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Signaling Fiscal Regime Sustainability

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SIGNALING FISCAL REGIME SUSTAINABILITY

by Francesco Drudi[*] and Alessandro Prati[**]

Abstract

This paper proposes a signaling model of fiscal stabilizations that offers a new perspective on why governments deviate from optimal tax smoothing. In our model, dependable - but not fully credible - governments have an incentive to tighten the fiscal regime when the signaling effect on credit ratings is larger (that is, when a sufficiently large stock of debt has been accumulated). At this point, they may deviate from tax smoothing in order to avoid being mimicked by weak governments. We show that a testable prediction of our model is that primary balances and debt stocks are complementary inputs in the credit rating function and we successfully test it on Irish, Belgian, and Danish data from the late 1970s to the early 1990s.

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1. Introduction[1]

Since the early 1980s, several European countries have adopted fiscal consolidation programs aimed at stabilizing their public debt-to-GDP ratios. This policy was dictated by the need to reassure the markets that the fiscal regime was sustainable and avoid otherwise constantly increasing risk premia and debt financing costs. In turn, the success of the fiscal tightening and its cost depended critically on the speed at which credibility was regained. This interplay between fiscal variables and interest rates is the focus of the theoretical and empirical analysis of this paper. The theoretical part of the paper consists of a signaling model of fiscal policy, whereas the empirical part focuses on the experience of Italy, Ireland, Belgium and Denmark from the late 1970s to the early 1990s.

The analytics of debt sustainability is well known. A country will have a sustainable fiscal regime if current and future primary balances, interest rates and growth rates are such that the government's intertemporal budget constraint is satisfied.[2] Whereas the mathematics is unambiguous, policy prescriptions are not. The key difficulty is that all relevant variables are endogenous, so that the feedback effects of a fiscal package on growth-sensitive revenues and expenditures, as well as interest rates, are crucial to determine whether the measures taken are sufficient to stabilize the fiscal regime. At the same time, shocks to growth rates and interest rates affect the propensity of the government to initiate fiscal consolidation.

[1] We would like to thank two referees for their comments on earlier versions of this paper. This paper does not necessarily reflect the views of the World Bank, the International Monetary Fund or the Bank of Italy. We also thank Maria Pia Mingarini for editorial assistance.

[2] See, for example, Spaventa (1987).

Whereas several recent papers have discussed the endogenous link between fiscal consolidation and growth,[3] our paper focuses on that between fiscal consolidation and the credit rating component of interest rates. Modeling the endogenous link between fiscal variables and the credit standing provides an insight into which fiscal variables signal debt sustainability (the primary balance, as we will see).

Our study is also related to the literature on the determinants of large public debts and on the deviations from the "tax smoothing" theory of the government budget (Barro, 1979). We propose a different explanation of why fiscal stabilizations are often delayed, that could be considered complementary to those recently surveyed by Alesina and Perotti (1995b) which are mainly based on the distributional consequences of fiscal adjustment[4] and on the strategic use of government debt.[5]

This paper links the timing of a fiscal correction to the credit standing and the debt level of a country. In our framework, a fiscal stabilization may be delayed if risk premia and debt levels are below a critical threshold so that no government has any incentive to tighten the fiscal regime: in this range, both dependable and weak policy makers choose

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[3] Giavazzi and Pagano (1990, 1995), for example, argue that there are instances in which a fiscal correction can be expansionary rather than contractionary. Their work is complemented by Alesina and Perotti (1995a, 1997), who point out that a fiscal tightening needs to cut expenditure items such as transfer programs and public employment to be expansionary.

[4] Fernandez and Rodrik (1991) show that the difficulty of identifying ex-ante individual gainers and losers from a reform could generate a bias toward the *status quo*. Similarly, Alesina and Drazen (1991) argue that a war of attrition between different social groups determines the timing of stabilization. In a related paper, Drazen and Grilli (1993) show that economic crises may have positive welfare effects when they prompt a fiscal stabilization.

[5] Alesina and Tabellini (1990) and Persson and Svensson (1989) show that policy makers may accumulate strategically government debt to constrain the actions of their successors.

to run primary deficits and build up the debt stock. Only when risk premia or debt levels exceed this critical threshold do interest payments become so large that dependable governments prefer to run primary surpluses, thus signaling the sustainability of the fiscal regime. Differently from other papers in this literature,[6] we endogenously derive the threshold triggering a fiscal stabilization as a function of the reputation and preferences of the government. Moreover, when we allow for endogenous debt accumulation (Appendix 4), we find a novel strategic role for government debt. We show that the optimal policy of governments that are dependable - but not fully credible - is to accumulate strategically a critical amount of debt that allows them to signal. In this case, there is only one equilibrium in which the dependable government first runs primary deficits and then deviates from optimal tax smoothing to signal its type.

An interesting case study is the Italian fiscal stabilization of the early 1990s. Figure 1 (top panel) shows Italy's country rating against the time profile of primary balances.[7] Although the rating improved somewhat during the 1980s when primary deficits were being reduced, it dropped considerably in the early 1990s when primary surpluses were about to be achieved and has only partially recovered since mid 1996. This evidence raises a number of questions: Is this

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[6] The existing literature often sets the trigger levels for the timing of stabilization exogenously. Bertola and Drazen (1993), for example, derive a nonlinear relationship between private consumption and government spending with government spending falling whenever it reaches exogenously given target points. An exogenous trigger level of government debt is also assumed in Sutherland (1995).

[7] The country rating is that published twice a year by Institutional Investor. Unfortunately, this rating is available only since the second semester of 1979. The country ratings of Institutional Investor are based on information provided by leading international banks. Bankers are asked to grade each of the countries on a scale of zero to 100, with 100 representing those with the least chance of default. The sample ranges from 75 to 100 banks. Banks are not permitted to rate their home countries. Individual responses are weighted by Institutional Investor using a formula that gives more importance to responses from banks "with greater worldwide exposure and more sophisticated country-analysis systems".

seemingly *non-monotonic* relationship between ratings and primary balances an Italian peculiarity or is it common also in other instances of fiscal stabilization? Can economic theory account for the observed behavior of credit ratings, primary balances, and debt stocks? And, finally, when should we expect Italian ratings to return to the level of the late 1980s?

To answer these questions, we first study the behavior of credit ratings, primary balances, and debt stocks during the Irish, Belgian, and Danish stabilizations of the mid 1980s. Figure 2 shows that the Italian case is *not* unique: in Ireland, Belgium, and Denmark, we find the same non-monotonic relationship between primary balances and credit ratings that we noted in Italy. In the late 1970s, these three countries enjoyed high ratings - the highest in the sample - despite sizeable primary deficits. As primary balances started improving in the early 1980s, ratings rapidly deteriorated. Only when primary surpluses were achieved in the mid 1980s did the ratings begin to recover. This evidence not only confirms the non-monotonic relationship between credit ratings and primary balances, noted for Italy, but also suggests that primary surpluses might have a signaling role.

Figure 3 sheds some light on the causes of the observed non-monotonic relationship by linking the evolution of credit ratings to that of debt-to-GDP ratios. The low debt stock of all three countries in the late 1970s - the lowest in the sample - seems to account for the high ratings enjoyed in those years, notwithstanding the primary deficits. When the debt stock rapidly increased in the early 1980s, possibly reflecting higher real world interest rates, as well as disinflationary monetary policies, the credit ratings deteriorated because investors did not know whether the primary balance would improve enough to make the fiscal regime sustainable. Figure 3 also shows that the debt-to-GDP ratio alone cannot fully account for the time-series behavior of ratings that began to recover after the achievement of primary surpluses, although debt-to-GDP ratios were still rising.[8]

In our view, the stylized facts of Figures 1-3 suggest that a bivariate analysis of the data might be misleading and that both debt stocks and primary balances concur to determine the credit rating of a country. This is also the first prediction of our theoretical model. The second prediction is that *primary balances have a signaling role at high debt levels. This is indeed the original claim of our paper* and, as discussed below, it distinguishes our model with *endogenous* uncertainty on the type of government in power from more conventional models with *exogenous* uncertainty. The testable implication is that debt stocks and primary balances not only concur to determine the credit rating of a country - as predicted also by models with exogenous uncertainty - but they are *complementary inputs* in the credit rating function until signaling is completed.[9] We present econometric tests of this complementarity hypothesis below, but Figures 2 and 3 already provide a first indication of its validity. In Ireland, Belgium, and Denmark, primary balances seem to have a greater effect on credit ratings when the debt stock is high and when the primary balance is about to swing from a deficit into surplus. This greater signaling power beyond a certain debt threshold can explain both the sudden deterioration of ratings at the beginning of the signaling phase, when there are still primary deficits, and their improvement after the achievement of a surplus, notwithstanding the high debt stock.

The paper is structured as follows. Section 2 presents the theoretical model, justifies its key assumptions and links

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8 The fact that the debt still keeps on rising when primary balances improve is not surprising, as its dynamics depends also on the spread between interest and growth rates, which widened in the presignaling period because credit ratings dropped and real interest rates increased.

9 We are indebted to a referee for suggesting this interpretation of our model.

it to the relevant economic literature. Section 3, after discussing how to derive testable implications from our stylized signaling model, presents econometric estimates based on Irish, Belgian, and Danish data, that confirm the predictions of the model. Section 4 debates possible alternative explanations of the empirical evidence. Section 5 concludes.

2. The theoretical model

Our model has the basic features of a class of signaling models used to study monetary policy signals. As in Barro (1986), we assume that there are two possible types of policy makers with identical preferences but different ability to precommit their policies. One policy maker is dependable and can precommit not to default on the outstanding stock of debt whereas the other cannot. Initially, investors do not know with certainty which policy maker they are facing, although they believe with positive probability that he is dependable. As fiscal policies are implemented, they then revise this prior probability. When the debt is low, neither type of policy maker is seen as being in danger of defaulting and primary deficits prevail until dependable governments start tightening fiscal policy to contain debt accumulation. As this critical time approaches, risk premia emerge because the public fears that a weak policy maker-if in power-might stop mimicking the policies of the dependable policy maker and default. Risk premia disappear only when the public observes policies that only a dependable policy maker would implement.

This sequence of equilibria implies a non-monotonic relationship between risk premia and primary balances like the one observed in the data. At low levels of government debt, pooling equilibria prevail and no policy maker is expected to default so that primary deficits are associated with high ratings. Conversely, at high levels of debt, separating equilibria emerge with dependable governments achieving primary surpluses and weak governments defaulting. When the debt stock reaches a critical threshold - which is a function of the reputation and preferences of the government - a shift from pooling to separating equilibria takes place and credit ratings drop. The model also predicts that primary surpluses have a *signaling role* because only dependable governments would achieve them without defaulting.

2.1 *The setup*

We consider a three-date, two-period model. At time zero, the government issues a *given* stock of one-period debt D_1[10] and the public sets the interest factor R_1 that will be paid in the following period. At time one, the government pays back $D_1\ R_1\,(1-q_1)$ -where q_1 is the fraction of debt defaulted,[11] spends g, levies distortionary taxes t_1 and rolls over a stock of debt D_2 to the last period, on which the public sets an interest factor R_2.[12] At time two, the government pays back $D_2\ R_2\,(1-q_2)$ and levies distortionary taxes t_2. The resulting government's budget constraints are:

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[10] At this stage, we can assume that the revenues from issuing D_1 are "put in the ground". In Appendix 4, we relax this assumption by modeling the government's problem at time zero of optimally choosing D_1, together with taxes, t_0, and expenditure, g_0.

[11] In this paper, we do *not* interpret default as inflating away the real debt value because it would not be consistent with our credit risk measure. In a framework that allowed for default through inflation, the maturity of the debt would play a role (see, for example, Calvo and Guidotti, 1990, for a model with exogenous uncertainty, and Drudi and Prati, 1995, for a signaling model with endogenous uncertainty).

[12] As noted below, the government can issue a positive stock of debt at time 1 only when default does not occur. Therefore, in equilibrium, the two actions of issuing new debt and defaulting on the outstanding stock of debt are incompatible.

(1) $D_1 \;\; R_1 \; (1-q_1) \; + \; g \; = \; t_1 \; + \; D_2$

(2) $D_2 \;\; R_2 \; (1-q_2) \; = \; t_2$

We assume that within each period the government moves first so that the timing of the game is:[13]

Time 0			*Time 1*			*Time 2*
↑	↑	|	↑	↑	|	↑
D_1	R_1		g, D_2, q_1, t_1	R_2		q_2, t_2

We consider D_1 a parameter of the model so that the government chooses g, D_2, q_1, q_2 to minimize the cost function:

(3) $\frac{h}{2}\; t_1^2 + \frac{h}{2} t_2^2 - a\, g$

where $\frac{h}{2}\; t_t^2$ are distortionary costs of taxation and a g are the benfits of government expediture. In Appendix 1, we show that minimizing (3) is equivalent to maximizing the welfare of an economy populated by risk-neutral agents.

After plugging the budget constraints into the objective function, the optimal policy of the government is the solution of the problem:

(4) $Min_{g, D_2, q_1, q_2} \quad \frac{1}{2}\left[D_1 R_1 (1-q_1) + g - D_2\right]^2 \; + \; \frac{1}{2}\; \left[D_2 R_2 (1-q_2)\right]^2 \; - \; \hat{a}\; g$

[13] The results of the paper would be analogous if the government's and the public's actions were simultaneous within each period. By contrast, an opposite timing with the public moving first would cause a multiplicity of equilibria.

where $\hat{a}$ is the ratio of the marginal benefit of government expenditure a to the parameter *h* of the quadratic function of distortionary costs of taxation.

Finally, we assume that two types of government might be in charge. Type *D* ("dependable") can precommit not to default and always chooses $q_t^D = 0$, whereas type *W* ("weak") cannot precommit and chooses either $q_1^W = 1$ or $q_2^W = 1$, depending on his incentives to mimic type *D* policies in period one.

At time zero, the public does not know with certainty which government is in charge, but it believes with probability $1\text{-}p_0$ that the government is type *D*. In the rest of the paper, we will loosely refer to the prior probability as "initial reputation". At time one, the public will observe the policies implemented by the government in charge and revise the probability p_0 using Bayes' rule:

(5)

$$P_1 = \frac{P_0 \; Prob\,(q_1 = \hat{q}_1, \; t_1 = \hat{t}_1, g = \hat{g} : \, type\ W)}{p_0 \; Prob(q_1 = \hat{q}, \; t_1 = \hat{t}_1, g = \hat{g} : \, type\ W) + (1 - p_0)\; Prob\,(q_1 = \hat{q}_1, \; t_1 = \hat{t}_1, g = \hat{g} : \, type\ D)}$$

where all probabilities are conditional on the type of government and $\hat{q}_1, \hat{t}_1$ and $\hat{g}$ are the observed policies.

As we show in Appendix 1, under the additional assumptions of risk neutrality and zero risk-free interest rate, investors will set interest factors according to the no-arbitrage condition:

(6) $$R_t \,(1 - q_t^e) = 1$$

where q_t^e is the default rate expected by investors.[14]

2.2 *The equilibria*

We investigate perfect Bayesian equilibria in pure strategies. Two types of equilibria may prevail: *separating equilibria* or *pooling equilibria*. In the first, the government *W* chooses $q_1^W = 1$ and reveals itself at time one. In the second, type *W* mimics type *D* policies at time one and reveals its type only in the last period by choosing $q_2^W = 1$. Note that we use subscripts to refer to time and, when needed, superscripts to indicate equilibria (*S* for separating and *P* for pooling) and types (*D* for dependable and *W* for weak).

In the absence of uncertainty, type *W* would be unable to issue any debt at time zero because the public would anticipate its incentive to default at time one. By contrast, in the game of incomplete information considered in this paper, the uncertainty about the government in power allows type *W* to issue debt until uncertainty is resolved. This can happen at time one or two. Type *W* will reveal its type in period one (separating equilibria) when the cost of imitating type *D* policies is larger than the benefit of issuing debt between period one and period two. Type *W* will reveal its type in period two (pooling equilibria) when the opposite is true.

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[14] The game studied in this paper is part of a general class of dynamic games with a large player (the government) and a large number of small players. The play of the large players is observed and is therefore part of the public history of the game, while the individual plays of the small players are not observed, so that only their aggregate play is part of the public history of the game. Similar games in an infinite horizon context are in Chari and Kehoe (1990, 1993), Stokey (1991).

As we will see, this tradeoff is crucially affected by: the marginal benefits of expenditure (the higher is the parameter a, the greater is the expenditure that type *W* would like to finance in period one and the greater are the benefits of issuing debt between periods one and two), the marginal cost of taxation (the higher is the parameter *h*, the lower are the taxes that type *W* is willing to levy in period one and the higher the cost of imitating type *D* policy), the initial stock of debt (the higher is D_1, the higher are the taxes that type *D* levies in period one and the higher the cost of imitating its policy), and the initial reputation (the higher is D_1, the smaller are the risk premia and the higher are the incentives to mimic type *D* policies).

In Appendix 2, we formally derive the equilibria. In this section, we state the main results in two propositions and provide the intuition behind them. First, consider separating equilibria. In this case, at time one, type *W* reveals its type by defaulting on the outstanding stock of debt. There are two possible cases. In the first, type *W* is unwilling to mimic type *D* policy of choosing optimally at the margin the level of expenditure and taxation. In the second, as type *W* would imitate type *D* optimal level of expenditure at the margin, type *D* chooses to cut expenditure below its optimal separating equilibrium level not to be confused with type *W*. Type *D* will choose this second signaling strategy only if the benefits of paying lower interest payments after signaling outweigh the cost of cutting expenditure below its optimal level. Evidently, the poorer is the initial reputation of the government, the higher are interest rate premia and the stronger are the incentives to signal. The following proposition specifies the range of parameters in which each case of separating equilibrium exists.

Proposition 1: Separating equilibria hold for

$$\frac{D_1 R_1^S}{2} < \hat{a} < D_1 (R_1^S)^2 (R_1^S + \sqrt{(R_1^S)^2 - 1}).$$

Case I: for $\frac{D_1 R_1^S}{2} < \hat{a} < D_1 R_1^S$*, type D runs a primary budget surplus in period one (Table 1 shows equilibrium strategies and interest rates).*

Case II: for $D_1 R_1^S \leq \hat{a} < D_1 (R_1^S)^2 (R_1^S + \sqrt{(R_1^S)^2 - 1})$ *type D runs a primary budget surplus in period one (Table 1 shows equilibrium strategies and interest rates).*

Proof: see Appendix 2 for the proof.

The amount of debt maturing in period one determines the relevant case. In Case I, the debt plus interest maturing in period one is *large* enough $(D_1 R_1^S > \hat{a})$ to make type *D* run a *primary surplus* by choosing an expenditure level $(g^{S,D} < \hat{a})$ *smaller* than the smoothed level of taxation $(t_1^{S,D} = t_2^{S,D} = \hat{a})$. This policy allows the public to distinguish type *D* from type *W*, which prefers a higher expenditure level $(g^{S,D} = g_2^{S,W} = \hat{a})$. In Case II, the debt plus interest maturing in period one is so *small* $(D_1 R_1^S \leq \hat{a})$, that, if type *D* followed the optimal separating equilibrium tax and expenditure policies of Case I, it would run a primary deficit by choosing an expenditure level $(g_1^{S,D} > \hat{a})$ *larger* than the smoothed level of taxation $(t_1^{S,D} = t_2^{S,D} = \hat{a})$. However, this tax and expenditure level would make the separating equilibrium unsustainable because type *W* would mimic such large expenditure. To avoid a breakdown of the separating equilibrium, as long as the debt plus interest maturing in period one is *small but not too small*

$\frac{\hat{a}}{R_1^S + (R_1^S + \sqrt{(R_1^S)^2 - 1})} < D_1 R_1^S \leq \hat{a}$, type *D* deviates from the optimal - but unsustainable - Case I policies. To prevent mimicking, type *D* runs a *balanced* period one *primary budget* rather than the primary deficit implied by Case I policies: expenditure is lower $(g_1^{S,D} = \hat{a})$ and period one taxes remain higher than period two taxes $(t_1^{S,D} = \hat{a} > t_2^{S,D})$ with a deviation from perfect tax smoothing.

In separating equilibria, type *W* repudiates the debt in period one $(q_1^{S,W} = 1)$ so that the interest paid between period zero and period one includes a risk premium $(R_1^S = 1)$, which is a function of the government's initial reputation $(1 = p_0)$. After separation, type *W* faces an infinite interest rate and does not issue any debt, whereas type *D* is able to issue debt at the risk-free interest rate.

Proposition 2: Pooling equilibria exist in the range

$$D_1 R_2^P (R_2^P + \sqrt{(R_2^P)^2 - 1}) < \hat{a} \ .$$

In pooling equilibria all governments run a primary budget deficit in period one (Table 3 shows equilibrium strategies and interest rates).

Proof: See Appendix 2 for the proof.

In pooling equilibria, the debt stock issued in period one is *small enough* $D_1 < \frac{\hat{a}}{R_2^P (R_2^P + \sqrt{(R_2^P)^2 - 1})}$ to make type *D* willing to be mimicked in period one, as type *D* considers the marginal benefits of expenditure larger than the interest cost of being confused with type *W*. In pooling equilibria, type *D* runs a *primary deficit* in period one and chooses an expenditure large enough $(g^{P,D} > \hat{a})$ to make type *W* imitate it together with all other type *D* policies in period one. As a consequence, type *W* defaults only in period two $(q_1^{P,W} = q_1^{P,S} = 0$ and $q_2^{P,W} = 1)$ and the government pays the risk-free rate $(R_1^P = 1)$ on the debt maturing in period one.

Figure 4 shows the parameter ranges in which each type of equilibrium exists. Initial reputation $(1\text{-}p_0)$ is on the horizontal axis, whereas the ratio of the marginal benefits of expenditure to the initial debt stock $(\frac{\hat{a}}{D_1})$ is on the vertical axis. Pooling equilibria exist in an area in the top right-hand corner where a small initial stock of debt (a high $\frac{\hat{a}}{D_1}$) is associated with a small risk premium (a high $1\text{-}p_0$). As we move toward the center of the box, the initial stock of debt and the risk premia increase, and separating equilibria (Case I and Case II) prevail.

Multiple equilibria are possible in an intermediate range where there is an overlapping of the ranges in which pooling and Case II separating equilibria exist. In this area, if investors choose the risk-free rate in period zero $(R_1^P\text{-}1)$, then the best response of both governments is to play their pooling equilibrium strategies; if investors instead choose the interest rate associated with separating equilibrium $(R_1^S > 1)$, then the best response of both governments is to play their Case II separating equilibrium strategies. The fact that in the multiplicity area both types of policy maker prefer pooling equilibria (see Appendix 3) suggests that if investors could coordinate their expectations, they would demand the risk-free rate in period zero and make pooling equilibria prevail. This would, indeed, be their optimal strategy given that both governments are ultimately trying to maximize the utility of the investors (see Appendix 1). However, since investors are atomistic, they may not coordinate their expectations on the risk-free rate and may well demand the higher rates associated with separating equilibria.[15] As a result, in the range of parameters where multiple equilibria exist, investors could force an early - but sub-optimal - resolution of uncertainty by failing to coordinate their expectations on the risk-free rate. *In the extension of Appendix 4, the multiplicity of equilibria disappears because we show that in Case II separating equilibria the optimal strategy of type D is to choose a level of* D_1 *that is not in the multiplicity range*.

2.3 *Key assumptions and extensions*

This section is devoted to discussing how we could relax some simplifying assumptions of the model presented above without affecting its main predictions. We also discuss how our modeling strategy differs from others used in the literature.

A first issue is whether our results depend critically on the two-period structure of the model. This issue is taken up in Appendix 4, where we add one period to the model by allowing the government to choose at time zero the optimal level of debt, D_1, taxes, t_0, g_0, and expenditure, g_0. This extension has the advantage of making the evolution of the

[15] The equilibrium refinement of *Pareto Dominance* (Fudenberg and Tirole, 1992, pp. 18-23) could rule out separating equilibria but its application requires players to be able to coordinate their actions.

debt-to-GDP ratio *endogenous* and with it the timing of the switch from pooling to separating equilibria.[16] In addition, it drastically simplifies the results of the model. In the three-period model, there is only one possible equilibrium in which the economy switches from a pooling equilibrium in period zero to a Case II separating equilibrium in period one. The main results of the two-period version are confirmed with the pooling in period zero being associated with a primary deficit and the separating in period one with a balanced primary budget. The key difference is that in the three-period model type D is allowed to choose D_1 optimally and eliminate welfare-inferior equilibria.[17]

Alternatively, to model a shift of equilibria strictly within the limits of a two-period model, we could have introduced *exogenous* shocks affecting the initial debt-to-GDP ratio, D_1, at time zero before R_1 is determined. As long as the shocks hitting D_1 do not push it beyond the critical threshold derived in Section 2, pooling equilibria prevail. But when a large enough positive shock hits D_1, dependable governments are forced to signal and a switch to separating equilibria takes place. Given that higher real interest rates (a risk-free factor greater than one) would lead *ceteris paribus* to a faster rise in the debt-to-GDP ratio, it is easy to find an empirical counterpart for such shocks in the experience of Ireland, Belgium, and Denmark in the early

[16] By contrast, the two-period model of Section 2 only allows the conjecture that, in an extension with more periods, the shift from pooling to separating equilibria would ultimately take place, given that the debt stock is growing in pooling equilibria $(D_2^P > D_1)$, and that separating equilibria prevail when the debt exceeds a certain threshold.

[17] The other possible equilibria considered in Appendix 4 are the following: pooling in period zero with switch to Case I separating in period one, pooling in period zero, one, separating in period zero, one.

1980s. In those years, the higher real interest rates prevailing worldwide and the tightening of the monetary policy regime associated with the creation of the EMS are likely to have made Ireland, Belgium, and Denmark switch from pooling to separating equilibria. As real interest rates increased, the debt dynamics and the sustainability of the fiscal regime worsened, making dependable governments, after an initial drop in credit ratings, switch to primary surpluses and signal their types.

A second issue is whether our assumption that type *D* can precommit its policies is justified. This assumption has been made in a number of papers that use game theoretical models to study monetary policy signals.[18] As Cukierman and Liviatan (1991) pointed out, an alternative to this approach is to assume, as in Vickers (1986), that there are two types of policy makers with different preferences and that the public is initially uncertain about which of the two is in power. The latter was indeed the approach we first took in this paper (see Drudi and Prati, 1993), but we subsequently adopted the precommitment assumption to simplify the exposition of the results. In that model, different redistributive preferences - not different precommitting ability - characterized the two types of policy maker. Type *D* was a government sufficiently "right-wing" (i.e., one for which the weight of the utility of bondholders in the social welfare function was sufficiently larger than in the population) to be willing ex-post to repay the debt. This larger weight on the utility of the bondholders solved the time-inconsistency problem and prevented the government from defaulting on the outstanding debt. By contrast, in that framework, type *W* was a government sufficiently "left-wing"

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[18] See Barro (1986), Persson and Tabellini (1990, Ch. 3-4) for a review of the literature.

not to be willing ex-post to repay the entire stock of debt outstanding.

Only two insights of the previous model are lost in the simplified version of this paper. First, because this paper characterizes type *D* as always willing to repay the debt no matter how large interest payments are, crisis equilibria in which no debt can be issued are impossible. By contrast, these existed in the earlier model whenever the probability of the "left-wing" government being in power was high enough to generate risk premia so high that even a "right-wing" government would repudiate. Second, because this paper characterizes type *W* as unable to precommit, its optimal repudiation rate is always $q_t = 1$, whereas in the previous version, a partial repudiation with $0 < q_t < 1$ was possible whenever the redistributive preferences of the "left-wing" government were not too extreme.

A third issue is whether a model with a continuum of types would yield different results. As it is difficult to imagine a continuum of types with varying degrees of precommitment ability, this extension is meaningful only in relation to a model with policy makers with different (redistributive) preferences. In this case, as policies are implemented, investors would update their prior probability that certain types are in power. As a result, signaling would no longer be instantaneous and credit ratings would change continuously once a signaling phase has begun.

Another feature of our model is that the weak government always defaults on the outstanding stock of debt. In this respect, this paper is different from Drudi and Giordano (1995), where the government defaults because of an exogenous shock to real interest rates, or Alesina, Prati and

Tabellini (1990), where it defaults because of a self-fulfilling confidence crisis, whose likelihood depends on the maturity structure of the debt (see also Cole and Kehoe, 1996b). We could allow for exogenous uncertainty (for example, on the risk-free rate) and have type *W* - and perhaps also type *D* - default only in certain states of the world, but this would only complicate the model without adding any additional insights. Note that the fact that in our model a weak government always defaults does not prevent this type of government from issuing debt, as long as investors do not know - because of incomplete information - that the weak type is in power. Only when uncertainty is resolved will the weak government face the traditional time-inconsistency problem and be unable to issue any debt.

The advantage of this setup is that we do not need to assume exogenous costs of default, as is often done in the literature, in order to have equilibria with a positive debt stock. Nevertheless, default is costly, because a weak government cannot issue new debt and finance its desired amount of expenditure after a default. It is important to note that this is not a "punishment" or a trigger strategy necessary to support equilibria with a positive debt stock, as in Grossman-Van Huyck (1988) and Eaton and Gersovitz (1981), but rather the sequentially rational strategy of all agents once default has occurred, as in Chari and Kehoe (1990, 1993). Of course, the cost of being excluded from borrowing after default is very much taken into account by the weak government to determine when it is optimal to stop mimicking the policies of the dependable government.

Some papers in the literature on sovereign lending study signaling models with features that resemble those of our paper, but none fully models the fiscal decision of the government and, as a consequence, characterizes the equilibrium path of the debt stock, the primary balances and the interest rates as we do here. Cole and Kehoe (1996a), for example, study a model where the "honest" government type always honors a debt contract because failing to do so would reduce its utility by a large exogenous amount. While their "honest" type is somewhat similar to our "dependable" type, they model the debt financing decision as exogenously determined by whether the economy is in an even or an odd period, so that the outstanding debt is either fully repaid or fully defaulted and no discussion of the optimal amount of debt to roll over is possible. In addition, given the different focus of their paper, they do not study signaling strategies that the "honest" one may follow to separate from the "normal" one. Detragiache (1989) considers a signaling model with two types of government characterized by different discount factors rather than by their ability to precommit their policies. As a result, in Detragiache's model the difference in the discount rates of the two borrowers determines whether pooling or separating equilibria prevail. Other papers modeling sovereign lending with imperfect information are Kletzer (1989), Atkeson (1991), and Cole, Dow and English (1995).

3. An econometric test of the signaling model

3.1 *Testable implications of the signaling model*

Figure 4 summarizes the key predictions of our model. When the debt stock is small and initial reputation is high (top right-hand corner), primary deficits - associated with pooling equilibria - prevail and ratings remain high because no government is expected to default. As the debt stock increases,[19] primary deficits decline and, when dependable governments are about to switch to primary surpluses and signal, credit ratings drop (intermediate area of the box). Only when primary surpluses are consolidated do credit ratings improve. This implies that a testable prediction of our model is that ratings (RATE) are negatively related to the debt-to-GDP ratio (*DY*) and positively related to the primary balance-to-GDP ratio (*PY*). If our model holds, we should then be able to estimate a rating function:

$$(7) \qquad RATE = f\,(DY, PY)$$

with $f_{DY} < 0$ and $f_{PY} > 0$, where f_i indicates the derivative with respect to the ith argument.

However, our model with *endogenous uncertainty* on the type of the policy maker is not the only one to predict a rating function of this type. A model with *exogenous uncertainty* on real interest rates or public expenditure could also generate very similar predictions.[20] With exogenous uncertainty, investors fear a default not because a weak policy maker might be in power (as in our model), but because a large enough shock to interest rates or public expenditure might hit the economy and force even a dependable government to default. In this model, for a given distribution of shocks, a default would be more likely the higher is the debt stock and the bigger is the primary deficit. As a consequence, a

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[19] As discussed in Section 2.3, the debt stock can increase either because we assume that in the two-period model of Section 2 the initial debt stock D_1 is subject to an exogenous shock or because it evolves endogenously as predicted by the three-period extension of Appendix 4.

[20] There are several theoretical models that allow for exogenous uncertainty. See, for example, Missale, Giavazzi and Benigno (1997), for the case of interest rate shocks, Calvo and Guidotti (1990), for the case of public expenditure shocks.

model with exogenous uncertainty would also predict that ratings are a negative function of the debt stock and a positive function of primary balances.

The above consideration implies that we need a sharper prediction than $f_{DY}<0$ and $f_{PY}>0$ to test the validity of our model. Indeed, our model predicts that the signaling power of primary balances (f_{PY}) is not constant but varies with the stock of debt. *When the debt stock is low, pooling equilibria prevail and f_{PY} should be small* because primary balances do not signal the type of government in power. By contrast, *when the debt stock is high, separating equilibria prevail and f_{PY} should be large* because primary balances have a signaling role. Therefore, *our signaling model predicts that f_{PY} should be greater than usual during a signaling phase, which is associated with primary balances swinging into surplus.*[21] *Once signaling has taken place, f_{PY} may be expected to return to its normal (presignaling) level*.

In summary, the novel prediction of our model is that *PY* and *DY* are *complements* in the rating function f(*PY*, *DY*), i.e., $f_{PY,DY}>0$.[22] Note that this is a prediction of the model *until signaling is completed*. The most straightforward way to test for complementarity would then be to create a sample that includes both low-debt periods (like the 1970s) and high-debt periods (like the 1980s). The *postsignaling observations* could then be either ignored or treated similarly to those from low-debt periods. This happens because, according to our model,

[21] A literal interpretation of our model would imply an instantaneous signaling phase. In our estimates, we assume more realistically that in a world in which governments change fiscal measures are often of a one-off nature, signaling takes place over a few years, requiring lasting primary surpluses. Alternatively, we would need a model with a continuum of agents as discussed in Section 2.3.

[22] We are indebted to a referee for suggesting this interpretation of our model.

once uncertainty is resolved, there is no reason to expect f_{PY} to remain larger than usual, even if the debt-to-GDP ratio remains high. This consideration is important because we are forced to include the postsignaling observations in our sample. As ratings are available only since 1979.2, our sample begins at the end of the 1970s and covers a period in which the debt stock is high most of the time, with the only exception being a few years at the very beginning of the sample. *To have enough observations, we need to include the postsignaling period of the late 1980s-early 1990s characterized by still high debt-to-GDP ratios but already improved ratings. Therefore, we test the complementarity of PY and DY by checking whether* f_{PY} *is significantly larger in the signaling phase than in the previous and following periods. The signaling phase is defined for each country as the sub-sample during which PY swings from a deficit into surplus.*

The complementarity of *PY* and *DY* in the rating function f(*PY*, *DY*) also implies that, if the government is dependable, the primary balance will always increase when the debt increases. The intuition is that the larger effects of the fiscal tightening on the credit rating always make it more profitable for the dependable government to tighten fiscal policy when the debt stock is high. To test this prediction, we check whether, in a regression of *PY* on *DY*, the estimated coefficient is positive and significantly greater than zero. Note that in this case a positive correlation between *PY* and *DY* should also be expected in the postsignaling phase, because a dependable government would continue to run primary surpluses as long as the debt-to-GDP ratio remains high.

3.2 *An econometric test on Irish, Belgian, and Danish data*

We test the predictions of our theoretical model on time-series data for Ireland, Belgium, and Denmark (Figures 2 and 3). We do not try to test them on Italian data (Figure 1), because the observations available for the signaling phase are insufficient.

Data are semi-annual, with the primary balance-to-GDP ratio (*PY*) obtained as a linear interpolation of annual data.[23] The credit rating (*RATE*) is published by Institutional Investor in March and September of each year and is available since 1979.2. The debt-to-GDP ratio (*DY*) is the end-of-period figure of June and December of each year. The samples are 1979.2-1995.1 for Ireland and Belgium and 1979.2-1992.1 for Denmark.[24]

The three variables *RATE*, *PY*, and *DY* can be considered stationary. Although univariate stationarity tests (augmented Dickey-Fuller tests) confirm the stationarity of all three series only in Belgium, cointegration tests very strongly reject the existence of less than three cointegrating vectors for all countries (Appendix 5). Both the trace and the maximum eigenvalue statistics (with or without the small sample correction) yield the same result, no matter whether we use one or two lags in the analysis. As the existence of a number of cointegrating vectors equal to the number of variables used

[23] Infra-annual data on interest payments, needed to derive semi-annual primary balances from the overall balances, were not available.

[24] The Danish sample is shorter because of a break in the Danish fiscal series.

in the cointegration analysis implies that the three variables are stationary,[25] we proceed under this assumption.

First, we test whether *PY* and *DY* are complements in the rating function f(*PY*, *DY*) by checking whether the positive effect of *PY* on *RATE* is stronger during the signaling phase (see Section 3.1). The estimated equation is:

$$(8) \qquad RATE_t = g_0 + g_1 RATE_{t-1} + g_2 DY_{t-1} + g_3 PY_{t-1} + g_4 (DSIG * PY_{t-1}) + \in_t \ .$$

One lag of the dependent variable is included to eliminate serial correlation of the residuals in the regressions for Ireland and Belgium.[26] *DY* and *PY* are lagged one period to avoid simultaneity bias.[27] *DSIG* is a dummy variable equal to one during signaling phases and zero otherwise. Signaling phases correspond to the periods in which primary balances swing from deficit to surplus in each country. We define them as the periods 1982.1-1988.1 in Ireland, 1981.1-1989.1 in Belgium, and 1982.2-1986.1 in Denmark.

Estimation results are summarized in Table 4. The coefficients g_2,g_3 and g_4 are all strongly significant and have the expected signs. In the long run, an increase in the debt-to-GDP ratio of 10 percent is estimated to reduce the rating

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[25] See, for example, page 276 of PcFiml 8.0 Manual. With a number of cointegrating vectors equal to the number of variables we can choose the three cointegrating vectors to be unit vectors (1 0 0), (0 1 0),(0 0 1) without restricting the cointegration space.

[26] For Denmark, the coefficient of the lagged dependent variable was not statistically significant. Its inclusion among the regressors had very little effect on the estimated coefficients of the variables of interest.

[27] We also estimated instrumental variable regressions with contemporaneous *DY*, *PY* using lagged variables as instruments, obtaining very similar results (available upon request).

by 2.7 points in Ireland, 3.9 points in Belgium, and 1 point in Denmark. In the long run, a 1 percent improvement in the primary balance during a normal (nonsignaling) phase is estimated to raise the rating by 0.9 points in Ireland, 3.0 points in Belgium, and 0.2 points in Denmark. A similar 1 percent improvement in the primary balance during a signaling phase is estimated to have an *additional* long-run effect of 2.2 points in Ireland, 1.2 points in Belgium, and 0.3 points in Denmark. This additional effect is strongly significant (at a confidence level of 99 percent in Ireland and Denmark and 95 percent in Belgium).

Estimation results suggest two considerations. First, the smaller estimated coefficients for Denmark probably depend on the smaller variation of ratings in this country combined with the larger range of variation of its primary balances (see Figure 2). Second, in Belgium, the estimated additional coefficient g_4 for the signaling phase is smaller than the estimated coefficient g_3 for normal periods, whereas in Ireland and Denmark we obtain the opposite result. This may suggest a smaller signaling effect of primary surpluses in Belgium due to their weaker response to increases in the debt-to-GDP ratio. This interpretation is confirmed by the next set of estimates.

As discussed in Section 3.1, if *PY* and *DY* are complements in the rating function f(*PY*, *DY*), the primary balance will always increase with the stock of debt when the government is dependable. To test this implication, we estimate the equation:

(9) $$PY_t = g_0 + g_1(L)PY_{t\text{-}1} + g_2 DY_{t\text{-}1} + \in_t \quad .$$

Estimation results are reported in Table 5. A varying number of lags of the dependent variable (two for Ireland and Denmark, and three for Belgium) are needed to eliminate serial correlation in the residuals. The estimated coefficient g_2 is strongly significant and has the expected positive sign. In the long-run, a 10 percent increase in the debt-to-GDP ratio is estimated to increase the primary balance by 2.6 percent in Ireland, 1.6 percent in Belgium, and 3.0 percent in Denmark. The weaker response of the primary balance in Belgium is consistent with the weaker signaling effects of the primary balance estimated in Table 4.

4. Alternative explanations of the empirical evidence

Are there alternative explanations that could account equally well for the empirical evidence? As noted in Section 3.1, a signaling model is not the only model predicting that credit ratings should decline with the debt stock and rise with the primary balance. A model with exogenous shocks to public expenditure or interest rates would have similar implications. We have argued, however, that our model makes the additional prediction that until signaling is completed the debt stock and the primary balance should be complements in the rating function. This implies that signaling should be associated with high debt-to-GDP ratios and with the primary balance swinging into surplus. In the previous section, we successfully tested the prediction by showing that during signaling phases the effect of an improvement in the primary balance is bigger.

Another explanation of the deterioration in the credit ratings of Ireland, Belgium, and Denmark in the early 1980s could be based on the contagion effects of the Mexican debt crisis, which would have made holders of government debt aware of the risks of their investments, inducing them to update their priors on default.[28] We can easily account for this alternative explanation in the framework of our model, because a shock to the default priors would result in a switch from pooling to separating equilibria. This can be verified by looking at Figure 4 where a higher prior probability of default could reduce $1\text{-}p_0$ enough to move the economy from a pooling equilibrium to a separating equilibrium area. This explanation of the evidence could complement those of Section 2.3 based on an endogenous evolution of the debt-to-GDP ratio (see Appendix 4) or an exogenous shock to the debt dynamics due to higher real interest rates (in our model, a risk-free factor greater than one). However, when we add the variable *RATE* to the determinants of the primary balance in equation (9), we find a statistically significant coefficient (with the expected negative sign) only for Belgium.

Another alternative explanation of the empirical evidence could be based on the assumption that investors are uncertain about the state of the public finances rather than the type of government.[29] In this context, the beginning of fiscal consolidation may indicate that things are actually worse than previously thought and credit ratings may drop if consolidation is uncertain to succeed. Credit ratings would then recover when uncertainty is eliminated. Although this story is consistent with the observed correlations, such a model needs to provide a rationale for the lack of transparency of the public accounts. Specifically, one would

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[28] This alternative explanation was suggested by one of the referees.

[29] This alternative explanation was suggested by one of the referees. A similar distinction exists in the corporate finance literature between imperfect information on the type of firm or management and imperfect information on the profitability of the project undertaken by only one type of firm or management.

need to explain why a government that knows that the public finances are in good shape would not find it to be in its interest to increase the transparency of its accounts and eliminate risk premia paid as a result of this uncertainty.[30] In fact, if the optimal policy were to have transparent accounts when the state of the public finances is good, investors would know with certainty that lack of transparency signals a bad state of public finances and the start of fiscal consolidation would not send any additional negative signal.

5. Conclusions

In this paper, we develop a signaling model to explain some stylized features of fiscal stabilization in Ireland, Belgium, and Denmark during the 1980s and in Italy during the early 1990s. The first prediction of our model is that credit ratings should be positively related to the primary balance and negatively related to the debt-to-GDP ratio. This explains why even a country with large primary deficits will have a high credit rating when the debt stock is small, and why that country will need a primary surplus to obtain the same rating when the debt stock is large. The intuition is that when the debt stock is small all governments would run primary deficits and no government would have any incentive to default, whereas when the debt stock is large, dependable governments would run primary surpluses to show that they are not of the weak (defaulting) type.

However, other types of models could predict a rating function positively related to primary balances and negatively related with to debt stock. For example, models with exogenous

[30] Of course, the government itself may not know the state of the public finances, but this seems unlikely.

shocks to interest rates or government expenditure would predict a similar rating function without any need to introduce uncertainty on the type of government in power. But these models could not explain why the primary balance seems to have a greater-than-usual effect on credit ratings when it is about to swing from deficit into surplus (Figures 1, 2, and 3 and Table 4). This is the novel prediction of our model, which implies that primary balances and debt-to-GDP ratios are complementary inputs in the function determining the credit rating. The positive effect of primary balances on credit ratings increases with the debt-to-GDP ratio until primary surpluses are achieved and the sustainability of the fiscal regime is signaled. This happens because it is at high debt-to-GDP ratios that the economy moves from a pooling to a separating equilibrium with primary balances having strong signaling power. Specifically, our model predicts that signaling should take place when the primary balance swings from deficit into surplus. We successfully test this prediction on Irish, Belgian, and Danish data, although further research is certainly needed to verify the predicted signaling role of primary surpluses on a larger sample of countries.

The results of this paper shed new light on the determinants of large public debts and on the deviations from the "tax smoothing" theory of the government budget. Our model implies that even dependable governments find it optimal to delay the stabilization of the debt-to-GDP ratio. This happens because they have an incentive to tighten the fiscal regime when the signaling effect on credit ratings is larger (that is, when a sufficiently large stock of debt has been accumulated). Indeed, in Appendix 4 we show that when a dependable - but not fully credible - government is allowed to choose the initial stock of debt strategically, its optimal policy is to accumulate a debt stock large enough to determine a switch from pooling to separating equilibria and signal its type by deviating from optimal tax smoothing. In other words, to obtain an early resolution of uncertainty, dependable governments accelerate the dynamics of the debt stock and seemingly delay stabilization to determine the signaling time optimally. Although further analytical research is certainly needed to check the robustness of this result in an infinite horizon setting, and possibly with a continuum of types, we believe that our novel explanation of delayed stabilizations may complement those based on distributional conflicts and on the strategic accumulation of debt aimed at constraining the actions of successive governments.

With regard to fiscal sustainability criteria, our paper suggests that standard measures should be interpreted with caution. On the one hand, as long as the debt stock is relatively small, explosive paths of the debt-to-GDP ratio with persistent primary deficits need not be a source of concern because both dependable and weak governments would run the same seemingly unsustainable policy. On the other hand, when the debt stock is large, explosive debt paths with persistent primary deficits are much more worrying because they signal that the government in power is not dependable and is likely to default.

Does this paper shed any light on the prospects for an improvement in Italy's credit ratings? The experience of Ireland, Belgium, and Denmark suggests not only that the deterioration in Italian credit ratings at the beginning of the 1990s is not surprising but also that, if Italian primary surpluses persist, the ratings will ultimately improve. Indeed, this has begun to happen since mid 1996. The only remaining peculiarity of the Italian case seems to be the relatively slow response of the ratings to the considerable primary surpluses of the early 1990s, although we certainly need more observations on the signaling phase to verify that this slower response is statistically significant. If confirmed, the seemingly smaller signaling power of Italian primary surpluses may - at least in part - be attributed to the extreme political instability experienced by Italy in the early 1990s and to the large share of one-off measures often included in Italian fiscal packages. Both factors would, in fact, tend to reduce the signaling effect of primary surpluses.

APPENDIX 1
An economy of risk-neutral agents

In this Appendix, we present a simple economy of risk-neutral agents, whose welfare is maximized by a government that solves problem (4) in Section 2.1 and whose optimal policy is to set interest factors according to the no-arbitrage condition (6). Agents are simultaneously consumers and investors.

We assume that the economy is populated by a large number of risk-neutral atomistic agents living for three periods. For simplicity, we set the discount factor to one, so that in period zero a representative agent maximizes the expected utility function:

$$U = E_0\left\{ c_o + c_1 + c_2 \right\}$$

where c_t is consumption in each period (t=0, 1, and 2).

In period zero, agents do not work and allocate their initial endowment e_0 between consumption and government debt, so that their aggregate budget constraint is:

$$c_0 = e_0 - D_1 .$$

At time one and two, agents work and receive labor income, y, reduced by labor taxes t_t and distortionary costs of taxation $\frac{h}{2}(t_t)^2$.[31] In both periods, the government may levy

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[31] This form of distortionary costs is often used in the literature, it is not particularly *ad hoc*. In fact, it is easy to show that by modelling explicitly the labor supply decision of the agents with a utility function separable in consumption, leisure, one would get analogous first order conditions for the government problem.

an ex-post tax on the maturing stock of debt plus interest, $q_t D_t R_t$. In addition, at time one, government expenditure increases private consumption by a factor a . Therefore, the agents' budget constraints at time one and two are:

$$c_1 = y - t_1 - \frac{h}{2} t_1^2 + \left[D_1 R_1 (1 - q_1) - D_2 \right] - a\ g$$
$$c_2 = y - t_2 - \frac{h}{2} t_2^2 + D_2 R_2 (1 - q_2).$$

It is easy to verify that maximizing the agents' welfare U subject to the government's budget constraints (equations (1) and (2) in Section 2.1) is equivalent to solve problem (4). Moreover, the following no arbitrage condition (identical to equation (6) in Section 2.1) is the solution of the agents' maximization problem:

$$R_1 (1 - q_t^e) = 1 \qquad t = 1,2$$

where q_t^e is the expected tax rate on debt maturing in period *t*, given the information set of agents in period *t*-1. Note that the first-order condition of the private sector would be identical, if we considered a small open economy with perfect capital mobility and a risk and tax-free international asset. Alternatively, we could have assumed a risk-free domestic technology with a rate of return equal to one.

APPENDIX 2

Propositions 1 and 2

Proposition 1: Separating equilibria hold for

$$\frac{D_1 R_1^s}{2} < \hat{a} < D_1 (R_1^S)^2 (R_1^S + \sqrt{(R_1^S)^2 - 1}) .$$

Case I: for $\frac{D_1 R_1^s}{2} < \hat{a} < D_1 R_1^S$, *type D runs a primary budget surplus in period one (Table 1 shows equilibrium strategies and interest rates).*

Proof: We derive *the optimal strategy of type W* in a separating equilibrium by solving problem (4) *without precommitment* and under the assumption that at the end of time one investors know that type *W* is in power:

(4.1)

$$Min_{g^{s,w}, D_2^{S,W}, q_1^{S,W}, q_2^{S,W}} \quad \frac{1}{2}\left[D_1 R_1^{S,W} (1 - q_1^{S,W}) + g - D_2\right]^2 + \frac{1}{2}\left[D_2 R_2^{S,W} (1 - q_2^{S,W})\right]^2 - \hat{a}\ g.$$

Solving backwards, the last period optimal strategy of type *W* at time two is clearly to default on the entire stock of debt outstanding by choosing:

$$q_2^{S,W} = 1 \qquad t_2^{S,W} = 0.$$

However, given that in separating equilibrium, investors perfectly anticipate the last period policy of type *W*, they will not buy any debt at the end of time one, i.e.:

$$D_2^{S,W} = 0 \qquad R_2^{S,W} = \infty.$$

This implies that, at the beginning of time one, type *W* faces the problem:

(4.2) $$Min_{g^{S,W},q_1^{S,W},} \quad \frac{1}{2}\left[D_1 R_1^{S,W}(1-q_1^{S,W})+g\right]^2 - \hat{a}\ g$$

whose only solution is:

$$q_1^{S,W} = 1 \qquad\qquad g_2^{S,W} = t_1^{S,W} = \hat{a}\ .$$

We derive *the optimal strategy of type D* in a separating equilibrium by solving problem(4) *with precommitment to zero default in both periods* and under the assumption that at the end of time one investors know that type *D* is in power:

(4.3) $$Min_{g^{S,D},D_2^{S,D}} \quad \frac{1}{2}\left[D_1 R_1^{S,D}+g^{S,D}D_2^{S,D}\right]^2 + \frac{1}{2}\left[D_2^{S,D}\right]^2 - \hat{a}\ \ g^{S,D}.$$

Table 1 shows the optimal policy that solves this problem. Note that, to have a positive $g^{S,D}$, we need to impose a limit on the range of parameters in which this equilibrium exists $\left[\frac{D_1 R_1^S}{2} < \hat{a}\right]$.

Given that the prior probability at time zero that type *W* is in power is p_0, the equilibrium strategy of *risk-neutral investors* in separating equilibrium is to set the interest factor on D_1 at:

$$R_1^{S,W} = R_1^{S,D} = R_1^S = \frac{1}{1 - p_0}$$

and to set the one on D_2 using Bayes' law:

$$R_2^{S,D} = 1, \text{ if } q_1^{S,D} = 0 \text{ \textit{is observed}} \qquad R_2^{S,W} = \infty, \text{ if } q_1^{S,W} = 1 \text{ \textit{is observed}} .$$

Separating equilibria exist only if both type *D* and type *W* have no incentive to deviate from the separating equilibrium policies derived above. As long as type *W* does not mimic type *D* policies, *type D would never* deviate *from his separating equilibrium strategy* because this is optimal by construction under the hypothesis of separation and because any other strategy that confused him with type *W* would make him worse off (by not allowing him to issue any debt in period one and preventing tax smoothing). By contrast, to finance a larger expenditure without levying more taxes, *type W may deviate from his separating equilibrium policies and mimic type D policies* at time one, causing a breakdown of the separating equilibrium. In the deviation strategy, type *W* mimics type *D* strategy at time one and defaults on the entire stock of debt at time two.[32] To rule out such deviation, we need to check the range of parameters for which:

$$C_W^{SDev} > C_W^S$$

where C_i^j is the cost for type *i* (*i* = *W* or *D*) either in equilibrium (*j* = *S* for separating and *j* = *P* for pooling) or in the deviation from equilibrium (*j* = SDev for the deviation from separating and *j* = *PDev* for the deviation from pooling). It is easy to verify that the above inequality is satisfied whenever $g^{S,D} < \hat{a}$ or $D_1 R_1^s > \hat{a}$. The latter inequality provides the upper limit for the range of parameters in which Case I

32 As off-equilibrium beliefs, we assume that investors believe that there is a zero probability of type *W* being in charge if they observe $q_1 = 0$.

separating equilibria exist and implies that these equilibria are associated with *primary surpluses*.

Case II: for $D_1 R_1^s < \hat{a} < D_1 (R_1^S)^2 (R_1^S + \sqrt{(R_1^S)^2 - 1})$*, type D runs a balanced primary budget in period one (Table 2 shows equilibrium strategies and interest rates).*

Proof: Case II separating equilibria may emerge in the range of parameters in which the stock of debt maturing in period one is so small, $D_1 R_1^s \leq \hat{a}$, that type *W* deviates from his Case I separating equilibrium strategy making Case I equilibria not viable. Case II separating equilibria will be possible in the range $D_1 R_1^s \leq \hat{a}$ only if type *D* finds optimal to restore the viability of a separating equilibrium by deviating from its Case I strategy and implementing policies that type *W* does not mimic.

The optimal strategy of type D solves the problem (4.3) subject to the constraint that type *W* must be unwilling to mimic, i.e. $C_W^{SDev} \geq C_W^S$, where C_W^{SDev} is now the cost for type *W* of mimicking the optimal Case II strategy of type *D*. This constraint amounts to a maximum level of expenditure for each level of taxes chosen by type *D* in period one:

$$g_1^{S,D} \leq \frac{(t_1^{S,D})^2}{2\hat{a}} + \frac{\hat{a}}{2}.$$

Type *D* problem in Case II can then be rewritten as the following minimization problem in

$$(4.4) \quad Min_{t_1^{S,D}} \; \frac{1}{2}\left[t_1^{S,D}\right]^2 + \frac{1}{2}\left[D_1 R_1^S + \frac{\left(t_1^{S,D}\right)}{2\hat{a}} + \frac{\hat{a}}{2} - t_1^{S,D}\right]^2 - \hat{a}\left[\frac{\left(t_1^{S,D}\right)}{2\hat{a}} + \frac{\hat{a}}{2}\right].$$

The unique real solution of this problem is $t_1^{S,D} = \hat{a}$, which implies a balanced primary budget in period one. Given taxation, the other equilibrium values follow from the constraint on $g^{S,D}$ and the government budget constraints. Type *W* equilibrium strategies are the same as in Case I.

Case II separating equilibria exist only if both type *D* and type *W* have no incentive to deviate from the policies derived above. Type *W* cannot deviate by construction. Conversely, type *D* could deviate by reoptimizing at time one. In the deviation, type *D* chooses a set of policies in period one that do not allow the public to distinguish him from type *W* because he reckons that the benefit of a higher expenditure in period one more than compensates the cost of paying an interest premium between period one and two.[33] Type *D* problem in the deviation is problem (4.3) modified to allow for

$$R_2^{SDev,D} = \frac{1}{1-p_0} > 1:$$

(4.5) $$Min_{g^{SDev,D},D_2^{SDev,D}} \ \frac{1}{2}\left[D_1 R_1^{S,D} + g^{SDev,D} - D_2^{SDev,D}\right]^2 + $$
$$+ \frac{1}{2}\left[D_2^{SDev,D} R_2^{SDev,D}\right]^2 - \hat{a}\ g^{SDev,D}$$

with solution:

$$D_2^{SDev,D} = \frac{\hat{a}}{\left[R_2^{SDev,D}\right]^2} \qquad g_2^{SDev,D} = \frac{\left[1+(R_2^{SDev,D})^2\right]\hat{a}}{\left[R_2^{SDev,D}\right]^2} - D_1^S R_1^S .$$

33 The off-equilibrium beliefs are the following: whenever investors observe the deviation strategy of type *D* in the separating equilibrium, they revert to the pooling pricing of bonds. This is justified from the observation that it would be in the interest of type *W* to mimic that policy in the deviation from separating equilibria.

To rule out the deviation of type *D* from Case II separating, we need to find the range of parameters in which:

$$C_2^{S,Dev} > C_D^S$$

or

$$\frac{1}{2}\hat{a} + \frac{1}{2}\left[\frac{\hat{a}}{R_2^{SDev,D}}\right]^2 - \hat{a}\left[\frac{\left[1+(R_2^{SDev,D})^2\right]\hat{a}}{(R_2^{SDev,D})^2} - D_1 R_1^S\right] > \frac{1}{2}\hat{a}^2 + \frac{1}{2}(D_1 R_1^S)^2 - \hat{a}^2.$$

This inequality holds in a range whose limits are the two values of $\hat{a}$s that solve the associated second order equation. The lower limit can, however, be neglected because it is outside the range of $\hat{a}s$ is relevant for case II $(D_1 R_1^s \leq \hat{a})$. Therefore, after setting $R_1^{SDev,D} = R_1^S = \frac{1}{1 - p_0}$, we conclude that Case II separating equilibria exist in the range:

$$D_1 R_1^s \leq \hat{a} < D_1 (R_1^S)^2 (R_1^S + \sqrt{(R_1^S)^2 - 1}) .$$

Proposition 2: Pooling equilibria exist in the range

$$D_1 R_2^P (R_2^P \sqrt{(R_2^P)^2 - 1}) < \hat{a} .$$

In pooling equilibria all governments run a <u>*primary budget deficit*</u> *in period one (Table 3 shows equilibrium strategies and interest rates).*

Proof: The optimal strategy of type W in pooling equilibrium is to choose:

$$q_2^{P,W} = 1 \qquad\qquad t_2^{P,W} = 0$$

and to mimic type *D* optimal strategy in period one.

Given that in pooling equilibria type *W* defaults only at time two, no revision of beliefs is possible at time one and the equilibrium strategy of *risk-neutral investors* is to set interest factors at:

$$R_1^{P,W} = R_1^{P,D} = 1 \qquad\qquad R_2^{P,W} = R_2^{P,D} = R_2^{P} = \frac{1}{1 - p_0} \ .$$

We derive *the optimal strategy of type D* in a pooling equilibrium by solving problem (4) *with precommitment to zero default in both periods* and under the assumption that investors set interest factors as indicated above:

$$(4.6) \quad Min_{g^{P,D}, D_2^{P,D}} \quad \frac{1}{2}\left[D_1 + g^{P,D} - D_2^{P,D}\right]^2 + \frac{1}{2}\left[D_2^{P,D} R_2^{P,D}\right]^2 - \hat{a}\ g^{P,D}.$$

Table 3 shows the optimal policy that solves this problem.

Pooling equilibria exist in a range of parameters in which neither type *W* nor type *D* deviate from the above equilibrium strategies. *Type W does not deviate from the pooling equilibrium strategy as long as type D runs a primary deficit at time one*:

$$g^{P,D} = g^{P,W} > t_1^{P,D} = t_1^{P,W} = \hat{a} \ .$$

The intuition is that, if type *D* chose to run a primary surplus by setting $g^{P,D} < t_1^{P,D} = \hat{a}$, type *W* would be better off defaulting on the outstanding stock of debt and running a balanced budget by setting $g^{PDev,W} < t_1^{PDev,W} = \hat{a}$.

The primary deficit requirement can be obtained formally by checking in which range of parameters:

$$C_W^{P,Dev} > C_W^P$$

or

$$\frac{1}{2}\hat{a}^2 - a^2 > \frac{1}{2}(t_1^{P,D})^2 - \hat{a}\ g^{P,D}.$$

This inequality is satisfied for:

$$g^{P,D} > t_1^{P,D} \leftrightarrow \hat{a} > D_1(R_2^P)^2 \leftrightarrow D_2^{P,D} > D_1$$

note that the inequality $\hat{a} > D_1(R_2^P)^2$ is always satisfied in the range of Proposition 2, which reflects the condition for no-deviation of type *D* that we are about to derive.

Type *D* could deviate from its pooling equilibrium strategy by reoptimizing at time one. In the deviation, type *D* chooses a set of policies in period one that distinguish him from type *W* because he reckons that the benefit of paying a risk-free interest rate between period one and two is larger than the cost of cutting expenditure to a level that type *W* would not mimic.[34] The optimal strategy of type *D* in the deviation is the one that solves the problem (4.6) with $R_2^{P,D} = R_2^{PDev,D} = 1$ and subject to the constraint that type *W* must

[34] We assume that in the deviation off-equilibrium beliefs are such that, if the optimal deviation policy of type *D* (derived below) is observed, investors require the risk-free interest rate.

not mimic. This constraint (analogous to the one derived above in the proof of Proposition 1 for Case II separating equilibria) amounts to a maximum level of expenditure for each level of taxes that type *D* chooses in period one in the deviation from pooling:

$$g^{PDev,D} \leq \frac{\hat{a}}{2} + \frac{\left(t_1^{PDev,D}\right)^2}{2\hat{a}} \quad .$$

Type *D* problem in the deviation from pooling can then be rewritten as the following minimization problem in $t_1^{PDev,D}$:

$$Min_{t_1^{PDev,D}} \quad \frac{1}{2}\left[t_1^{PDev,D}\right]^2 + \frac{1}{2}\left[D_1 + \frac{\left(t_1^{PDev,D}\right)^2}{2\hat{a}} + \frac{\hat{a}}{2} - t_1^{PDev,D}\right]^2 +$$

$$- \hat{a}\left[\frac{\left(t_1^{PDev,D}\right)^2}{2\hat{a}} + \frac{\hat{a}}{2}\right].$$

The unique real solution of this problem is $t_1^{PDev,D} = \hat{a}$, which implies $g_1^{PDev,D} = \hat{a}$ and a balanced primary budget in period one.

To rule out the deviation of type *D* from pooling, we need to find the range of parameters in which:

$$C_D^{P,Dev} > C_D^P$$

or

$$\frac{1}{2}\hat{a}^2+\frac{1}{2}D_1^2 - \hat{a}^2 > \frac{1}{2}\hat{a}^2+\frac{1}{2}\left[\frac{\hat{a}^2}{R_2^P}\right]^2 - \hat{a}\left[\frac{\left[1+\left(R_2^{P,D}\right)^2\right]\hat{a}}{\left(R_2^{P,D}\right)^2}-D_1\right].$$

This inequality is satisfied in the following two separate ranges:

$$\begin{aligned}\hat{a} &< D_1 R_2^P\left(R_2^P-\sqrt{\left(R_2^P\right)^2-1}\right)\\ \hat{a} &> D_1 R_2^P\left(R_2^P+\sqrt{\left(R_2^P\right)^2-1}\right)\end{aligned}\quad .$$

We conclude that pooling equilibria exist only in the upper range because only in this one the condition $\hat{a} > D_1 (R_2^P)^2$ for the no-deviation of type *W* is satisfied.

APPENDIX 3

Pareto dominance in multiplicity range

This appendix proves that in the multiplicity range both type *W* and type *D* prefer pooling equilibria to Case II separating equilibria.

Type W

Type *W* will prefer pooling equilibria to Case II separating equilibria if:

$$C_W^P < C_W^S$$

or

$$\frac{1}{2}\hat{a}^2 - \hat{a}g^{P,W} < \frac{1}{2}\hat{a}^2 - \hat{a}^2 .$$

This inequality is always satisfied in the multiplicity range because in that range pooling equilibria exist and, to prevent a deviation of type *W* from pooling, the inequality $g^{P,W} > \hat{a}$ must hold (i.e., pooling equilibria exist only if there is a primary deficit in period one, see proof of Proposition 2 in Appendix 1).

Type D

Type *D* will prefer pooling equilibria to Case II separating equilibria if:

$$C_D^P < C_D^S$$

or

$$\frac{1}{2}\hat{a}^{2} + \frac{1}{2}\left[\frac{\hat{a}}{R_2^{P,D}}\right]^2 - \hat{a}g^{P,D} < \frac{1}{2}\hat{a}^{2} + \frac{1}{2}\left(D_1 R_1^S\right)^2 - \hat{a}^{2} \quad .$$

This inequality is always satisfied in the multiplicity range because in that range pooling equilibria exist and, to prevent a deviation of type *D* from its pooling strategy, the inequality $C_D^{PDev} > C_D^P$ must hold (see proof of Proposition 2 in Appendix 1), but, given that $C_D^S > C_D^{PDev}$, also the inequality $C_D^S > C_D^P$ holds.

APPENDIX 4
A three-period model

In this Appendix, we add one period to the model of Section 2 by allowing the government to choose at time zero the optimal level of debt, D_1, taxes, t_0, and expenditure, g_0. The new government's budget constraints are:

(0) $$g_0 = t_0 + D_1$$

(1') $$D_1 R_1 (1 - q_1) + g_1 = t_1 + D_2$$

(2) $$D_2 R_2 (1 - q_2) = t_2 \,.$$

The timing of the game becomes:

Time 0			*Time 1*			*Time 2*
↑	↑	|	↑	↑	|	↑
g_0, D_1, t_0	R_1		g_1, D_2, q_1, t_1	R_2		q_2, t_2

equation (3) becomes:

$$\frac{h}{2}(t_0^2 + t_1^2 + t_2^2) - a\,(g_0 + g_1)$$

problem (4) becomes:

(4') $$Min_{g_0, D_1, g_2, D_2, q_1, q_2} \quad \frac{1}{2}(g_0 - D_1)^2 + \frac{1}{2}(D_1 R_1 (1 - q_1) + g_0 - D_2)^2 + \\ + \frac{1}{2}(D_2 R_2 (1 - q_2))^2 - \hat{a}\,(g_0 + g_1).$$

Note that the model needs to be solved backwards to insure sequential rationality. This implies that the results of Propositions 1 and 2 still characterize the possible equilibria of the game starting at time one for any given D_1 and that we need to study how these equilibrium strategies for periods one and two can be combined with the optimal strategy in period zero. There are four types of possible equilibria: (1) pooling in period one combined with pooling in period zero; (2) Case I separating in period one combined with pooling in period zero; (3) Case II separating in period one combined with pooling in period zero; (4) separating in period zero.

Proposition 3: In the three-period model, there is only one equilibrium with type W and type D choosing Case II separating equilibrium strategies in periods one and two (Table 3) and the following pooling equilibrium strategy in period zero:

$$t_0 = \hat{a}\ ,\ g_0 = \hat{a}\ \left(\frac{1+(R_1^S)^2}{(R_1^S)^2}\right),\ D_1 = \frac{\hat{a}}{(R_1^S)^2}.$$

In this equilibrium, the primary budget is in deficit in period zero (pooling) and is balanced in period one (separating).

Proof: Our solution strategy is the following. First, we derive the optimal policies and the conditions for the existence of each of the four possible equilibria. Second, we let type *D* choose the debt level, D_1, that minimizes overall costs.

(1) *Pooling in period one combined with pooling in period zero*

In this equilibrium, to find the optimal strategy of type *D* at time zero, we let the government solve problem (4') subject to the constraint on D_1 in Table 3 and taking the pooling equilibrium strategies in period one and two of Table 3 as given:

$$(4'.1)\ Min_{g_0,D_1} \quad \frac{1}{2}(g_0 - D_1)^2 + \frac{1}{2}(\hat{a})^2 + \frac{1}{2}\left(\frac{\hat{a}}{R_2^P}\right)^2 - \hat{a}\,(g_0) - \hat{a}\left(\frac{\left[1+(R_2^P)^2\right]\hat{a}}{(R_2^P)^2} - D_1\right)$$

subject to:

$$D_1 < \frac{\hat{a}}{R_2^P(R_2^P + \sqrt{(R_2^P)^2 - 1})}$$

the solution of this problem is:

$$t_0 = \hat{a} \qquad\qquad -\hat{a} < D_1 < \frac{\hat{a}}{R_2^P(R_2^P + \sqrt{(R_2^P)^2 - 1})}$$

type *D* can choose any D_1 in the specified range because, with R_1=1, g_0 and g_1 have the same marginal utility so that type *D* can shift expenditure between period zero and period one by varying D_1 without affecting welfare. The LHS inequality on D_1 follows from the optimal policy $t_0 = \hat{a}$ combined with the non-negativity requirement for g_0, whereas the RHS inequality follows from Proposition 2. A negative D_1 implies that the government accumulates assets between period zero and period one that are then used to finance a larger g_1. A negative D_1 also implies that the government runs a primary surplus in period zero to which it corresponds a larger primary deficit in period one. This means that even though in a three-period model primary surpluses at zero may be associated with pooling equilibria, these surpluses are not lasting.

The pooling-pooling equilibrium strategy will be viable only if neither type *W* nor type *D* find optimal to deviate from it. Type *W* will never deviate from it because the cost of not mimicking type *D* policy in period zero (and then adopt an "autarchy" strategy in which he runs balanced budgets in period zero and one by choosing $t_0 = g_0 = t_1 = g_1 = \hat{a}$) is larger than the cost of mimicking it:

$$\frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}^2 - \hat{a}^2 > \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}(D_1 + \hat{a}) - \hat{a}\left[\frac{\left[1 + (R_2^{P,D})^2\right]\hat{a}}{R_2^P} - D_1\right].$$

Type *D* will also never deviate from the pooling-pooling strategy. To show it, we first need to find the primary surplus at time zero at which type *W* prefers the "autarchy" strategy and then show that type *D* always prefers the pooling-pooling strategy to running such a large surplus at time zero. To force type *W* into "autarchy", type *D* needs to choose a larger than optimal level of taxes in period zero $\bar{t}_0 \gg \hat{a}$ together with $D_1 = -\bar{t}_0 \ll -\hat{a}$, $g_0 = 0$, $t_1 = t_2 = \hat{a}$, $g_1 = 2\hat{a} - D_1$ so that:

$$\frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}^2 - \hat{a}^2 < \frac{1}{2}(\bar{t}_0)^2 + \frac{1}{2}\hat{a}^2 - \hat{a}(2\hat{a} + \bar{t}_0)$$

which is satisfied for any $\bar{t}_0 > \hat{a}^2(1+\sqrt{2})$. Type *D* will then never deviate from the pooling-pooling strategy if:

$$\frac{1}{2}(\bar{t}_0)^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}(2\hat{a} + \bar{t}_0) > \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}^2 - \hat{a}\left[\frac{\left[1 + (R_2^{P,D})^2\right]\hat{a}}{(R_2^{P,D})^2}\right]$$

which is always satisfied for any $\bar{t}_0 > \hat{a}^2(1+\sqrt{2})$. Note that in the RHS of the above inequality we have arbitrarily chosen D_1=0. This can be done without loss of generality because D_1=0 is in the pooling-pooling equilibrium range.

(2) *Case I separating in period one combined with pooling in period zero*

In this equilibrium, to find the optimal strategy of type *D* at time zero, we let the government solve problem (4') subject to the constraint on D_1 in Table 1 and taking the Case I separating equilibrium strategies in period one and two of Table 1 as given. We also rewrite problem (4') in terms of $\bar{t}_0$ and D_1:

$$(4'.2)\quad Min_{t_0, D_1} \quad \frac{1}{2} + (t_0)^2 \; + \; \frac{1}{2}(\hat{a})^2 + \frac{1}{2}(\hat{a})^2 - \hat{a}\,(t_0 - D_1) - \hat{a}(2\hat{a} - D_1 R_1^S)$$

subject to:

$$D_1 > \frac{\hat{a}}{R_1^S}$$

the solution of this problem is:

$$t_0 = \hat{a} \qquad\qquad \text{liminf}\left(D_1 < \frac{\hat{a}}{R_1^S}\right).$$

Note that the solution for D_1 is a corner solution corresponding to the minimum D_1 at which Case I separating equilibria exist. This happens because the derivative of the cost function (4'.2) with respect to D_1 is always positive implying that D_1 should be chosen as small as possible. At time zero, type *W* never deviates from this equilibrium because type *D* always runs a primary deficit. Also type *D* never deviates because the following inequality always holds for:

$$\bar{t}_0 > \hat{a}\ (1+\sqrt{2}):$$

$$\frac{1}{2}(t_0)^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}\,(2\hat{a} + \bar{t}_0) > \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}\left(\frac{(1+R_1^S)\hat{a}}{R_1^S}\right) - \hat{a}^2.$$

(3) *Case II separating in period one combined with pooling in period zero*

In this equilibrium, to find the optimal strategy of type *D* at time zero, we let the government solve problem (4') subject to the constraint on D_1 in Table 2 and taking the Case II separating equilibrium strategies in period one and two of Table 2 as given:

$$\text{(4'.3)}\quad Min_{g_0, D_1}\ \frac{1}{2}(g_0 - D_1)^2 + \frac{1}{2}(\hat{a})^2 + \frac{1}{2}\left(D_1^S R_1^S\right)^2 - \hat{a}\,(g_0) - \hat{a}^2$$

subject to:

$$\frac{\hat{a}}{(R_1^S)^2(R_1^S + \sqrt{(R_1^S)^2 - 1})} < D_1 \le \frac{\hat{a}}{R_1^S}$$

the solution of this problem is:

$$t_0 = \hat{a} \qquad D_1 = \frac{\hat{a}}{(R_1^S)^2} \qquad g_0 = \hat{a}\left(\frac{1+(R_1^S)^2}{(R_1^S)^2}\right)$$

at time zero, type *W* never deviates from this equilibrium because type *D* always runs a primary deficit. Also type *D* never deviates because the following inequality always holds for $\bar{t}_0 > \hat{a}^2(1+\sqrt{2})$:

$$\frac{1}{2}(\bar{t}_0)^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}\,(2\hat{a} + \bar{t}_0) > \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\left(\frac{\hat{a}}{R_2^S}\right)^2 - \hat{a}\left[\frac{(1+(R_1^S)^2)\hat{a}}{(R_1^S)^2}\right] - \hat{a}^2.$$

(4) *Separating in period zero*

The separating equilibrium in period zero never exists because type *D* will always prefer equilibria (1), (2), and (3) above. This follows from the fact that the conditions for no deviation of type *D* at time zero from such equilibria are always satisfied.

Equilibrium selection

Type *D* chooses the D_1 in period zero that corresponds to the equilibrium that minimizes the overall cost. This is equilibrium (3). The cost associated with equilibrium (3) is, in fact, always smaller than the one associated with equilibrium (2):

$$\frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\left(\frac{\hat{a}}{R_1^S}\right)^2 - \hat{a}\left[\frac{(1+(R_1^S)^2\hat{a})}{(R_1^S)^2}\right] - \hat{a}^2 < \frac{1}{2}\hat{a}^2 + \\ + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}\left[\frac{(1+R_1^S)^2\hat{a})}{R_1^S}\right] - \hat{a}^2.$$

Similarly, the cost associated with equilibrium (3) is always smaller than the one associated with equilibrium (1):

$$\frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\left(\frac{\hat{a}}{R_1^S}\right)^2 - \hat{a}\left[\frac{(1+(R_1^S)^2\hat{a})}{(R_1^S)^2}\right] - \hat{a}^2 < \frac{1}{2}\hat{a}^2 + \\ + \frac{1}{2}\hat{a}^2 + \frac{1}{2}\hat{a}^2 - \hat{a}^2 - \hat{a}\left[\frac{1+(R_2^P)^2\hat{a})}{(R_2^P)^2}\right].$$

APPENDIX 5

Cointegration analisys

(THREE VARIABLES: RATING, PRIMARY BALANCE-TO-GDP RATIO, DEBT-TO-GDP RATIO)

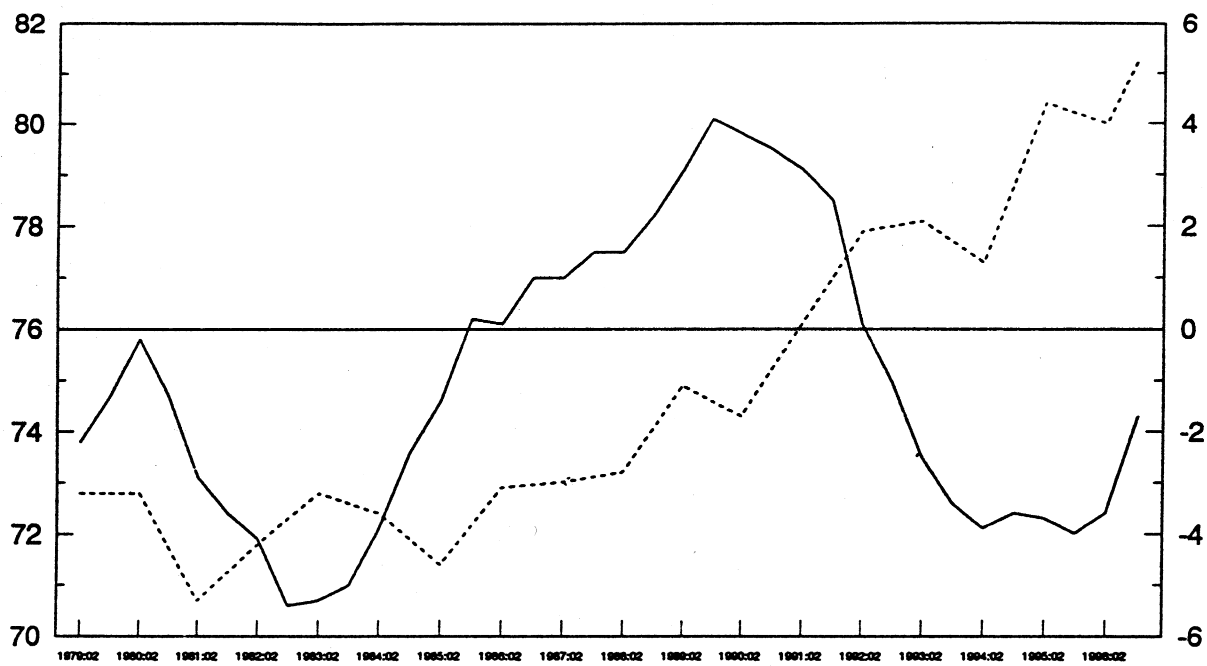
Ho: p coint. vectors	Maximum eigenvalue statistic	small sample	95% critical value	Trace statistic	small sample	95% critical value
(IRELAND. Number of lags used in the analysis: 1. Sample: 1980 (1) to 1995 (1))						
p == 0	28.70**	25.92**	21.0	52.43**	47.36**	29.7
p <= 1	19.15**	17.29*	14.1	23.73**	21.44**	15.4
p <= 2	**4.58***	**4.14***	**3.8**	**4.58***	**4.14***	**3.8**
(IRELAND. Number of lags used in the analysis: 2. Sample: 1980 (2) to 1995 (1))						
p == 0	17.24	13.79	21.0	32.26*	25.81	29.7
p <= 1	8.95	7.16	14.1	15.02	12.01	15.4
p <= 2	**6.06***	**4.85***	**3.8**	**6.06***	**4.85***	**3.8**
(BELGIUM. Number of lags used in the analysis: 1. Sample: 1980 (1) to 1995 (1))						
p == 0	32.57**	29.42**	21.0	58.87**	53.17**	29.7
p <= 1	16.80*	15.17*	14.1	26.30**	23.76**	15.4
p <= 2	**9.50****	**8.58****	**3.8**	**9.50****	**8.58****	**3.8**
(BELGIUM. Number of lags used in the analysis: 2. Sample: 1980 (2) to 1995 (1))						
p == 0	33.55**	26.84**	21.0	67.58**	54.06**	29.7
p <= 1	21.44**	17.15*	14.1	34.03**	27.22**	15.4
p <= 2	**12.59****	**10.07****	**3.8**	**12.59****	**10.07****	**3.8**
(DENMARK. Number of lags used in the analysis: 1. Sample: 1980 (1) to 1992 (1))						
p == 0	24.27*	21.36*	21.0	53.02**	46.66**	29.7
p <= 1	19.68**	17.32*	14.1	28.74**	25.29**	15.4
p <= 2	**9.07****	**7.98****	**3.8**	**9.07****	**7.98****	**3.8**
(DENMARK. Number of lags used in the analysis: 2. Sample: 1980 (2) to 1992 (1))						
p == 0	24.73*	18.55	21.0	45.18**	33.88*	29.7
p <= 1	11.56	8.67	14.1	20.44**	15.33	15.4
p <= 2	**8.89****	**6.66***	**3.8**	**8.89****	**6.66****	**3.8**

All statistics are calculated by PcFiml 8.0 (see pages 276-278). (**) and (*) mark that the null hypothesis is rejected at a confidence level of 99 and 95 percent respectively. The maximum eigenvalue statistic tests H_0: p cointegrating vectors (cvs) against H_1: p+1 cvs. The trace statistic tests H_0: p cvs against H_1: > p cvs.

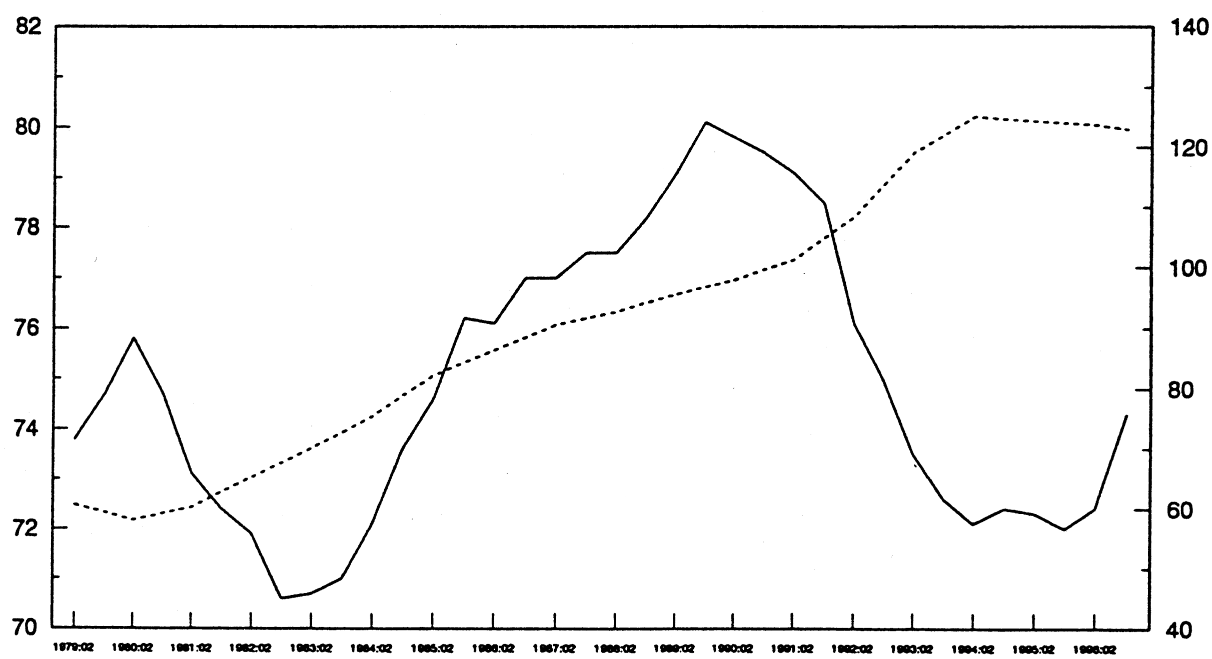
Figures and tables

Figure 1

ITALY



Rating (left scale) Primary Balance (right scale)



Rating (left scale) Debt (right scale)

Figure 2

RATING AND PRIMARY BALANCE-TO-GDP RATIO

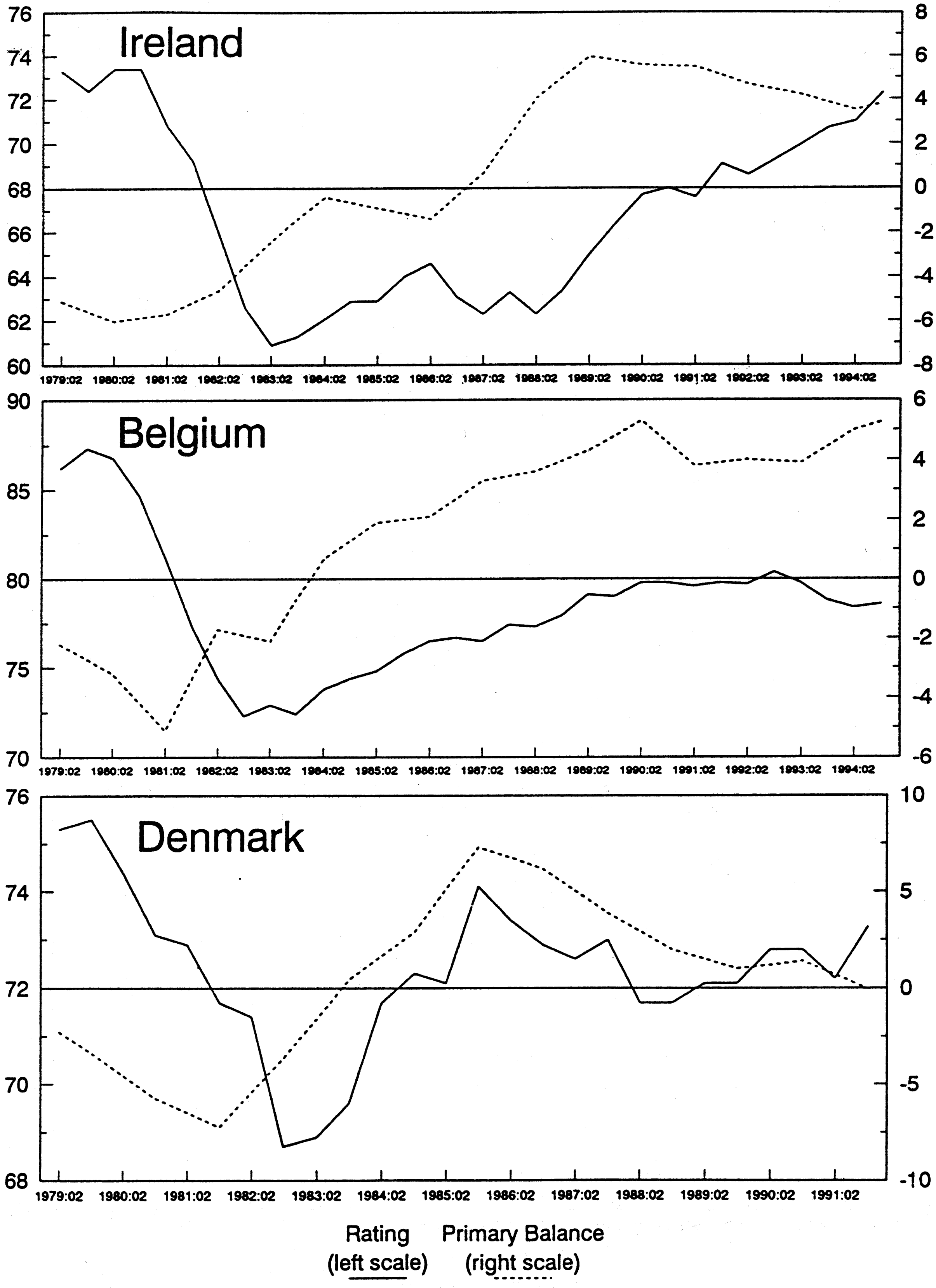


Figure 3

RATING AND DEBT-TO-GDP RATIO

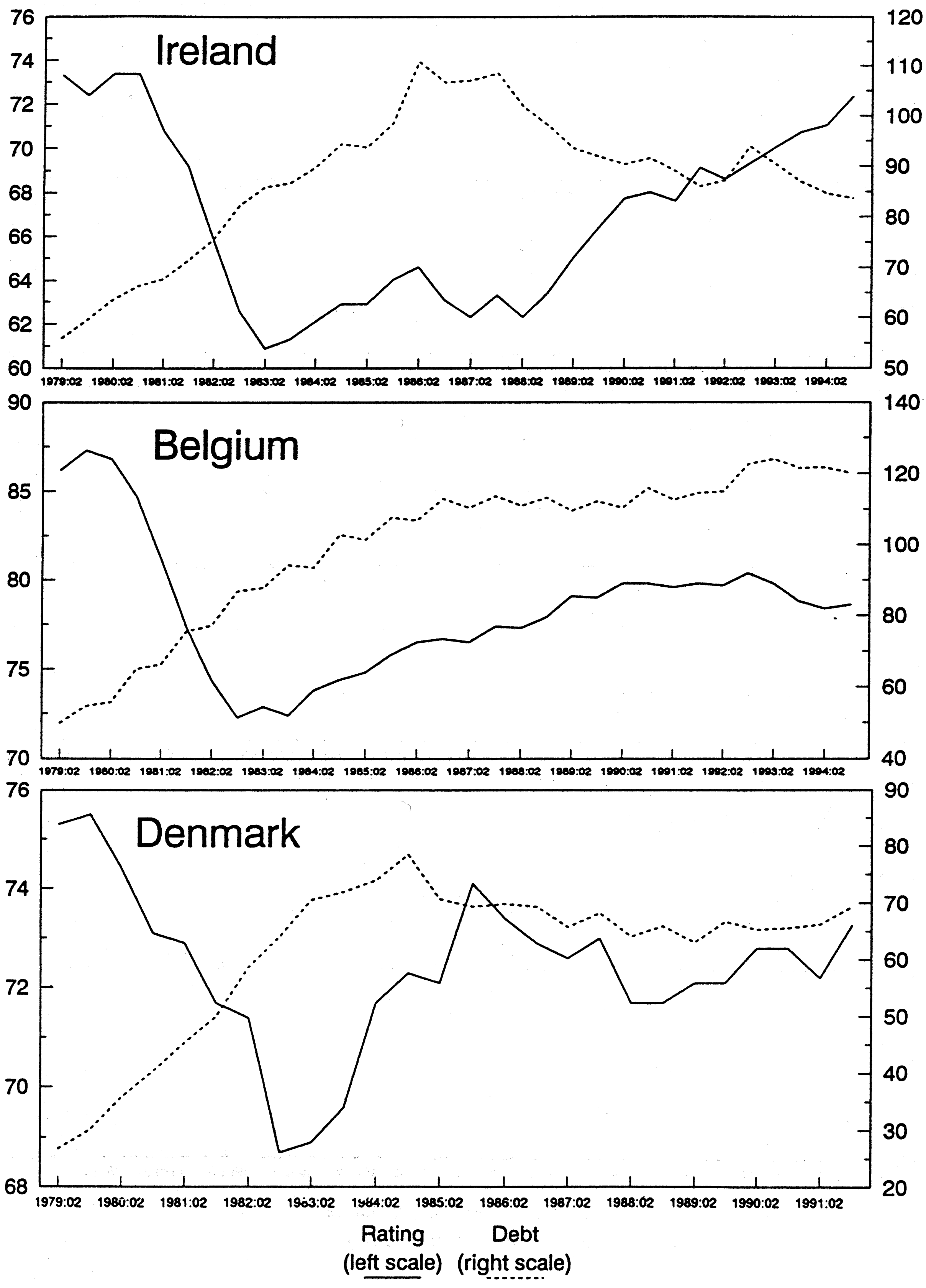


Figure 4

EQUILIBRIUM EXISTENCE RANGES

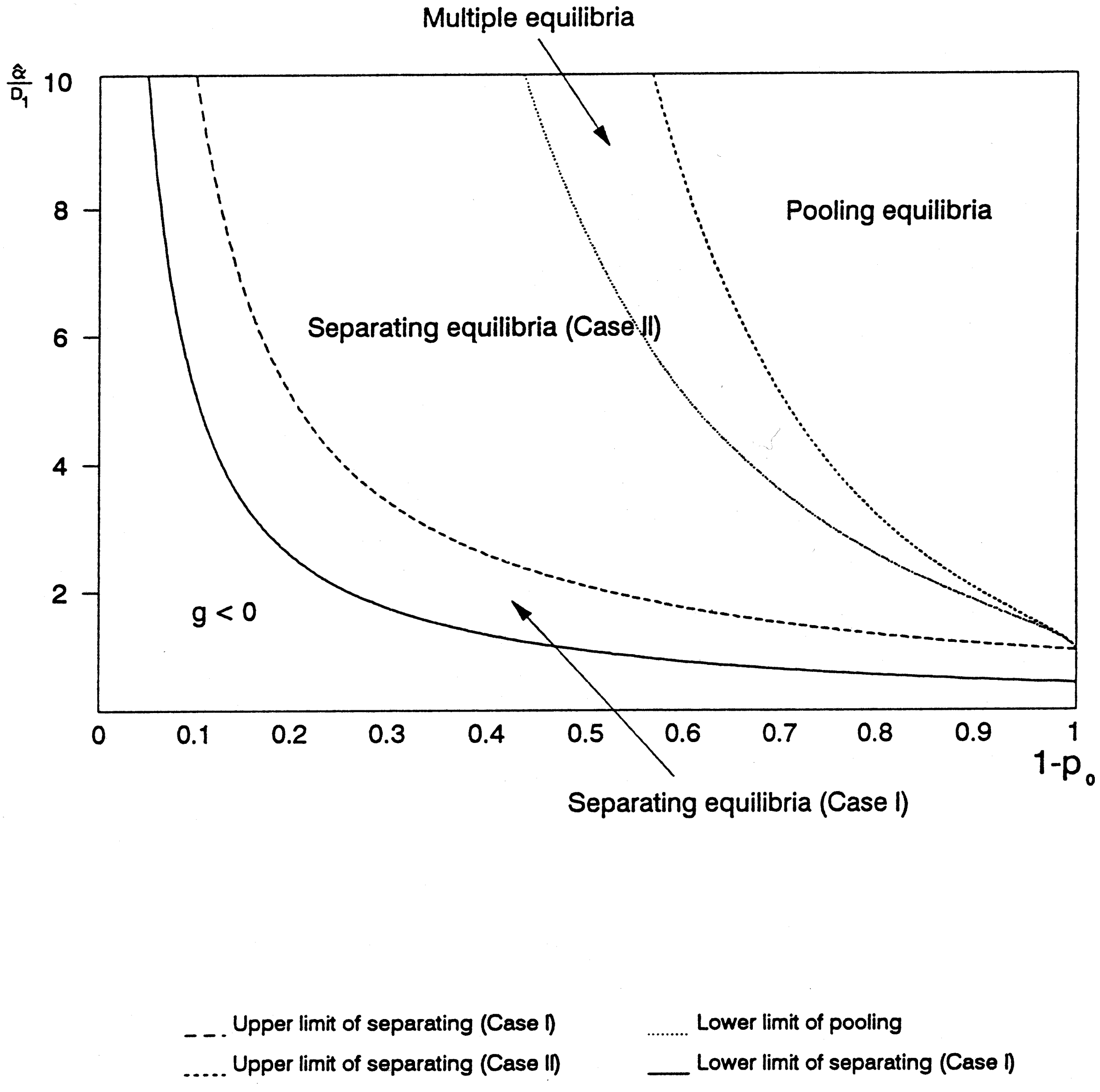


Table 1

SEPARATING EQUILIBRIUM (CASE I)

Equilibrium range:

$$\frac{D_1 R_1^S}{2} < \hat{\alpha} < D_1 R_1^S \;\Leftrightarrow\; \frac{1}{2(1-p_0)} < \frac{\hat{\alpha}}{D_1} < \frac{1}{(1-p_0)}$$

Equilibrium policies:

$$R_1^S = R_1^{S,W} = R_1^{S,D} = \frac{1}{1-p_0}$$

$$g^{S,W} = \hat{\alpha} \qquad g^{S,D} = 2\hat{\alpha} - D_1 R_1^S < \hat{\alpha}$$

$$\theta_1^{S,W} = 1 \qquad \theta_1^{S,D} = 0$$

$$\tau_1^{S,W} = \tau_1^{S,D} = \hat{\alpha}$$

$$D_2^{S,W} = 0 \qquad D_2^{S,D} = \hat{\alpha}$$

$$R_2^{S,W} = \infty \qquad R_2^{S,D} = 1$$

$$\theta_2^{S,W} = 1 \qquad \theta_2^{S,D} = 0$$

$$\tau_2^{S,W} = 0 \qquad \tau_2^{S,D} = \hat{\alpha}$$

Primary balance of type D in period 1:

$$\tau_1^{S,D} - g^{S,D} = \hat{\alpha} - (2\hat{\alpha} - D_1 R_1^S) > 0$$

Table 2

SEPARATING EQUILIBRIUM (CASE II)

Equilibrium range:

$$D_1 R_1^S \leq \hat{\alpha} < D_1 (R_1^S)^2 \left(R_1^S + \sqrt{(R_1^S)^2 - 1} \right) \Rightarrow \frac{1}{(1-p_0)} \leq \frac{\hat{\alpha}}{D_1} < \frac{1 + \sqrt{1-(1-p_0)^2}}{(1-p_0)^3}$$

Equilibrium policies:

$$R_1^S = R_1^{S,W} = R_1^{S,D} = \frac{1}{1-p_0}$$

$$g^{S,W} = g^{S,D} = \hat{\alpha}$$

$$\theta_1^{S,W} = 1 \qquad \theta_1^{S,D} = 0$$

$$\tau_1^{S,W} = \tau_1^{S,D} = \hat{\alpha}$$

$$D_2^{S,W} = 0 \qquad D_2^{S,D} = D_1 R_1 < \hat{\alpha}$$

$$R_2^{S,W} = \infty \qquad R_2^{S,D} = 1$$

$$\theta_2^{S,W} = 1 \qquad \theta_2^{S,D} = 0$$

$$\tau_2^{S,W} = 0 \qquad \tau_2^{S,D} = D_1 R_1 < \hat{\alpha}$$

Primary balance of type D in period 1:

$$\tau_1^{S,D} - g^{S,D} = \hat{\alpha} - \hat{\alpha} = 0$$

Table 3

POOLING EQUILIBRIUM

Equilibrium range:

$$D_1 R_2^P \left(R_2^P + \sqrt{(R_2^P)^2 - 1} \right) \leq \hat{\alpha} \quad \rightarrow \quad \frac{1 + \sqrt{1 - (1-p_0)^2}}{(1-p_0)^2} \leq \frac{\hat{\alpha}}{D_1}$$

Equilibrium policies:

$$R_1^{P,W} = R_1^{P,D} = 1$$

$$R_2^P = R_2^{P,W} = R_2^{P,D} = \frac{1}{(1-p_0)}$$

$$g^{P,W} = g^{P,D} = \frac{\left(1 + (R_2^P)^2\right) \ \hat{\alpha}}{R_2^2} - D_1 > \hat{\alpha}$$

$$\theta_1^{P,W} = \theta_1^{P,D} = 0$$

$$\tau_1^{P,W} = \tau_1^{P,D} = \hat{\alpha}$$

$$D_2^{P,W} = D_2^{P,D} = \frac{\hat{\alpha}}{(R_2^P)^2}$$

$$\theta_2^{P,W} = 1 \qquad \theta_2^{P,D} = 0$$

$$\tau_2^{P,W} = 0 \qquad \tau_2^{P,D} = \frac{\hat{\alpha}}{R_2^P}$$

Primary balance of type D in period 1:

$$\tau_1^{P,D} - g^{P,D} = \hat{\alpha} - \left[\frac{(1 + (R_2^P)^2)}{(R_2^P)^2} \hat{\alpha} - D_1 \right] < 0$$

Table 4

Model $RATE_t = g_0 + g_1 RATE_{t-1} + g_1 DY_{t-1} + g_1 PY_{t-1} + g_4 (DSIG*PY_{t-1}) + \varepsilon_t$ **1/**

Country (Sample in parenthesis)	Parameter Estimates (Standard Error in parenthesis) g_0	g_0 Static Long-run 2/	g_1	g_2	g_2 Static Long-run 2/	g_3	g_3 Static Long-run 2/	g_4	g_4 Static Long-run 2/	R^2	σ	Serial Corr. up to the 2nd Order $\chi^2(2)$ (p-value in parenthesis)	Normality $\chi^2(2)$ (p-value in parenthesis)
Ireland (1980: 01 - 1995: 01)	20.0 ** (7.1)	91.3 ** (6.1)	0.781 ** (0.077)	-0.060 * (0.025)	-0.274 ** (0.070)	0.204 ** (0.059)	0.930 ** (0.350)	0.481 ** (0.143)	2.197 ** (0.782)	0.949	0.949	0.530 (0.767)	1.356 (0.508)
Belgium (1980: 01 - 1995: 01)	21.8 ** (5.8)	111.2 ** (7.9)	0.804 ** (0.052)	-0.077 ** (0.024)	-0.392 ** (0.089)	0.595 ** (0.170)	3.031 ** (0.708)	0.230 * (0.093)	1.171 * (0.649)	0.960	0.783	1.101 (0.577)	4.235 (0.120)
Denmark (1980: 01 - 1992: 01)		78.1 ** (0.9)			-0.100 ** (0.015)		0.247 ** (0.058)		0.279 ** (0.079)	0.796	0.741	2.170 (0.338)	2.200 (0.333)

<u>Legend:</u> RATE = Institutional Investor rating, DY = debt-to-GDP ratio (in percent), PY = primary balance-to-GDP ratio (in percent), DSIG = one during signaling phase and zero otherwise. Signaling phases are the periods: 1982:01 - 1988:01 in Ireland, 1981:01 - 1989:01 in Belgium, and 1982:02 - 1986:01 in Denmark.

1/ Data are semi-annual. Two (**) and one (*) stars mark statistical significance respectively at the one and five percent levels.

2/ Standard errors of the static long-run estimates are those calculated by PC GIVE (see PC GIVE 8.0 Manual p. 331) using numerical differentiation.

Table 5

Model $PY_t = \gamma_0 + \gamma_1(L)PY_{t-1} + \gamma_2 DY_{t-1} + \varepsilon_t$ 1/

Country (sample in parenthesis)	Parameter Estimates (Standard Error in parenthesis)						R^2	σ	Serial Corr. up to the 3rd Order $\chi^2(3)$ (p-value in parenthesis)	Normality $\chi^2(2)$ (p-value in parenthesis)
	γ_0		γ_1		γ_2					
		Static long-run 2/	Lags			Static Long-run 2/				
Ireland (1980: 02 - 1995: 01)	-1.49 * (0.67)	-20.3 ** (7.3)	1	1.50 ** (0.13)	0.019 * (0.008)	0.260 ** (0.083)	0.992	0.403	4.764 (0.190)	3.212 (0.201)
			2	-0.58 ** (0.12)						
			SUM	0.93 ** (0.02)						
Belgium (1981: 01 - 1995: 01)	-5.21 ** (1.32)	-13.6 ** (1.3)	1	1.11 ** (0.16)	0.060 ** (0.014)	0.157 ** (0.012)	0.981	0.454	1.574 (0.666)	3.101 (0.211)
			2	-0.88 ** (0.22)						
			3	0.39 ** (0.13)						
			SUM	0.62 ** (0.09)						
Denmark (1980: 02 - 1992: 01)	-3.56 ** (1.15)	-17.5 ** (3.8)	1	1.34 ** (0.15)	0.060 ** (0.019)	0.296 ** (0.060)	0.981	0.633	3.874 (0.275)	2.518 (0.283)
			2	-0.54 ** (-0.13)						
			SUM	0.80 ** (0.05)						

<u>Legend:</u> DY = debt-to-GDP ratio (in percent), PY = primary balance-to-GDP ratio (in percent).

1/ Data are semi-annual. Two (**) and one (*) stars mark statistical significance respectively at the one and five percent levels.

2/ Standard errors of the static long-run estimates are those calculated by PC GIVE (see PC GIVE 8.0 Manual p. 331) using numerical differentiation.

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