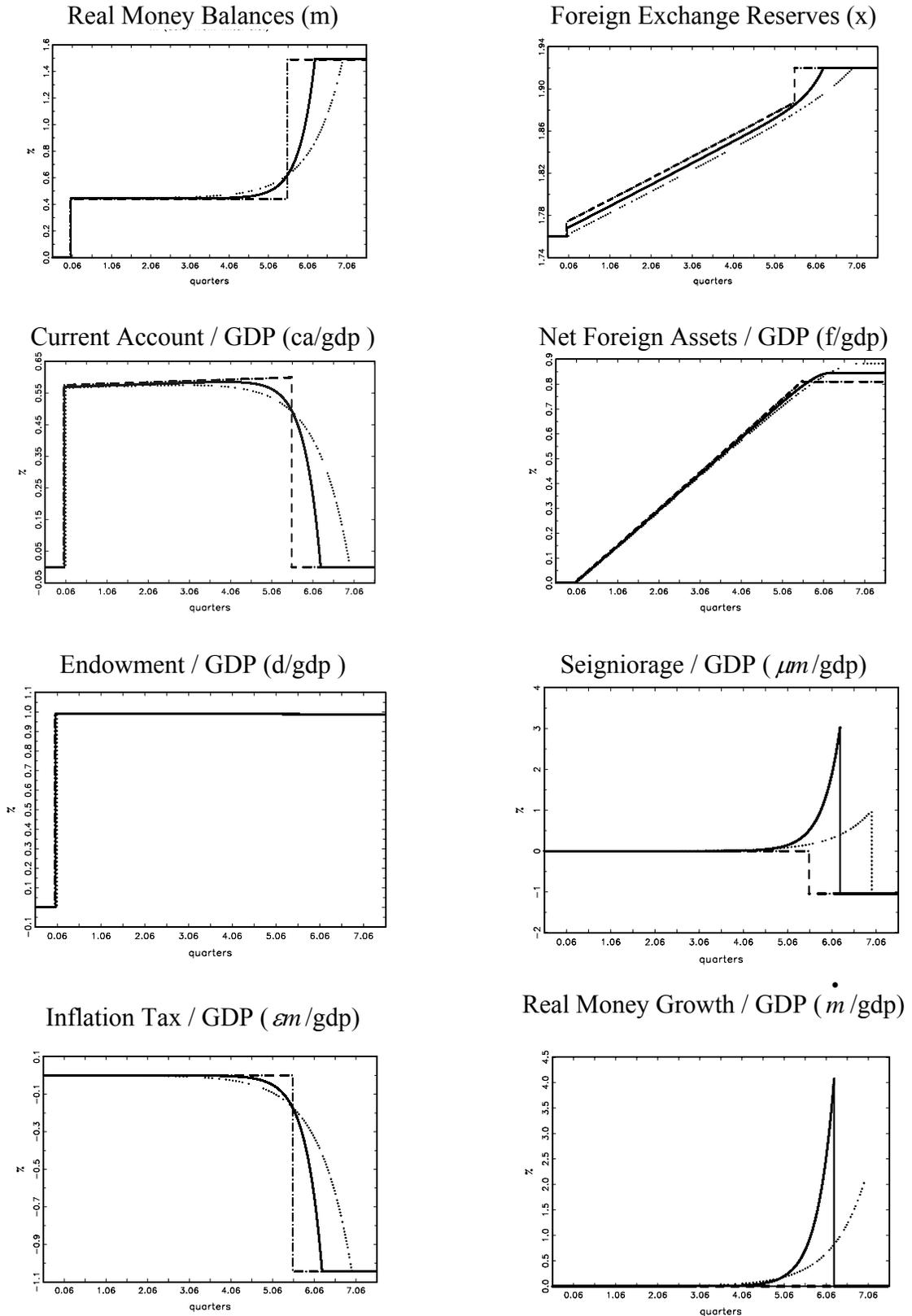
Figure 3. (d) Anti-Crisis — Price Levels and Inflation Rates
ET = --, CPIT = —, DIT = …

Nominal Money Stock (M)

Nominal Money Growth (μ)

Nominal Exchange Rate (E)

Nominal Depreciation (ε)

Nominal Nontradables Price Level (P^N)

Nominal Nontradables Inflation (π^N)

Nominal CPI Price Level (P)

Nominal CPI Inflation (π)