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Reserve Requirements, Bank Runs, and Optimal Policies in Small Open Economies

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Abstract: This paper rationalizes as the outcome of an optimal policy decision the pattern of reserve requirements and other macroeconomic variables in the aftermath of a bank run. The paper develops a general equilibrium model that departs from the standard small open economy (SOE) model in three dimensions: (i) capital mobility is not perfect, (ii) there exists a costly banking system, and (iii) there is an externality affecting individual banks' decisions. The results suggest that the path of reserve requirements would depend on the type of shock that the economy receives and the effect that this shock produces on the interest rate. Interestingly, the size of the risk premium will affect the reaction of the economy to the shock. It is also shown that the dynamic adjustment will be slightly different for permanent and temporary shocks, and it will also depend on the access that the economy has to foreign funds.

JEL classification: E44, E58, F30, F41, G28

Key words: reserve requirements, optimal policy, financial crisis, emerging markets

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Reserve Requirements, Bank Runs, and Optimal Policies in Small Open Economies

1. Introduction

"Saving for a rainy day" is well understood in all economic fields. If regulators want to apply this policy to the amount of liquidity that banks should hold, they will say "accumulate liquidity in normal times and use it in bad times", which in principle seems intuitive and reasonable. But, the evidence does not support this conventional wisdom. In fact, it suggests that the policymaker "flips a coin" when bad times arrive. This paper shows that resorting to the liquidity accumulated during the good days will depend on the underlying shock and the state of the economy at the time of the shock. Also, it shows that the same shock will generate a "cloudy day" under some circumstances and will not under others.[1] Therefore, the policymaker's reaction could be understood as an optimal response to different situations, instead as of "flipping coins".

Liquidity provision is key in the management of systemic banking crises, especially in emerging economies, where the lack of systemic liquidity can exacerbate problems. On one hand, without enough support, a liquidity crisis could lead to a solvency crisis and/or a credit crunch in the economy. On the other hand, the overuse of rediscounts or repos to provide liquidity assistance could lead to excessive money printing, and could weaken the peg in a fixed exchange rate regime or generate inflationary pressures.

There is evidence that shows that during the 90's several central banks provided systemic liquidity to finance the bank runs generated in the financial crises.[2] In general, the liquidity support includes all the funds provided to the system through rediscounts, repos, contingent contracts, and the reduction of reserve requirements.[3] This last instrument is the focus of the paper.

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[1] Continuing with the weather comparison, having one week of rain is a very bad shock if you live in LA (think about finding an indoor place to eat on UCLA's campus!) but it is a normal day in London.
[2] For more details see Lindgren, C. et al. (1999).
[3] Reserve requirement is the ratio of liquid assets over deposits imposed by the monetary authorities to commercial banks. A reduction in the requirement allows banks to use some liquid reserves that would otherwise be immobilized in their balance sheets.

The literature on the optimality of maintaining a stock of liquid reserves is broad (Baltensperger (1974), Santomero (1984), Cothren and Waud (1994), Stein (1995), Agénor et al. (2000)). Also, there are some works that analyze the use of reserve requirements from a macroeconomic standpoint: as a countercyclical tool (Edwards and Végh (1997), Calvo et al. (1993)), as a mechanism to enforce capital requirements (Fernandez and Guidotti (1996)), or as an instrument that helps to collect the inflation tax (Englud and Svensson (1988)). There are some other papers that study optimal policies under financial crises (Lahiri and Végh (2003); Rebelo and Végh (2001), Ganapolsky (2003)).[4] But, in spite of the importance of reserve requirements as a liquidity provider, there is no work that studies its optimal use in a financial crisis.

The purpose of this paper is to provide a framework to understand the behavior of reserve requirements as the outcome of an optimal policy decision. In particular, it rationalizes the pattern of reserve requirements and other macroeconomic variables in the aftermath of a bank run.[5]

With that aim, the paper develops a general equilibrium model that departs from the standard small open economy (SOE) model in three dimensions: (i) capital mobility is not perfect, (ii) there exists a costly banking system, and (iii) there is an externality affecting individual bank's decisions.

The imperfect capital mobility is introduced through an upward sloping supply of funds curve. Technically, this assumption will allow the study of interest rate shocks in the SOE set up, providing a mechanism for adjusting to a new steady state.[6] Also, this is a realistic assumption for most emerging markets, which tend to pay a risk premium on their debt. With perfect capital mobility, countries would be able to completely finance a bank run abroad, and nothing would happen domestically. But if the cost of funds increases with the amount borrowed, it would not be optimal to finance the run totally

[4] In general, they are concerned with the defense of the exchange rate in a balance-of-payment type of crisis, using international reserves and interest rate as the main policy instruments.

[5] The relevance of reserve requirements in the management of systemic liquidity depends on several features of the economy in consideration, as the degree of capital mobility, the existence of some kind of illiquidity costs and the degrees of freedom to perform monetary policy. They are important for example in economies with fixed exchange rates, currency board arrangements, or even flexible exchange rates where the stock of deposits is highly dollarized.

[6] For other mechanism to close the SOE model under interest rate shocks see Schmitt-Grohe, S. and M. Uribe (2001). The purpose of those mechanisms is to generate some transitional dynamics that put the SOE in a steady state, otherwise it will diverge forever.

abroad; thus, some domestic adjustments would occur. Obviously, the importance of this margin will depend on the size of the risk premium, economies paying high interest rates will react differently than economies paying lower rates.

Banking activity is costly because of the assumption that there are some operational expenditures related to the bank's assets management, which are reduced if part of the portfolio is invested in liquid assets.

The externality consists of individual banks considering only their own liquidity in their optimization problems, and forgetting the effect of aggregate liquidity in their decisions. Therefore, to improve the welfare of the economy the government should intervene by making the bank internalize the benefits of aggregate liquidity.

The results suggest that the path of reserve requirements would depend on the type of shock that the economy receives and the effect that this shock produces on the interest rate. For instance, a permanent negative output shock will produce a withdrawal of deposits but will affect neither the interest rate nor the reserve requirements. Only when the interest rate is increased, will the opportunity cost of holding liquidity be higher and, therefore, be worth reducing the stock of liquid assets.

This paper analyzes in detail the response of the economy to an interest rate shock. Interestingly, the size of the risk premium will affect the reaction of the economy to this shock. An increase in the international interest rate will generate a flight "from" deposits when the risk premium is high enough, but will generate a flight "into" deposits for low risk premia. Also, the magnitude of the bank run in the first case will be directly related to the size of the risk premium.

It is also shown that the dynamic adjustment will be slightly different for permanent and temporary shocks, and it will also depend on the access that the economy has to foreign funds. In general, these paths are consistent with the evidence presented in Section 2.

The paper is organized as follows. Section 2 shows evidence and analyzes some episodes of deposits drainage during the last two decades in Asia, Europe and Latin America. Section 3 presents a SOE model with perfect foresight, imperfect capital mobility and costly banking. Section 4 studies the bank runs generated in that context by

interest rate shocks. Section 5 analyzes the bank runs produced by output shock. Finally, Section 6 summarizes the main findings.

2. The evidence

Choosing the bank runs episodes to analyze could be done following two different routes: an episodic approach or a mechanical rule. Given that the purpose of the paper is to understand the behavior of reserve requirements in a particular type of banking crisis, a liquidity crisis, the mechanical rule is chosen. The episodes are defined according to the following rule: a bank run is an episode where there is at least a 5% reduction in total deposits, during at least 2 months in a row, and it lasts until deposits start to recover again.[7] The problem of analyzing the episodes defined in previous literature, is that the definition of a banking crisis is broad. It could refer to a liquidity problem, a solvency problem or both. Following the rule defined above, the paper focuses just on those cases where liquidity was the main issue.

Following that definition we construct Table 1 with data from the International Financial Statistics (IFS) database. We use monthly data (quarterly when not available) to search for bank runs in Asia, Europe and Latin America during the period January 1980 to December 2002. The deposits series include demand, saving and time deposits of deposit money banks. The reserve ratio series is the ratio between liquid reserves and total deposits of the same group of banks.

We found 94 episodes of what we call a bank run. Interestingly, only in 49% of the episodes the reserve ratio was reduced. The percentages are very different across different regions as Table 2 shows. Europe and Latin America seem to give more support to the conventional wisdom than the Middle East and Transition Countries. On one extreme, in 63% of the cases in Europe the reserve ratio falls; on the other, only 31% of the cases in the Middle East show a reduction in the ratio.

[7] Two qualifications are worth mentioning: (i) if deposits recover for one period and fall again in the next, then the run will be extended if the net contribution of the additional period is negative; (ii) some outlier cases were disregarded.

In sum, as was mentioned in the introduction, we cannot say that the evidence suggests that liquid reserves are always reduced during a deposit drainage.

We also study in more detail some of the cases presented in Table 1. The criterion to choose the cases was based on two pillars: (i) we pick the cases that overlap with the episodes mentioned in Caprio and Klingebiel (1996), (ii) we focus on those with available data. Filtering with this criterion, we obtained five cases to analyze in more depth: Argentina 1994/95, Estonia 1992/93, Lithuania 1995/96, Spain 1982/83 and Sweden 1992.

In Figure 1, the first chart for each country shows the evolution of deposits, credit and the reserve ratio. The common feature of the crises is that there is a fall in deposits that is not matched by the reduction in domestic credit.

We also observe that in Argentina, Sweden and Lithuania the reserve ratio falls. These facts should be interpreted with the balance-sheet identity of the financial system in mind,

$$Assets \equiv Liabilities,$$

$$Liquid\ reserves + Credit = Deposits + Other\ liabilities + Net\ worth.$$

If other liabilities and net worth do not change, the fall in deposits should be absorbed either by a fall in liquid reserves or a fall in credit. Obviously, if liabilities as a whole do not change, assets would not change either, but this is not what should be expected in a crisis when capital is flowing out of the country. In those situations banks also find it harder to levy more capital or issue more debt. Therefore, it seems that systemic liquidity buffered the shock on domestic credit in these 3 countries.[8]

The second chart for each country presents the evolution of interest rates and the reserve ratio. In the cases of Argentina, Lithuania, Spain and Sweden both variables are negatively correlated, but in Estonia they are positively correlated.

We show the paths of the current account and GDP of each country in the last charts. We can see there that in all the cases the current account improves (when compared with the same quarter of the previous year) immediately after the crisis, except in Sweden where the current account becomes more negative on impact and it recovers later.

[8] It is worth mentioning that in Spain there were some changes in regulation at that time due to the entrance of some foreign banks into the system.

Summarizing, we have several episodes of bank runs where the responses to the crises are not always the same. This is precisely what we expect, given that not all the countries received the same shock (in some of them interest rate went up and in others it went down), the countries were not in the same situation and the international environment during the 80's was quite different than during the 90's.

3. The model

Consider a SOE populated by infinitely lived households, with a banking sector and a government. In this economy there exists only a tradable good, c_t, which is the numeraire, and the law of one price holds. Both assumptions together imply that, $P=P^*=1$, where P is the price of the good in the domestic economy and P^* is the price of the good in the world market. In this world there exists capital mobility, but it is not perfect: the economy faces an upward sloping supply of funds.[9] This means that the country will pay a risk premium on its borrowing which depends on the net assets position at each point in time. In this case the interest parity condition will read as:

$$i_t = r^* + \phi(k_t),$$
$$\phi'(k_t) < 0;\ \phi''(k_t) > 0;\ \forall k_t < 0,$$

where i_t is the interest rate this "risky" economy pays, r^* is the risk free interest rate given in the international capital markets, and $\phi(k_t)$ is the risk premium, which depends negatively on the financial wealth of the economy (k_t).

3.1. Households

The representative household derives instantaneous utility from the consumption of the good c_t, according to the following utility function:

$$W = \int_0^\infty u(c_t)e^{-\beta t}dt, \qquad (1)$$

where $u(.)$ is strictly concave, and $\beta<1$.

[9] See for example, Harberger (1980).

In this economy there is no cash. Assume then that the only way in which the agent can buy goods is paying with a debit card. To be able to use the debit card, it needs to have part of its wealth in a bank under the form of deposits, which can be used in any moment. In other terms, the household faces a deposit-in-advance constraint of the following form:[10]

$$d_t \geq \gamma c_t, \qquad (2)$$

where d_t is the quantity of deposits held by the household, and γ is an exogenous parameter.

The representative agent has a portfolio composed by internationally traded bonds, that pay an interest rate i_t, deposits, that pay i_t^d and loans, that cost i_t^l. It will be assumed that the household does not internalize the effects of its actions on the interest rate i_t, that means i_t is given from the agent's point of view.

$$a_t = b_t^c + d_t - l_t, \qquad (3)$$

where a_t is the household's portfolio, b_t^c is the bond's holding, and l_t is the amount of loans.

The agent produces goods using its own labor as the only input, which is supplied inelastically and is normalized to *1*, according to the following production function:

$$\begin{aligned} &y_t = f(n_t); \quad f' > 0;\ f'' < 0, \qquad (4) \\ &n_t = 1, \end{aligned}$$

where n_t is the amount of labor supplied at time t.

The household needs some credit to be able to use its own labor endowment. It faces the following credit-in-advance constraint:

$$l_t \geq \rho f' n_t, \qquad (5)$$

where l_t is the amount of loans borrowed from the bank until time t, ρ is an exogenous parameter, and f' is the marginal product of labor, which will be equal to the real wage in a decentralized economy.[11]

[10] It can be shown that this is a first order approximation of the actual deposit-in-advance constraint for continuous time.

[11] The purpose of this very simple supply side is just to generate an inelastic demand for loans. In this way, the stock of loans would be demand determined, and from the bank point of view they would play the same role as an illiquid asset.

At each point in time, it produces and pays the cost of production, earns interest from its holdings of bonds and deposits, receives profits from the banks and consumes. The flow constraint for this agent is:

$$\dot{a} = i_t a_t + y_t - (i_t^l - i_t) l_t + \Omega_t - c_t - (i_t - i_t^d) d_t, \qquad (6)$$

where $\dot{a}$ is the instantaneous change in household's assets, $(i_t^l - i_t)$ is the spread paid over loans, Ω_t are banks' profits and $(i_t - i_t^d)$ is the opportunity cost of holding deposits.[12]

Therefore the household's problem is to choose the path for c_t that maximize (1) subject to (6), (2), (4) and (5).

To solve the optimal control problem lets define the current value Hamiltonian as:

$$H \equiv u(c_t) + \lambda_t \{ i_t a_t + y_t - (i_t^l - i_t) \rho f' + \Omega_t - c_t [1 + \gamma (i_t - i_t^d)] \}, \qquad (7)$$

where λ_t is the co-state variable, interpreted as the marginal value of the household's financial wealth at time t.

The first order conditions and the law of motion for the co-state variable are given by:

$$u'(c_t) = \lambda_t [1 + \gamma (i_t - i_t^d)], \qquad (8)$$

$$\dot{\lambda} = \lambda_t (\beta - i_t). \qquad (9)$$

Equation (8) says that at any point in time the marginal utility of consumption should be equal to the marginal value of wealth times the "effective" price of the good (which includes not only the price, 1, but also the opportunity cost of holding the deposits needed to use the debit card). Equation (9) shows how the marginal valuation of wealth evolves over time.

3.2. Banks

The representative bank in this economy receives deposits and invests the proceedings either in a liquid asset with zero return (i.e. dollars or gold), an illiquid domestic asset (i.e. loans), or an internationally traded bond.

Its activity is costly, and the cost will depend on the way the bank manages its portfolio of assets. For every dollar the bank receives, it should decide if it buys the liquid

[12] In the case of interest, $(i_t - i_t^d) > 0$, the deposit-in-advance constraint will always hold as equality.

asset, the internationally traded bond or if it gives a loan to the household. The last alternative is the most expensive, in the sense that the bank has to use resources to do the evaluation and to instrument each particular loan, while in the other two it can buy the assets in the market without any previous research on them. However, the two liquid assets are not perfect substitutes, the bank would spend more resources to operate in the international capital market than to keep the "dollars" received from the depositors in vault.[13]

This cost can be interpreted as an operative cost, which is lower the simpler the bank's investment decisions are; in other terms, the more liquidity it holds.[14] The bank can reduce its costs holding a liquid asset, h_t, which does not pay any interest, or holding an internationally traded bond, b_t^b, which return is i_t. To keep the problem simple, I will assume that the only asset that permits cost reductions is the domestic one. That means that the effort of investing in loans is the same as investing in the international capital markets.[15]

The cost function per unit of deposit assumes the following form:

$$\xi\left(\frac{h_t}{d_t}, \frac{h_t^A}{d_t^A}\right); \qquad \xi_1, \xi_2 \leq 0, \qquad (10)$$

where the superscript A stands for aggregate variables, which are not internalized by the individual bank. This cost function tells that not only individual liquidity is important, but also that systemic liquidity matters.[16]

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[13] Stein, J. (1995) presents a model to rationalize the effect of reserves on banks' funding costs.

[14] Catalán (2001), found some evidence for Argentina and Mexico in this sense.

[15] It is a fact that banks hold as part of their liquid portfolio not only "dollar bills" but also other kinds of highly liquid international bonds. And it is also a fact that the cost of investing in a liquid bond is not the same as the cost of giving a loan or keeping the dollars in vaults. Obviously, with more than one alternative, the banks would face a kind of portfolio problem, deciding the optimal weights of each asset in such a way that they minimize its "operational costs".
It is not in the aim of this paper to analyze that portfolio decision, which in itself deserves careful attention. Instead, the purpose is to study the macroeconomic effects that are produced when the portfolio shrinks, without considering the consequences that could arise when its composition changes. Therefore, to keep the model simple, it is assumed that the liquid asset is the only one that reduces the banking costs.

[16] Operational costs would be reduced by systemic liquidity when some sort of externality exists in the economy. For example, when an individual bank run out of "cash" it could sell part of the illiquid portfolio to other domestic banks, or sell it in the international capital markets. Obviously, the latter alternative would be more expensive because the foreign counterparts would have less information about the domestic assets, and therefore the risk they would face is bigger. Therefore, the deeper the interbank market, the cheaper liquidity would be.

The bank's balance sheet is given by:

$$h_t + l_t = d_t - b_t^b + w_t, \qquad (11)$$

where w_t is the net worth.

For simplicity, it is assumed that $w_0=0$, and that the bank distributes all the profits as dividends, which implies that w_t is always equal to zero.

The bank's problem is then to choose the level and composition of its portfolio that maximize its profits,

$$\underset{l_t, d_t, b_t^b, h_t}{Max}\ \Omega_t = i_t^l l_t - i_t^d d_t + i(k_t) b_t^b - \xi\left(\frac{h_t}{d_t}, \frac{h_t^A}{d_t^A}\right) d_t, \qquad (12)$$

subject to its balance sheet restriction (11).

When the bank solves this problem it determines the optimal level of liquidity from the private point of view, which will be different from the social optimum, given that it does not internalize the beneficial effects of aggregate liquidity. As it will be shown later, the social optimum requires the bank to hold more liquidity than the amount prescribed by the individual optimization problem. Therefore, the government will impose a reserve requirement that will be binding for each individual bank. This reserve requirement is given by:

$$h_t = \alpha d_t. \qquad (13)$$

Thus, the individual bank maximizes (12), subject to (11) and (13).

The solution of this problem is given by the following FOCs:

$$(1-\alpha) i_t^l - \xi(.) = i_t^d, \qquad (14)$$

$$i_t^l = i(k_t). \qquad (15)$$

Equation (14) says that the spread between lending and borrowing rates is a function of the cost incurred in managing deposits and the reserve requirement. In the costless case, there is no distortion in the banking activity and therefore the lending and the

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Another example has to do with the nature of the banking industry and its specific activity. When a bank has to decide a loan, as it was said above, it uses some resources to perform the evaluation of its potential customer, for example it will demand the services of a credit analyst. In a competitive environment, the individual bank is too small to affect the price of those specific services. Considering the industry as a whole, and to the extent that the resources used to perform the analysis of domestic customers would not be useful in other activities or countries, it would be big enough to affect the factor prices. Then, the competitive solution would led to an overuse of those resources relative to the monopsony case, and therefore more illiquid assets would be held in the former.

borrowing rates are the same. But, when there exists a distortion, the cost of that is transferred to the side of the market in which the bank has some kind of market power, in this case to depositors. The bank cannot transfer the cost to the borrowers because in that side of the market it is facing the competition of the international capital market. The last statement is reflected in the equation (15), in which the lending rate and the rate the country faces in the world capital market is the same.

3.3. Government

The government is a "Ramsey" planner that cares about the utility of the representative household, takes into account the resource restriction of the economy, and picks the allocations such that they could be implemented as a competitive equilibrium.[17] It does not have any budget constraint, or any other activity besides internalizing the effect of aggregate liquidity on the welfare of the economy. The planner's problem is then:

$$\underset{\{c_t^A,\alpha_t\}}{Max}\, W = \int_0^\infty u(c_t^A)e^{-\beta t}\,dt, \qquad (16)$$

subject to the aggregate resource constraint:

$$\dot{k}^A = i_t k_t^A + y_t^A - c_t^A[1+\alpha\gamma i_t + \gamma\xi(\alpha,\alpha)], \qquad (17)$$

where:

$$k_t^A \equiv h_t^A + b_t^{cA} + b_t^{bA},\ \alpha \equiv \frac{h_t^A}{d_t^A},$$

and the following implementability constraints derived form the household's and bank's FOCs:

$$u'(c_t) = \lambda_t[1+\gamma(i_t - i_t^d)], \qquad (19)$$

$$i_t^d = (1-\alpha)i_t - \xi(.). \qquad (20)$$

The solution of this problem is given by the following FOCs:

$$\mu_t[1+\alpha\gamma i_t + \gamma\xi(\alpha,\alpha)] - \varphi u''(c_t) = u'(c_t), \qquad (21)$$

$$\{i_t + [\xi_1(\alpha)+\xi_2(\alpha)]\}(\mu_t c_t + \varphi\lambda_t) = 0, \qquad (22)$$

$$\dot{\mu} = \mu_t(\beta - i_t), \qquad (23)$$

[17] The planner faces an upward sloping supply of funds curve but he does not internalize it in its decisions.

where μ_t is the multiplier associated to the resource constraint (17) and φ is the multiplier associated to the implementability constraint (19).

Equation (21) gives the optimality condition for consumption and equation (23) describes the optimal path that the multiplier should follow.

Finally, equation (22) sets the condition to compute the optimal reserve ratio. It shows a functional relationship between i_t and α of the form:

$$i_t = -g(\alpha); \qquad \mathrm{g}(.) < 0, \quad \mathrm{g}' > 0,$$

then,

$$\alpha = q(i(k_t)); \qquad q(.) = g^{-1}(\alpha) \quad q' < 0 \quad for\ \xi(.) > 0. \qquad (24)$$

The last equation shows that the optimal reserve ratio from the planner's point of view is different from the one computed by the representative bank.[18] The government should intervene in the decentralized economy to attain the first best allocation. A plausible way to do this is imposing a reserve requirement to the bank, which in equilibrium will be binding.

3.4. Solution

The model presented above has intrinsic dynamic, therefore the steady state properties of this economy should be studied with a system of dynamic equations.

To characterize the equilibrium in the planner's problem, let construct a system of two differential equations in c_t and k_t. To capture the motion of c_t over time, differentiate the planner's FOC, equation (21), with respect to time, and replace μ_t and $\dot{\mu}_t$ by the expressions coming from equations (21) and (23), respectively. That yields:[19]

$$\dot{c} = u'(c_t)/u''(c_t)\{\beta - i(k_t) + \gamma\alpha\phi'\dot{k}/[1 + \gamma\alpha\, i(k_t) + \gamma\xi(\alpha)]\}. \qquad (25)$$

The motion of k_t is given by the aggregate resource constraint:

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[18] In the representative bank's problem $g^b(\alpha) = \xi_1$, while in the planner's problem $g(\alpha) = \xi_1 + \xi_2$. ξ_1 and ξ_2 are both negative, therefore $\alpha^b < \alpha$.
Not only there is a difference in the level of the ratio, but also the optimal path would be different, given that g^b and g do not necessarily establish the same functional relationship between the ratio and the interest rate.

[19] To simplify the algebra in the following discussion assumes $u'''(.)=0$.

$$\dot{k} = i(k_t)k_t + y_t - c_t[1 + \gamma\alpha i(k_t) + \gamma\xi(\alpha)]. \qquad (26)$$

This system displays saddle-path stability as it is shown in the Appendix.

Figure 2 shows how the steady state equilibrium looks in a phase diagram. The phase line $\dot{c} = 0$ is given by,

$$\beta = i(k_t) + \gamma\alpha\phi'\dot{k}/[1 + \gamma\alpha\, i(k_t) + \gamma\xi(\alpha)]. \qquad (27)$$

The phase line corresponding to $\dot{k} = 0$ is given by,

$$c_t = [i(k_t)k_t + y_t]/[1 + \gamma\alpha i(k_t) + \gamma\xi(\alpha)]. \qquad (28)$$

In the steady state both $\dot{c} = 0$ and $\dot{k} = 0$, then the economy rest at the point A in Figure 2, where:

$$c_{ss} = [i(k_{ss})k_{ss} + y_t]/[1 + \gamma\alpha i(k_{ss}) + \gamma\xi(\alpha)],$$
$$k_{ss} = z(\beta).$$

4. Bank runs generated by interest rate shocks

Let assume that the bank run is produced by an exogenous shock that makes the household cut instantaneously its demand for deposits. With that purpose, assume the shock is an unexpected increase in the international interest rate, r^*. The same results would be obtained with a parallel upward shift of risk premium function. In other terms, there is an exogenous increase in the domestic interest rate.

What would happen after the economy is hit by the shock?

Focusing in the phase diagram presented in Figure 2, the $\dot{c} = 0$ phaseline shifts to the right every time the international interest rate is increased. Nevertheless, the change in the $\dot{k} = 0$ phaseline depends on the value of some parameters, like the risk premium function.

Proposition 1 *When $\phi' \to 0$ the slope of the $\dot{k} = 0$ phaseline goes up, while when $\phi' \to \infty$ its slope goes down.*

Proof *See Appendix* ■

This proposition has a very important implication about the reaction of the economy to an increase in the domestic interest rate. The economy would have a bank run when the risk premium it is paying is strictly positive and above a certain threshold. Given the initial motivation was to study how the economy reacts in a bank run, the paper focuses just in this case.[20]

4.1. Permanent increase in r^*

Figure 3.a illustrates the adjustment process the economy follows after a permanent shock on the international interest rate.

On impact, consumption jumps down to the point B (below the new steady state level), and the demand for deposits goes down accordingly. At the instant of the shock people change the composition of their portfolio, switching from deposits to bonds, which produces a "run" against the banks.

How does the representative bank finance the run? To answer this question it will be necessary to take a closer look at the bank's balance sheet. On the assets side, there exists some release of liquidity proportional to the loss in deposits (for each unit of deposit withdrawn, the bank recover α units of reserves), making the need for funds equal to *(1-α)* per unit of deposit withdrawn. Loans cannot be reduced because they are inelastically demanded by the household (they are "illiquid" in some sense). The government relaxes the reserve requirement, because with the higher interest rate the optimal reserve ratio would be lower. Then, the bank can use these released liquidity to finance the flight of deposits, and it will borrow or lend abroad to equilibrate its balance sheet.

The paths of some macroeconomic variables are shown in Figure 4. The upper graphs reflect the dynamics in consumption and financial wealth derived from Figure 3.a. On impact, given the increase in the price of the good produced by the external shock consumption falls. It goes below the $\dot{k} = 0$ line, implying that the current account has an instantaneous surplus (k jumps up at time t). This means that the amount of national

[20] Anyway, the analysis of the other case is very similar and it is interesting in itself because it could generate higher consumption on impact, and therefore a substitution from international assets towards deposits.

saving (the difference between output and consumption) is not compensated by the increase in the interest payments to foreigners. Just after the shock, consumption starts to recover, but it remains below the level of output for some time. The economy continues as before, it lends its excess of saving abroad, and financial wealth increases.

The path of the domestic interest rate is the mirror image of financial wealth's path given the form of the country's risk premium that is assumed, except on impact, when domestic interest rate is affected by the higher r^*.

The optimal reserve ratio varies according to the changes in domestic interest rate. It jumps down on impact with the higher interest rate and then starts to recover while interest rate is reduced. The path of systemic liquidity depends on both, the behavior of deposits and the optimal reserve ratio.[21]

Finally, output in this economy is given by the inelastic supply of labor, the same as loans which are demand determined, and remains constant by assumption.

4.2. Temporary increase in r^*

Figure 3.b shows the dynamic behavior of the economy after it is hit by a temporary shock to the international interest rate.

In this case, the phase lines move in the same way as before but they do not stay forever in that position. When the shock is temporary, the economy adjusts in such a way that it comes back to the initial steady state, which is the point A. The economy will never catch the new saddle path or reach the point C, because that would imply that at time *T*, when the shock is reversed, the economy would fall in a non-equilibrium path and would diverge forever. At time *T* the economy should be on the saddle path that will put it again on the initial steady state.

The following propositions are useful to pick the adjustment path.

---

[21] From the deposit-in-advance constraint, on impact the discrete jump of deposits is, $\Delta d_t = \gamma \Delta c_t$; and the time path is given by, $\dot{d} = \gamma \dot{c}$.
From the optimal reserve requirement equation, on impact the discrete jump of the ratio is, $\Delta \alpha = q(\Delta i_t)$; and the time path is given by, $\dot{\alpha} = q' \dot{i}$.
From the reserve requirement constraint, on impact the discrete jump of liquidity is, $\Delta h_t = \alpha \Delta d_t + \Delta \alpha d_t$; and the time path is given by, $\dot{h} = \alpha \dot{d} + \dot{\alpha} d$.

Proposition 2 *At time T, consumption jumps up in a discrete amount.*

Proof *See Appendix* ■

Proposition 3 *The longer lasting the shock, the bigger the initial jump of consumption.*

Proof *See Appendix* ■

Proposition 4 *The higher the level of indebtness, the bigger the initial jump of consumption.*

Proof *See Appendix* ■

Thus, with those pieces of information the equilibrium path can be picked and depends on the duration of the shock and the magnitude of k_t. On impact, the economy jumps down, households reduce consumption and run to the banks to withdraw part of their deposits. The adjustment path will be different in an economy that receives a shock that last a short time or which has a small debt (therefore, it has access to international capital paying a low risk premium), from another in which the shock last a long time or which has a large debt (thus, it has to pay a huge risk premium). The intuition is clear, in the last case, financing the run with external funds will be very difficult or at least extremely expensive. To avoid paying such a huge cost, or even because the economy is rationed, it should finance the deposits' withdrawal with internal saving, inducing a strong fall in consumption (it jumps to the point B′). In the other case, it is still convenient to take more debt to buffer the impact on current consumption, which makes the economy to jump down to the point B.[22]

4.2.1. Case 1: Economies with non-restricted external borrowing

This is the case in which the economy borrows abroad to buffer the impact on consumption, that means when the system jumps to the point B in Figure 3.b.

[22] To interpret the graphs, the chapter labels the two cases using Proposition 4. Anyway, similar dynamic patterns would be obtained for economies with the same level of indebtedness but with shocks of different duration.

On impact, the increase in the interest rate, and consequently in the price of consumption, makes households to cut down the amount of the good they are consuming. But, as it was said before, the economy has access to the international capital markets to finance part of the fall in current consumption. Therefore, the economy starts its adjustment path with an instantaneous current account deficit. Just after the initial shock, consumption starts to grow; it grows for some time after time T until it reaches the original steady state value.

Deposits follow the pattern of consumption, given that the only use of them is to finance the purchase of goods. An interesting result appears in this case. As it was mentioned above, when the economy has access to international capital markets the fall in consumption is lower than when there is not possibility to borrow abroad at a reasonable interest rate. That implies the run on deposits is buffered if the economy has access to external financing and worsened when it is difficult to access to the international capital markets.

Given that on impact the interest rate is higher, the optimal reserve ratio should be reduced, which releases some low cost funds to finance the deposits' flight. The requirements would be reduced until time T, when the shock is reversed. At this time, the government should start tightening again, increasing the ratio until it reaches the steady state level.

4.2.2. Case 2: Economies with restricted external borrowing

This case could be thought as if the economy cannot borrow abroad. Then, given the increase in the international interest rate, consumption falls by more than in the Case 1, jumping to the point B′ in Figure 3.b.

Basically, the differences with Case 1 were commented before. Given the economy is paying an extremely high interest rate, it is not profitable to borrow in the foreign markets, therefore it starts to accumulate assets (or repaid its debt) by a strong reduction in consumption. The debt repayments are possible because consumption falls by more than the increase in the interest payments on the external debt, and therefore the country runs a current account surplus from t to T. The other important difference is a quantitative

one, deposits fall by more in this case than when the economy can borrow more easily in the international capital markets.

On impact, the interest rate increases in a discrete amount, but after time *t* it follows a downward path given the reduction in the risk premium, which implies that the government starts tightening immediately after the initial reduction of reserve requirements.

5. Bank runs generated by output shocks

Other way in which a bank run can be produced in this economy is through an unexpected fall in output.

5.1. Permanent fall in output

This is the case depicted in Figure 5.a. When there is an unexpected and permanent reduction in output, consumption adjusts immediately to the new steady state level. This jump in consumption will generate a proportional run out of deposits, given that it is no longer necessary to maintain the initial amount of them to finance purchases. The jump in consumption exactly compensates the change in output, and therefore there will be no effect on the current account and the net stock of assets. Given that the net foreign assets position of the economy does not change, the risk premium and the domestic interest rate do not change either. As it was shown above, the reserve requirement is a function of the domestic interest rate, thus it remains the same, even though deposits are flowing out from the system.

5.2. Temporary fall in output

Figure 5.b shows the response of the economy to a temporary output contraction. On impact, consumption fall by less than output, as the permanent income hypothesis would suggest. Obviously, lower consumption will imply lower demand for deposits, which

generates an outflow of funds from the banks. Given that consumption does not adjust too much, the temporary excess of consumption over output should be financed abroad running a current account deficit. As long as consumption is above output, the economy reduces its net foreign asset position, pushing up the risk premium and the domestic interest rate. While the interest rate increases, the reserve requirement decreases.

After time T, when the shock is reverted, output overcomes the level of consumption, which remains below output for some time. During this period, the economy accumulates foreign assets through a current account surplus and the domestic interest rate starts to go down. This reduction in the interest rate, induce an increase in the reserve requirements and the economy begins replenish the stock of liquid assets.

6. Conclusion

The conventional wisdom suggests that reserve requirements should be reduced in a bank run to provide liquidity to the financial system. However, the evidence does not show a clear pattern on this matter. In 48 out of 94 of the episodes identified in the paper the reserve ratio goes up. One of the purposes of the paper is to give a rationale to this seemingly contradictory behavior, explaining the path of reserve requirements as the optimal response to different shocks.

The results obtained from the model developed in the paper suggest that the path of reserve requirement is intimately related to the type of shock that the economy receives and its initial conditions. Key to the results is the negative relationship between reserve requirements and interest rates. If the shock does not affect the opportunity cost of holding reserves there will be no change in the optimal ratio, as it is the case of an output shock. On the other hand, when the interest rate goes up, it will be "cheaper" to finance the run with the hoarded liquidity.

The initial condition of the economy is mainly captured by the risk premium that the country is paying. It is shown that this premium acts as an amplifier of the run (also, it should be above a threshold for a given shock to generate a bank run) and it might change the dynamics of the current account. The intuition is clear, when the risk premium is high enough it would be very costly to finance the run borrowing in the international capital

markets and therefore it will be worth depleting the liquid reserves and saving domestically (reducing consumption and therefore the transactional demand of deposits), which would generate a current account surplus. If the access to foreign funds is cheaper, the economy can avoid the sacrifice of adjusting downward present consumption by borrowing in the international capital markets, which will generate a current account deficit. This result is useful to explain the different behavior of the current account observed in countries like Argentina, Estonia, Lithuania and Spain, from the one observed in others like Sweden.

Finally, an important lesson that could be learned from the paper is that other channels exist through which the risk premium contributes to the vulnerability of a SOE. The risk premium exacerbates the impact of a given shock; in this particular case it generates a larger bank run. Thus, policymakers have another good reason to implement policies consistent with the reduction of the country risk.

Appendix

Stability properties of the dynamic system

Proof It is known that the necessary and sufficient condition to have saddle-path stability is that the Jacobian matrix of the differential equations system has a negative determinant. In the case of interest, the solution of a system with 2 equations and 2 unknowns will have 2 roots. A negative determinant means that one of those roots would be positive and the other would be negative, or in other terms the system would be stable in one dimension and unstable in the other.

The Jacobian for the system (2.24)-(2.25), evaluated in the steady state, is:

$$J = \begin{bmatrix} \left.\frac{\partial \dot{c}}{\partial c}\right|_{ss} & \left.\frac{\partial \dot{c}}{\partial k}\right|_{ss} \\ \left.\frac{\partial \dot{k}}{\partial c}\right|_{ss} & \left.\frac{\partial \dot{k}}{\partial k}\right|_{ss} \end{bmatrix},$$

$$\left.\frac{\partial \dot{c}}{\partial c}\right|_{ss} = 0,$$

$$\left.\frac{\partial \dot{c}}{\partial k}\right|_{ss} = -\phi'(.)\frac{u'(.)}{u''(.)},$$

$$\left.\frac{\partial \dot{k}}{\partial c}\right|_{ss} = -[1 + \alpha\gamma i(.) + \gamma\xi(.)],$$

$$\left.\frac{\partial \dot{k}}{\partial k}\right|_{ss} = \phi'(.)k_t + i(.) - c_t\gamma\alpha\phi'(.).$$

$\Rightarrow \quad |J| < 0$ ■

Proposition 1

Proof The equation of the phaseline $\dot{k} = 0$ is given by:

$$c_t = [i(k_t)k_t + y_t]/[1 + \gamma(\alpha i(k_t) + \xi(\alpha))].$$

The slope in the (k_t, c_t) space is:

$$\frac{dc}{dk} = \frac{i_t + \phi' k_t}{1 + \gamma(\alpha i_t + \xi)} - \frac{\gamma\alpha\phi'(i_t k_t + y)}{[1 + \gamma(\alpha i_t + \xi)]^2} > 0.$$

After the shock to r^*, the slope varies according to:

$$\frac{d^2c}{dkdr^*} = \frac{1}{1+\gamma(\alpha i_t + \xi)} - \frac{(i_t + \phi' k_t)\alpha\gamma}{[1+\gamma(\alpha i_t + \xi)]^2} - \frac{\gamma\phi' q'(i_t k_t + y) + \gamma\phi'\alpha}{[1+\gamma(\alpha i_t + \xi)]^2} + \frac{\gamma\phi'\alpha(i_t k_t + y)2[1+\gamma(\alpha i_t + \xi)]\gamma\alpha}{[1+\gamma(\alpha i_t + \xi)]^4}.$$

Then,

$$\lim_{\phi'\to 0}\frac{d^2c}{dkdr^*} > 0, \qquad \lim_{\phi'\to\infty}\frac{d^2c}{dkdr^*} < 0. \blacksquare$$

Proposition 2

Proof At time T the international interest rate is reduced in a discrete amount. To see what happen with the consumption at that point in time it is useful to focus on equation (8) in the household's FOC,

$$u'(c_t) = \lambda_t[1+\gamma(i_t - i_t^d)].$$

(i) The price of consumption depends on r^* and k_t among other things. Given that k_t cannot jump and given the other exogenous variables, the change in the price of consumption is driven by the change in r^*. It jumps in the same direction as the international interest rate, which is easily seen from the derivative of the price with respect to r^*,

$$\frac{\partial[1+\gamma(i_t - i_t^d)]}{\partial r^*} = \gamma[(\xi_1 + \xi_2)q' + i_t q' + \alpha] > 0.$$

(ii) The shadow price λ_T does not jump because its law of motion is governed by equation (9).

Therefore from (i) and (ii) we can conclude that when r^* is reduced at time T, consumption goes up in a discrete amount. ■

Proposition 3

Proof It can be seen from equations (27) and (28) that on impact, the movement of the phaselines does not depend on the duration of the shock. In other terms, on impact, both phaselines move to the same place independently of having a permanent or a temporary shock.

When the shock is permanent, the system jumps straightforward to the new saddle-path, which will put it into the new equilibrium point. When the shock is temporary, the system would never reach the new saddle-path, but it should be on the old one at time T to be able to come back to the initial equilibrium point.

By continuity, it can be said that the longer lasting the shock, the closer would be the "temporary" solution to the "permanent" one, and therefore the jump would be closer to the new saddle-path. ■

Proposition 4

Proof From Proposition 2 it can be seen that on impact consumption should decrease. Therefore:

$$\frac{dc}{dr^*} < 0.$$

Total differentiation of the resource constraint gives:

$$d\dot{k} = k_t dr^* - [1 + \gamma(\alpha_t i_t + \xi_t)]dc - \gamma c_t \alpha_t dr^*,$$
$$d\dot{k} = (k_t - h_t)dr^* - [1 + \gamma(\alpha_t i_t + \xi_t)]dc.$$

The economy would start its adjustment process with a current account deficit if:

$$d\dot{k} < 0,$$
$$(k_t - h_t)dr^* < [1 + \gamma(\alpha_t i_t + \xi_t)]dc,$$
$$\frac{dc}{dr^*} > \frac{(k_t - h_t)}{[1 + \gamma(\alpha_t i_t + \xi_t)]}.$$

Taking limits to the RHS and assuming $\alpha > 0 \ \forall k_t$:

$$\lim_{k_t \to \infty} RHS = 0, \qquad \lim_{k_t \to 0} RHS = \frac{-h_t}{[1 + \gamma(\alpha_t i_t + \xi_t)]}.$$

The limits above imply that there would not be any current account deficit at time t when the country is highly indebted. ■

Tables and Figures

Table 1: Banks Runs and Reserves Ratios

Country	Episode	Δ Deposits	Δ Reserve Ratio
East Asia			
Indonesia	Dec 82 - Jan 83	(0.06)	(0.18)
	Jul 98 - Aug 98	(0.05)	0.04
Europe			
Croatia	Mar 99 - May 99	(0.10)	0.18
Denmark	Jul 86 - Aug 86	(0.08)	(0.55)
	Jan 87 - Feb 87	(0.10)	(0.45)
	Jan 89 - Feb 89	(0.09)	(0.05)
	Apr 94 - Feb 95	(0.15)	(0.17)
	Oct 98 - Nov 98	(0.12)	(0.02)
	Jul 99 - Aug 99	(0.06)	(0.04)
Greece	Jan 83 - Feb 83	(0.13)	(0.21)
	Jan 91 - Feb 91	(0.05)	0.01
Ireland	Jan 82 - Feb 82	(0.35)	(0.54)
	Feb 86 - Mar 86	(0.07)	0.16
	Jan 92 - Mar 92	(0.05)	(0.04)
Italy	Jan 91 - Feb 91	(0.05)	0.04
	Jan 97 - Nov 97	(0.12)	0.06
Slovak Republic	Jan 94 - Mar 94	(0.06)	(0.02)
Spain	Jan 83 - Feb 83	(0.12)	2.14
Sweden	Apr 84 - Jun 84	(0.06)	0.34
	Mar 90 - Aug 90	(0.15)	(0.46)
	Jul 92 - Oct 92	(0.07)	(0.62)
Latin America			
Argentina	Dec 94 - Apr 95	(0.17)	(0.06)
	Jul 01 - Dec 01	(0.18)	(0.01)
	Feb 02 - Apr 02	(0.13)	(0.08)
Bolivia	Jun 89 - Jul 89	(0.17)	0.10
	Jun 02 - Jul 02	(0.15)	1.07
Chile	Jan 83- May 83	(0.09)	0.01
	Jan 00 - Feb 00	(0.07)	(0.26)
Colombia	Feb 83 - Mar 83	(0.05)	(0.12)
Dominican Republic	Apr 80 - May 80	(0.05)	0.16
	Jan 81 - Jul 81	(0.07)	0.18
	Jun 82 - Sep 82	(0.07)	0.08
	Jul 87 - Aug 87	(0.06)	0.07
Ecuador	Jan 81- Feb 81	(0.10)	(0.20)
	Jan 87 - Feb 87	(0.05)	(0.20)
Guatemala	Aug 83 - Oct 83	(0.09)	(0.02)
	Sep 87 - Nov 87	(0.06)	(0.03)
	Feb 94 - Mar 94	(0.06)	(0.09)
	Oct 95 - Jun 96	(0.07)	(0.02)
	Jul 98 - Aug 98	(0.16)	0.37
	Jan 99 - Feb 99	(0.07)	(0.03)
Mexico	Nov 00 - Jan 01	(0.06)	0.09
	Jan 02 - Apr 02	(0.10)	(0.03)
Paraguay	Jun 84 - Sep 84	(0.07)	(0.05)
	Jan 85 - Feb 85	(0.07)	(0.09)
	Jul 85 - Oct 85	(0.13)	(0.09)
	Jan 89 - Feb 89	(0.06)	0.00
	Jun 97 - Jul 97	(0.12)	(0.03)
	Jan 99 - Mar 99	(0.06)	(0.02)
	Aug 00 - Sep 00	(0.05)	(0.01)
	Feb 02 - Jul 02	(0.20)	0.09
Venezuela	Jul 81 - Aug 81	(0.05)	0.05
	Dec 87 - Jan 88	(0.07)	0.08
	Jan 92 - Mar 92	(0.09)	0.01
	Feb 99 - Mar 99	(0.05)	0.03
	Apr 01 - May 01	(0.05)	(0.00)
	Jan 02 - Mar 02	(0.16)	(0.04)
Middle East			
Iran, I.R. of	Oct 80 - Nov 80	(0.07)	(0.22)
Jordan	Dec 93 - Jan 94	(0.09)	0.08
Kuwait	Jul 82 - Aug 82	(0.05)	0.06
	Aug 91 - Sep 91	(0.06)	1.18
Pakistan	Jan 89 - May 89	(0.09)	(0.09)
Syrian Arab Republic	May 82 - Jul 82	(0.10)	(0.29)
	Feb 86 - Aug 86	(0.12)	(0.10)
	Jan 96 - Feb 96	(0.07)	0.03
	Jan 98 - Mar 98	(0.12)	0.73
	Jan 99 - Mar 99	(0.11)	0.13
	Aug 01 - Sep 01	(0.09)	0.11
United Arab Emirates	Jan 81 - Feb 81	(0.06)	0.22
	Jul 90 - Sep 90	(0.18)	0.12
Transition Economies			
Armenia	Sep 95 - Oct 95	(0.16)	0.14
	Mar 99 - Apr 99	(0.09)	(0.16)
	Dec 01 - Feb 02	(0.16)	0.20
Azerbaijan	Nov 95 - Jun 96	(0.48)	0.86
	Dec 97 - Mar 98	(0.11)	(0.22)
	May 99 - Jun 99	(0.34)	0.37
	Jan 01 - Feb 01	(0.51)	0.46
	Jan 02 - Apr 02	(0.14)	0.03
Estonia	Aug 92 - Sep 92	(0.12)	0.23
	Dec 92 - Apr 93	(0.27)	0.64
Georgia	Sep 98 - Nov 98	(0.21)	(0.08)
	Mar 99 - Apr 99	(0.10)	0.17
	Dec 00 - Feb 01	(0.10)	0.09
Kazakhstan	Dec 97 - Feb 98	(0.16)	(0.50)
	Sep 98 - Mar 99	(0.13)	0.19
	Jan 02 - Feb 02	(0.06)	(0.19)
Lithuania	Dec 95 - Jul 96	(0.20)	(0.21)
	Jan 99 - Feb 99	(0.05)	(0.27)
Moldova	Feb 94 - Mar 94	(0.19)	0.07
	Feb 95 - Mar 95	(0.06)	(0.03)
	Jul 98 - Nov 98	(0.17)	1.08
Tajikistan	Feb 99 - Mar 99	(0.24)	0.32
	Mar 01 - Apr 01	(0.11)	0.50
Ukraine	Oct 97 - Nov 97	(0.06)	0.08

Source: Own calculations based on IFS data.

Table 2: Reserve Ratio Response

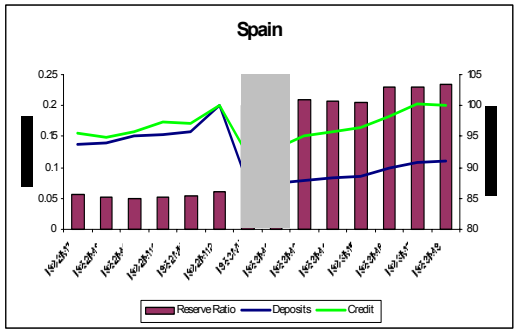
	# of runs	Reduced RR	Increased RR		
			Lower rates	Higher rates	No info
Total	94	49%	11%	11%	32%
East Asia	2	50%		50%	
Europe	19	63%	16%	5%	16%
Latin America	36	58%	8%	6%	28%
Middle East	13	31%		8%	62%
Transition Economies	24	33%	17%	21%	38%

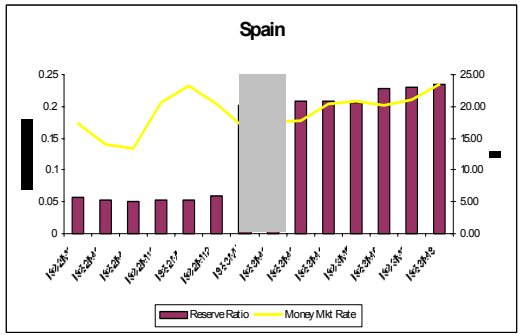
Source: Own calculations based on IFS data.

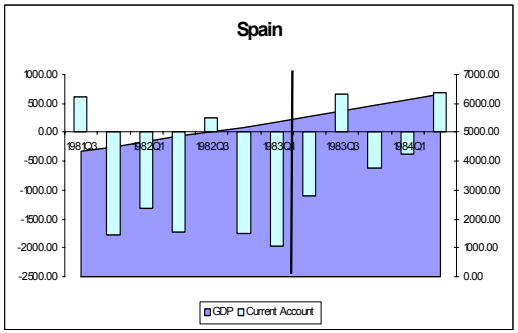
Figure 1

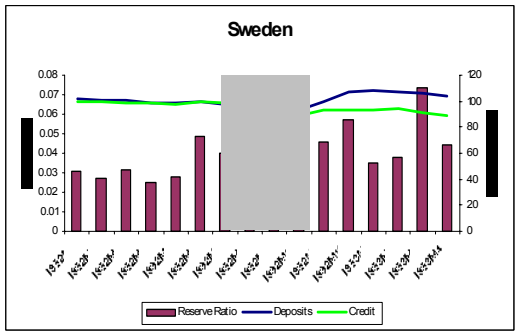
Argentina
Reserve Ratio
Deposits
Credit
Argentina
Reserve Ratio
Lending Rate
Argentina
GDP
Current Account
Estonia
Reserve Ratio
Deposits
Credit
Estonia
Reserve Ratio
Lending Rate
Estonia
GDP
Current Account
Lithuania
Reserve Ratio
Deposits
Credit
Lithuania
Reserve Ratio
Money Mkt. Rate
Lithuania
GDP
Current Account

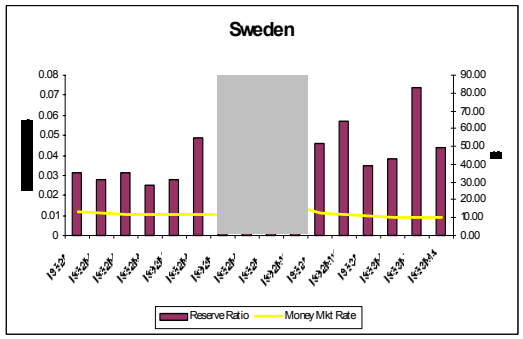
Figure 1 (cont.)











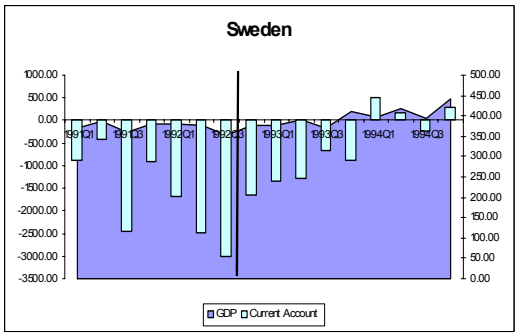


Figure 2: Steady state equilibrium.

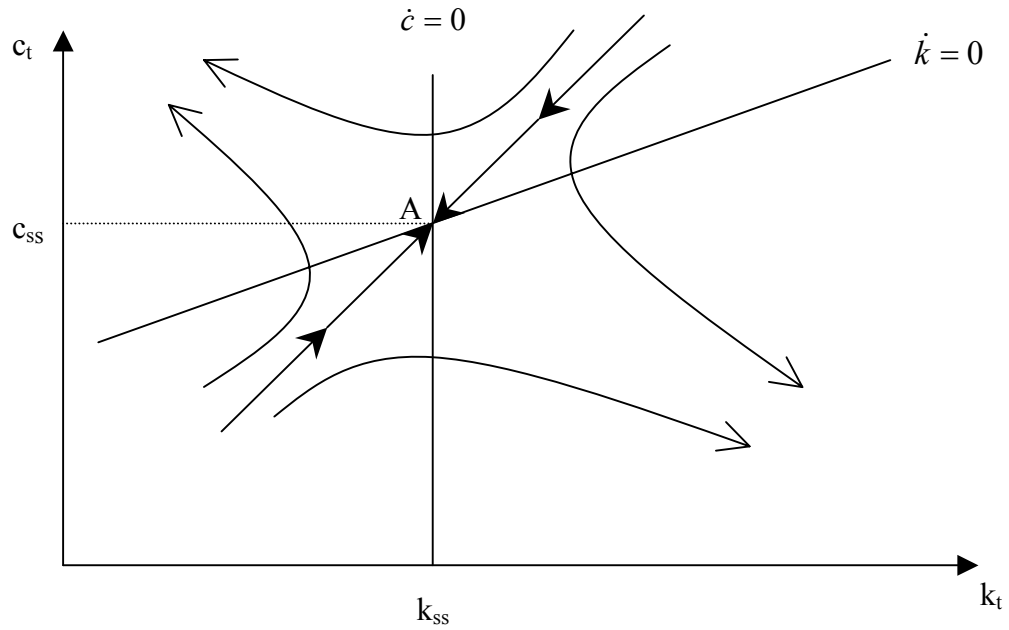


Figure 3.a: Permanent increase in the interest rate.

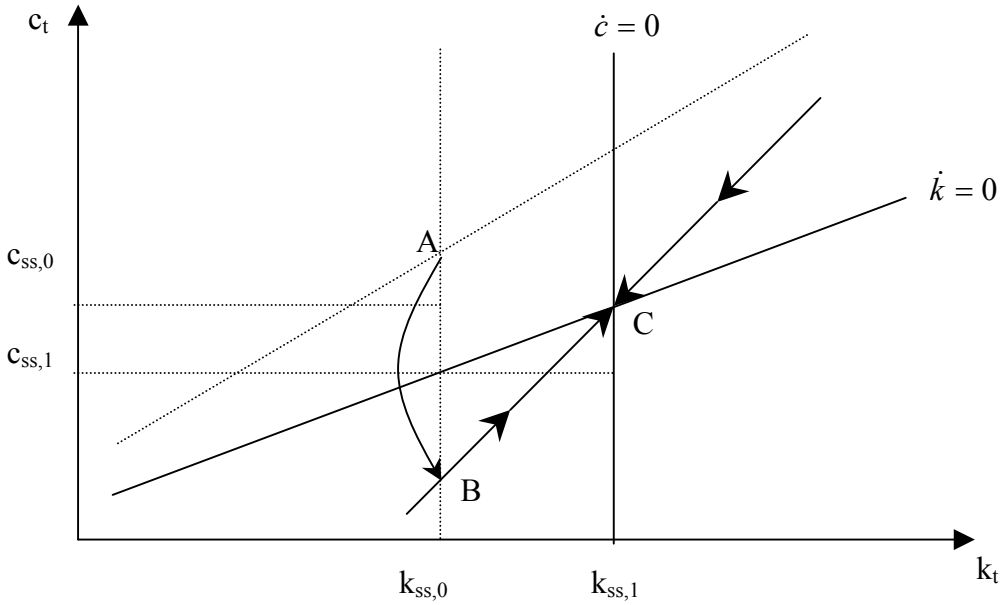


Figure 3.b: Temporary increase in the interest rate.

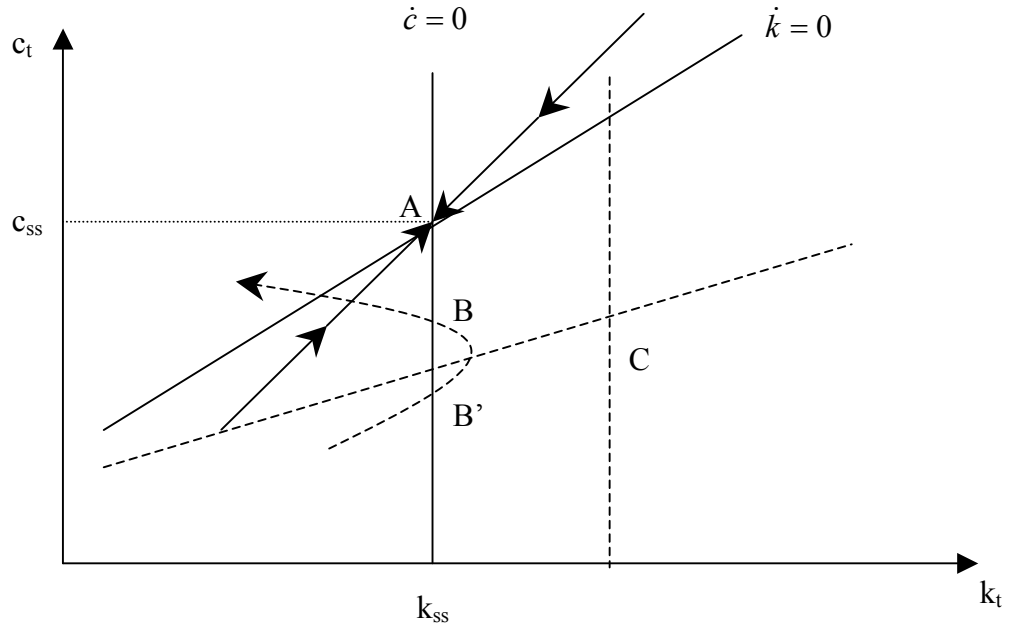


Figure 4: Dynamic paths after the permanent interest rate shock.

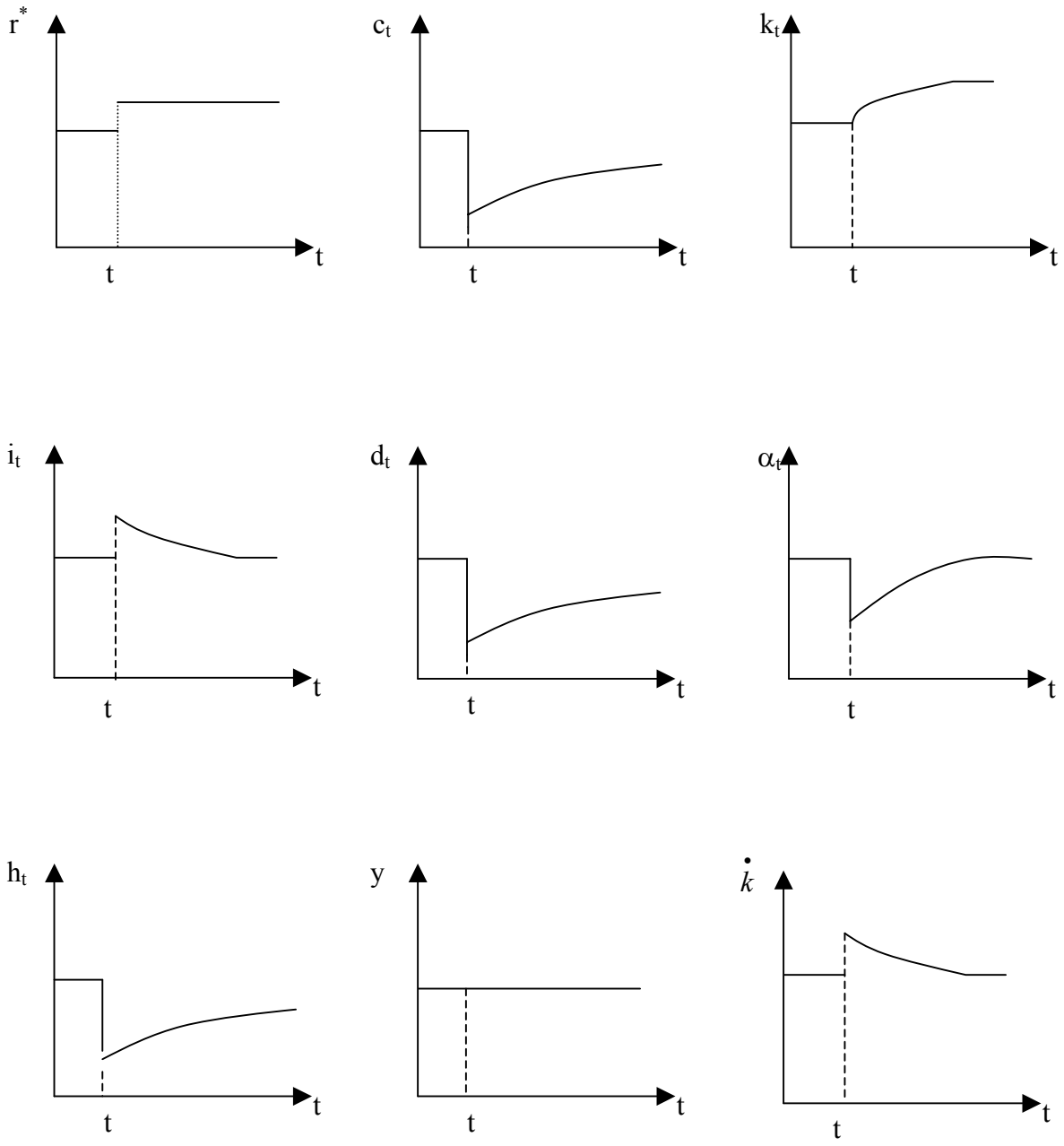


Figure 5.a: Permanent fall in output.

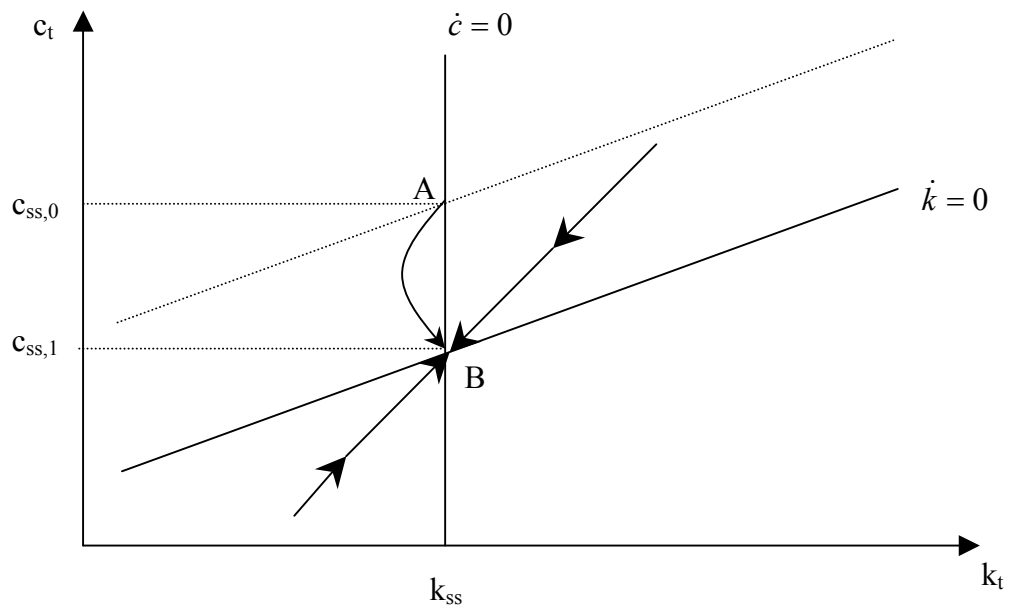
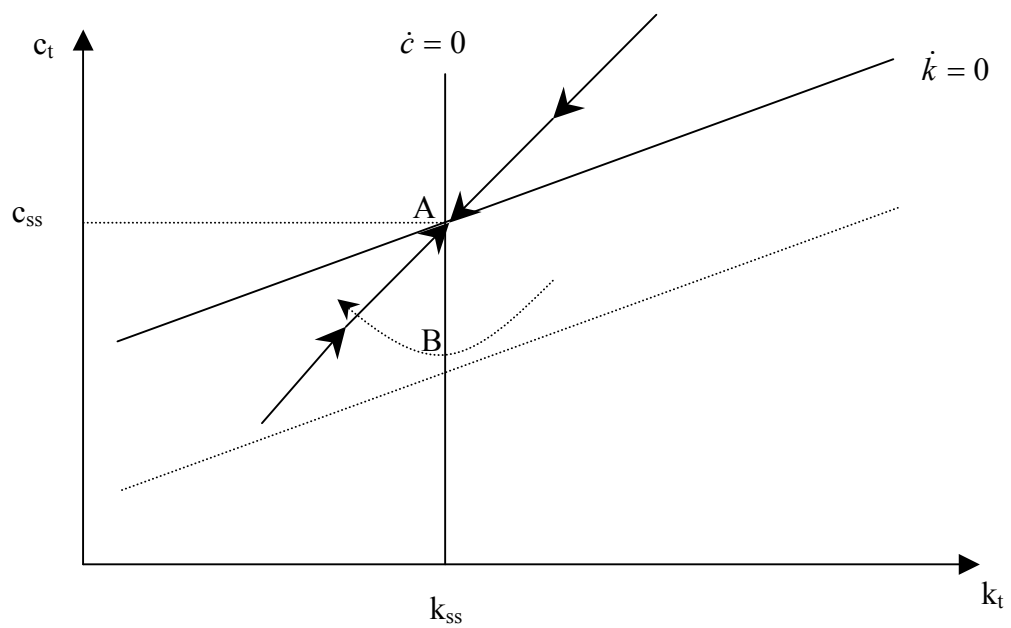


Figure 5.b: Temporary fall in output.



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