

Structural Convergence under Reversible and Irreversible Monetary Unification*

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Abstract

We explore endogenous monetary unification in the context of a model in which a country with serious structural distortions (and, hence, high inflation) is admitted into a monetary union once its economic structure has converged sufficiently towards that of the existing participants. If unification is reversible, so that the new entrant can always be forced to leave the union again later, convergence stops for a while after the high inflation country has joined. With irreversible unification, temporary divergence occurs, and unification is most likely to be delayed.

Keywords: Monetary unification; structural distortions; inflation; convergence.

JEL: E61, E63, F33

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1. Introduction

Eleven countries formed the European Monetary Union (EMU) on January 1, 1999. There has always been skepticism in some countries, most notably Germany, about the idea of forming a monetary union with other countries that have less of a history of monetary and fiscal policy discipline (see, e.g., Buiter et al., 1993, and Deutsche Bundesbank, 1998, p. 39). As a result, certain entrance criteria were adopted for countries to be eligible for union participation. These criteria were mainly aimed at structural convergence of “less disciplined” economies towards more disciplined ones. Now that all countries, except for Greece and those that explicitly opted out, have made it into EMU, the fear exists that some of them may relax their efforts in implementing further economic reform. This fear has, for example, been evident by the adoption of the so-called Stability and Growth Pact, aimed at preventing countries from running too high deficits once EMU has started off (see also *The Economist*, 1999, p. 20).

The main objective of this paper is to address whether this fear is warranted by investigating how the incentive to conduct costly economic reform is affected by monetary unification. We consider a situation in which a country (or group of countries) with relatively minor structural economic distortions has the possibility of allowing another country (or group of countries) to join its monetary union.¹ However, this latter country is initially characterized by relatively severe economic distortions that lead to a preference for a relatively loose monetary policy. Having this “high-inflation country” join the union implies that it will acquire influence on union-wide monetary policymaking, thereby pushing up inflation for the initial union member(s). These “low-inflation countries” therefore have to weigh the costs of higher inflation against the benefits of unification when deciding on admitting the potential entrant into the union.

We consider two possible schemes for monetary unification in order to show that the answer to our question, whether countries relax their reform efforts once admitted into the union, depends on the form of unification. More specifically, we consider *reversible* unification under which the high-inflation country can always be forced to leave the union at a later date or, which amounts to the same thing, the low-inflation country (or countries) can break up the union and form a monetary union by itself. Under *irreversible* unification, in contrast, once the high-inflation country has joined, it can never be forced out.

¹Throughout the paper we deliberately refrain from focusing on a particular type of structural distortion. Examples of the types of distortions we have in mind, however (e.g., labour market inefficiencies), are provided in Section 2.

Of course, monetary arrangements can in reality never be split up at zero cost, and they are never completely set in stone. Nevertheless, a situation in which countries retain their own currencies but try to maintain a fixed exchange rate seems to correspond to reversible monetary unification, while having a centralized monetary policy with only one currency in circulation corresponds more closely to irreversible monetary unification. Thus, even though EMU is intended to be irreversible (the huge investments in, for example, setting up the European Central Bank, adjusting payments systems and adopting the new single currency are clear signals thereof), it may in principle be perceived as reversible during its early stages when the original currencies are still in circulation, and people have not yet become fully accustomed to EMU.

The model shows that structural distortions in the high-inflation country will be worse — all things equal — under monetary unification than with independent monetary policymaking. This is because the lower average union inflation rate reduces the incentive of the government of the distorted economy to conduct structural adjustment. This property of the model corroborates what, e.g., Sibert (1997), Sibert and Sutherland (1997) and Calmfors (1998) have established in related models, and it provides the starting point for our main results. They arise from the interplay between endogenous structural reform and the timing of unification under reversibility and irreversibility.

As regards to this interplay, the form of unification matters as follows. Under reversibility, the high-inflation country will at some point in time undergo a one-time adjustment so as to meet the requirement for entering the union. This entry requirement, endogenously determined by the existing union members, is formulated in terms of the level of structural distortions of the high-inflation country. After entry, structural distortions remain unchanged for a while, as further adjustment is too costly, and as structural divergence triggers exclusion from the union.

Under irreversible unification, entry into the union will also take place after a one-time adjustment. However, in contrast to reversible unification, the adjustment is followed by structural *divergence* because the threat of being excluded again is absent under irreversibility. The government of the new union member can therefore reap the gains of lower inflation without having to suffer the losses associated with structural adjustment. Because the initial union members suffer from such divergence, they are likely to impose a stricter entrance criterion under irreversible than under reversible unification. This tends to postpone irreversible unification. Indeed, numerical analyses show that under irreversibility, monetary unification is likely to take place *later* than under reversibility.

Given that EMU is intended to be irreversible, these results are consistent with the

insistence on the tight entry requirements for EMU as compared with the participation in reversible arrangements such as the Bretton Woods system or the Exchange Rate Mechanism of the European Monetary System.² As our analysis indicates, only countries that have sufficiently reformed their economies, and thus pose less of a danger for inflationary pressures in the union, can make the leap towards meeting the entry criteria. Moreover, the prediction of our model that structural divergence results, once irreversible unification has materialized, lends theoretical support to the fear mentioned earlier that, once admitted to EMU, countries may relax their efforts at structural reform. But if EMU in its early stages is perceived as being reversible, the results suggest that structural divergence may not occur initially. This could, for example, lead opponents of budgetary rules to argue that the Stability and Growth Pact is unnecessary.³ If such arguments turn out to be successful, the implication could be even further divergence once EMU is perceived as irreversible.

Recent literature related to this paper is Sibert (1997), Sibert and Sutherland (1997) and Calmfors (1998) who, as indicated above, all investigate the incentives for structural reform inside and outside a monetary union. These papers, however, do not explore the endogenous formation and timing of monetary unification (nor do they consider different types of unification). In that respect, our analysis is more closely related to Martin (1995), who examines when low-inflation countries have the incentive to admit into their monetary union a high-inflation country. In that paper, however, the severity of the structural distortions in the high-inflation country evolves exogenously. This precludes an explicit interaction between the incentives for structural economic reform and the likelihood of being admitted into the monetary union — an issue that is at the heart of our analysis.

To the best of our knowledge, only Ozkan et al. (1997) have previously considered the interplay between monetary regime formation and structural reform. Their focus, however, is very different from ours as they examine the implications of an exogenous entry condition on the inflation rate for the behavior of a potential entrant into a monetary union. Hence, they do not consider the strategic interaction between the potential entrant and the existing union members that is central to our results on the entry conditions and

²Strictly speaking, the EMU entry requirements are based on exchange rates, inflation rates, interest rates and budgetary performance (debts and deficits), rather than structural distortions. Clearly, in practice it would be difficult to apply the latter as a criterion. But as more severe structural distortions tend to lead to higher inflation, interest rates and to make it more difficult for governments to balance their budgets, the EMU requirements have at least to some extent induced governments to attack structural distortions in their economies.

³Several voices already advocate a less strict adherence to the Pact. A strong case in point is the French “resolution on employment and growth” — adopted at the Luxembourg summit, November 1997 — which is clearly intended to counterbalance the Pact (cf., Camenen and Sibout, 1998).

the timing of unification. Moreover, in their model structural reform is a one-shot event before unification occurs. Therefore, the evolution of reform after a country has entered the union is not explored in their paper.⁴

The remainder of this paper is structured as follows. The basic model is set out in Section 2. Section 3 explores monetary policy under independent monetary policymaking and under monetary unification. In Section 4 we then determine the timing of monetary unification under both reversibility and irreversibility and the associated dynamics of structural convergence. Section 5 concludes the main body of the paper. The Appendix contains some proofs.

2. The model

We consider a world of two countries (or groups of countries) labelled L and H , respectively. Country L will be referred to as the “low-inflation country,” whereas country H is the “high-inflation country.” Inflation is (relatively) high in H as a result of structural economic problems which are not present in L . The assumption that distortions are absent in L is unimportant: the key ingredient is that they are more pervasive in H than in L . Apart from differences in structural distortions the two economies are the same otherwise.

The policymakers in these countries are engaged in an infinite horizon, discrete-time game. The timing of events and policymakers’ decisions within each period are as follows. Initially, part of country H ’s structural distortions is given exogenously. Subsequently, the government in country H , GH , implements some structural policy measures which, together with the exogenous component of the distortions, summarize structural distortions for the remainder of the period. Then, on the basis of the H ’s level of structural distortions, the government of country L , GL , decides whether to admit H to form a monetary union (if H wants to; we will see, however, that this is always the case).⁵ We thus follow Martin (1995) and incorporate the choice of the monetary policy regime explicitly into the game. Thereafter, inflation expectations are formed (say, through nominal wage contracting), followed by the determination of monetary policy. Effectively, this amounts to the determination of the inflation rate. With independent monetary policymaking, monetary policy is conducted simultaneously by the central banks of L and H , CBL and CBH ,

⁴However, formulating the entry requirement in terms of (past) inflation introduces an interesting strategic role for inflation expectations, which may lead to multiple equilibria along the lines of Obstfeld (1997). This aspect does not feature in our model.

⁵In the case in which L represents a group of countries, we assume that this group already forms a monetary union. Our model could then, for example, serve as a stylized representation of the game played between the “ins” and “outs” in the context of EMU.

respectively. In the case of unification, monetary policy is conducted cooperatively by *CBL* and *CBH* or, which amounts to the same thing, by a common central bank. (This situation is reminiscent of the organization of European Central Bank's (ECB) Board, in which each country has a representative with a vote.) Finally, output is determined.

Under an alternative timing, *GL* would first announce the critical level of structural distortions for which country *H* would be allowed to join, and then *GH* would select its structural policy measures. However, as should become clear from the ensuing analysis, the problem with this set-up is that it is time inconsistent: *ex post*, *GL* may have the incentive to admit *H* under weaker conditions than it originally announced. This is the case if the entry requirement that leaves *GH* indifferent between following a policy compatible with unification and following the optimal policy outside a union is lower than that for which *GL* is indifferent between admitting or not admitting country *H*. *GH* could then reduce distortions by less than what would be needed to fulfill the announced entry requirement, and *GL* would nevertheless find it optimal to admit *H* into the union. For this reason, we feel that the timing chosen here is the more relevant one.⁶

Unification can be either reversible or irreversible. In the former case, *H* can be excluded (at zero cost) from the union whenever *GL* is dissatisfied with *GH*'s structural performance. In the latter case, however, *H* will forever stay in the union. As will become clear below, *GL*'s decision concerning the status of *H* basically weighs the benefits of monetary unification against the costs of higher average inflation as *L* "imports" some of *H*'s higher inflation, which arises from its structural problems. Therefore, once its structural problems have been overcome to a sufficient extent, *H* will be admitted into the union.

We now turn to a more detailed description of the economies. The log of output in period *t* in country *i*, y_t^i , $i = L, H$, is given as

$$\begin{aligned} y_t^H &= \pi_t^H - E_{t-1} [\pi_t^H] - \bar{y}_t, & \bar{y}_t &\geq 0, \\ y_t^L &= \pi_t^L - E_{t-1} [\pi_t^L], \end{aligned} \tag{1}$$

where π_t^i and $E_{t-1} [\pi_t^i]$, respectively, denote the actual and (rationally) expected inflation rates in country *i* ($E_{t-1} [.]$ is the expectations operator conditional on all information available up to and including period $t - 1$). By normalization, the average output level in *L* is zero, whereas average output in *H* is $-\bar{y}_t \leq 0$, reflecting the presence of relatively

⁶It is interesting to note that, when the actual decision about which countries were to be admitted into EMU was taken (Spring 1998), the entry criteria were less strictly interpreted in some cases than they were intended to be when the Maastricht Treaty was signed. In particular, the criterion on the public debt level had to be applied rather loosely. Apparently, *ex post* it was optimal, if only for political reasons, to admit all of the eleven countries that now form EMU.

serious structural distortions when compared with L . Equation (1) has the feature of conventional Lucas supply schedules where unexpectedly high inflation in country i raises its output.⁷

As mentioned, structural distortions, \bar{y}_t , have two components. One is an exogenous component which cannot be affected by policy measures. The other is an endogenous component, which is under the control of GH . For simplicity, we assume that

$$\bar{y}_t = \varphi_t + k_t, \quad (2)$$

where $\varphi_t \geq 0$ is the exogenous component of the structural distortions, while k_t is the endogenous component. When $k_t < 0$ we say that structural adjustment is taking place, i.e., GH is alleviating some of the existing structural distortions in the economy. Note that (2) implies that structural distortions are not subject to inertia, as \bar{y}_t is independent of past periods' structural policies. While this is certainly unrealistic for some kinds of structural policy, e.g., comprehensive reforms of labor-market institutions, it may be a reasonable first approximation for other types. An example is the determination of marginal tax rates, unemployment benefits, or minimum wages. These policy measures can, in principle, be changed freely from period to period. Also, it quite often happens that reforms are rolled back, for example when a new government takes office.

The exogenous component of \bar{y}_t evolves according to the following simple process:

$$\begin{aligned} \varphi_t &= (T - t) \kappa, & \text{for } t < T, & \quad \kappa > 0, \\ \varphi_t &= 0, & \text{for } t \geq T. \end{aligned} \quad (3)$$

Hence, from time T and onwards, φ_t is zero, and H has no structural distortions other than those potentially created by the policy conducted by GH . In any period before T , there will be structural distortions unless $k_t = -\varphi_t$.

One could think of φ_t as representing distortions in the goods or labor markets which gradually disappear over time in absence of public intervention (or reach a tolerable level for the policymakers). For example, monopoly power in goods markets may gradually erode through entry of new firms, or labor-market rigidities may gradually be softened by structural changes enacted by labor market participants themselves.⁸ Alternatively, φ_t could portray tax-induced distortions of various sorts causing equilibrium output to be

⁷This simple portrait of the economies enables us to highlight the strategic aspects as clearly as possible. A similar reduced-form model is applied by Alesina and Grilli (1992).

⁸When applied to the European Union, one could interpret the exogenous downward time trend in φ_t as being the result of ongoing economic integration stimulated by the Single Market Programme.

inefficiently low (see, for example, Alesina and Tabellini, 1987). Then, the gradual decline in φ_t over time could represent changes in the tax system (which reduce tax distortions) at a pace that is publicly tolerable.

The main distinction between φ_t and k_t is that structural adjustment ($k_t < 0$) implies a cost for GH whereas φ_t does not [as will be clear from its utility function (5), below]. So, setting $k_t < 0$ could capture the adoption of politically costly measures to reform goods or labor markets. In the case in which distortions arise from the tax system, structural adjustment could capture tax cuts that necessitate undesirable reductions in public spending.

It should thus be stressed that the particular sources of the structural distortions are not crucial for the results of the paper, as they would go through in any model in which structural problems of some kind cause a country to have excessive inflation relative to other countries.

We now specify the preferences of the policymakers. The governments of the two countries care about the trade-off between output and inflation. In addition, they both derive some (exogenous) net benefit b from participating in a monetary union. This net benefit lumps together the various economic advantages and disadvantages of monetary unification: for example, enhanced trade and efficiency gains due to further economic integration, savings in transactions costs and potentially more efficient (symmetric) shock stabilization, but also less effective stabilization of country-specific shocks.⁹ Furthermore, b captures potential political benefits (for example, the political prestige associated with being part of a union). We assume that $b > 0$. Of course, merging two arbitrary countries in the world into a monetary union may well result in a net loss (i.e., b would be negative). However, we assume that L and H are not an arbitrary combination of countries. Apart from the differences in structural distortions in their economies, the combination of L and H is sufficiently close to being an optimum currency area that the net benefit from unification is positive.

We assume that GL 's utility function is:

$$V_t^{GL} = \sum_{j=t}^{\infty} \beta_L^{j-t} \left(-\psi (y_j^i)^2 - (\pi_j^i)^2 \right) + \zeta^U b. \quad (4)$$

GL 's utility is decreasing in the deviations of output and inflation from their targets. The target for (the log of) output is normalized to zero, while the target for inflation corresponds to price stability. Parameter $\psi > 0$ is the relative weight at which the government trades

⁹Appendix A presents a slightly-adjusted model with international spillovers in which the benefit from monetary unification is modelled explicitly and arises from efficient stabilization of common shocks.

off the output objective against the inflation objective. Furthermore, $\zeta^U = 0$ in the case of monetary policy independence, while $\zeta^U = 1$ in the case of monetary union. Finally, $0 \leq \beta_L \leq 1$ is GL 's discount factor. A lower discount factor means that the government is more “myopic”. Such myopia may arise from a shorter expected government tenure, assuming that the government attaches more weight to the economic performance when it is in office than to what happens after it has left office.

Because it controls k_t directly and k_t affects \bar{y}_t , conform (2), GH will be able to affect average output in equilibrium. Obviously, *ceteris paribus* it would prefer to entirely offset the exogenous part of the structural distortions in the economy (thereby inducing $y_t^H = 0$). However, implementing structural reform is assumed to be politically costly. Therefore, GH 's utility is assumed to be given by:

$$V_t^{GH} = \sum_{j=t}^{\infty} \beta_H^{j-t} \left(-\psi \left(y_j^H \right)^2 - \delta k_t^2 - \left(\pi_j^H \right)^2 \right) + \zeta^U b, \quad \delta > 0, \quad (5)$$

where the quadratic term in k_t captures the costs of structural adjustment.¹⁰ GH 's discount factor is given by $0 \leq \beta_H \leq 1$.

Monetary policy is delegated to the central bankers, who share their governments' preferences concerning inflation and output. Thus, we assume that the utility of the central bank in country i is:

$$V_t^{CBi} = \sum_{j=t}^{\infty} \beta_i^{j-t} \left(-\psi \left(y_j^i \right)^2 - \left(\pi_j^i \right)^2 \right), \quad i = L, H. \quad (6)$$

The outcomes would be unaffected if we would also include b in V_t^{CBi} , $i = L, H$. Therefore, we rather arbitrarily assume that the central banks do not care about b . Because the cost of structural adjustment is borne by the government in the first place, we assume that k_t does not enter CBH 's utility function. This assumption is also without any consequences for the outcomes.

3. Monetary policy under independence and unification

We now examine, for given structural policy in H , monetary policy under two alternative regimes. First, we consider the case in which both countries conduct an independent monetary policy (indicated with superscript “ I ,” wherever relevant). Then, we investigate

¹⁰If structural distortions are interpreted as arising from taxation, V_t^{GH} resembles the loss function introduced by Alesina and Tabellini (1987), since a lower $k_t < 0$ can then be interpreted as lower public spending under a balanced budget.

the case of monetary unification (indicated with superscript “ U ,” wherever relevant).

3.1. Independent monetary policies

Under independent monetary policymaking, CBL determines π_t^L , while CBH simultaneously determines π_t^H . CBL and CBH maximize V_t^{GL} and V_t^{GH} , respectively, subject to (1) taking as given inflation expectations and (in the case of CBH) structural distortions.

The Nash equilibrium outcomes for inflation and output in both countries are

$$\pi_t^H = \psi \bar{y}_t, \quad y_t^H = -\bar{y}_t, \quad \pi_t^L = y_t^L = 0. \quad (7)$$

Whenever $\bar{y}_t > 0$, H suffers from an inflation bias (cf. Barro and Gordon, 1983). Given inflation expectations, CBH has the incentive to boost inflation in order to raise output above its natural rate, $-\bar{y}_t$. In a rational expectations equilibrium, however, the private sector anticipates this incentive and, hence, the only result is higher inflation without any systematic increase in output or employment. In country L , the natural rate of output coincides with CBL 's output target. Therefore, CBL has no incentive to loosen monetary policy and, hence, expected inflation is zero in country L .

Using (7), we can state the governments' per-period pay-offs under independent monetary policymaking. One has:

$$u^{GL,I} = 0, \quad (8)$$

$$u_t^{GH,I}(\bar{y}_t) = -\psi(1 + \psi)(\bar{y}_t)^2 - \delta(\bar{y}_t - \varphi_t)^2, \quad (9)$$

where $u^{GL,I}$ and $u_t^{GH,I}$ are, respectively, GL 's and GH 's per-period pay-offs. GH 's utility is decreasing in \bar{y}_t . More structural distortions (a higher \bar{y}_t) imply lower output and higher inflation. In addition, GH 's utility is lower the more \bar{y}_t diverges from φ_t as this corresponds to more substantial, politically costly, structural reform (i.e., a higher absolute value of k_t).

3.2. Monetary unification

Under monetary unification, countries at least fix their bilateral nominal exchange rates and possibly even use a common currency. In either case, inflation rates coincide throughout the union, and the central banks cooperate so as to determine the common inflation rate, $\pi_t = \pi_t^L = \pi_t^H$. With a common inflation rate, the supply functions (1) reduce to

$$y_t^H = \pi_t - \mathbf{E}_{t-1}[\pi_t] - \bar{y}_t, \quad y_t^L = \pi_t - \mathbf{E}_{t-1}[\pi_t]. \quad (10)$$

The disadvantage for country L of forming a monetary union with country H is that CBH gains some influence in the determination of the common monetary policy. In particular, under monetary unification, the central banks jointly maximize $V_t^L + \lambda V_t^H$, $\lambda > 0$, taking \bar{y}_t and inflation expectations as given. Parameter λ measures country H 's relative "bargaining power" in the determination of the common monetary policy.

The outcomes for inflation and output are now given by:

$$\pi_t = \frac{\psi\lambda}{1+\lambda}\bar{y}_t, \quad y_t^H = -\bar{y}_t, \quad y_t^L = 0. \quad (11)$$

Because of CBH 's influence on the common, union-wide monetary policy, country L imports some of H 's inflation bias (to an extent which, of course, is increasing in country H 's relative influence, λ , and structural distortions, \bar{y}_t). Hence, comparing monetary unification with independent monetary policymaking, inflation in L will be higher, while inflation in H will be lower, because the relative weight of CBL in the cooperative arrangement is positive.

The governments' utilities, for given structural distortions \bar{y}_t in H , are:

$$u^{GL,U}(\bar{y}_t) = -\left[\frac{\psi\lambda}{1+\lambda}\bar{y}_t\right]^2 + b, \quad (12)$$

$$u_t^{GH,U}(\bar{y}_t) = -\psi\left[1 + \frac{\psi\lambda^2}{(1+\lambda)^2}\right](\bar{y}_t)^2 - \delta(\bar{y}_t - \varphi_t)^2 + b. \quad (13)$$

A comparison of (9) and (13) shows that for given structural distortions, GH would favor monetary unification (even if $b = 0$). The first term in (13), which arises from output falling short of its target and inflation exceeding its target, is higher than the corresponding term in (9): output is the same, while inflation is lower under monetary unification. Hence, in sum, we have:

Lemma 1. For all \bar{y}_t , $u_t^{GH,U}(\bar{y}_t) > u_t^{GH,I}(\bar{y}_t)$.

A comparison of (8) and (12) reveals that in its choice whether to admit H to form a monetary union, GL weighs the benefit b against the cost of importing an inflation bias.

4. Convergence and monetary unification

4.1. Structural policy for given monetary policy regime

Now, we consider structural policy in more detail. To this end, it is helpful first to derive the optimal degree of structural reform for a given monetary policy regime. If in period t ,

GH knows that monetary policy independence will prevail, it maximizes (5) with respect to k_t subject to (7) and (2). This yields an optimal value for k_t . For convenience, however, we insert it back into (2) and express the optimal policy in terms of total structural distortions:

$$\bar{y}_t^I \equiv \frac{\delta}{\delta + \psi(1 + \psi)} (T - t) \kappa. \quad (14)$$

The natural rate, $-\bar{y}_t^I$, will for $t < T$ be too low for the taste of the policymakers, even though GH alleviates some of the market-based distortions through structural policy by setting $k_t < 0$. For our purpose, it is important to note that a more inflationary monetary policy, arising through a higher ψ , implies *fewer* structural distortions. Because GH cares about inflation and anticipates higher inflation for a given level of distortions, it has a stronger incentive to implement structural adjustment.

If the monetary policy regime is known to be one of monetary unification in period t , GH maximizes (5) with respect to k_t subject to (11) and (2). The solution is:

$$\bar{y}_t^U \equiv \frac{\delta}{\delta + \psi \left[1 + \psi \lambda^2 / (1 + \lambda)^2 \right]} (T - t) \kappa. \quad (15)$$

Comparing (14) and (15) we have

Lemma 2. *If $t < T$, $\bar{y}_t^U > \bar{y}_t^I$, i.e., total structural distortions in country H are worse under monetary unification than under an independent monetary policy.*

The intuition for Lemma 2 is that, because inflation in H is lower under monetary unification, the gain from structural reform in terms of the implied reduction in the inflation bias will be smaller than under independent monetary policymaking. A very similar result is obtained in Sibert and Sutherland (1997) and in Calmfors (1998). In Calmfors (1998), for example, governments conduct labor-market reform with the aim of reducing the equilibrium inflation bias. In a monetary union the effect of a unilateral increase in reform is smaller than the effect on inflation under independent monetary policymaking. Hence, the marginal benefit of labor-market reform is smaller inside than outside the union.¹¹

So far, we have compared structural distortions across *given* monetary regimes. In order to explore how structural distortions develop when the determination of the monetary policy regime is endogenous, we need to consider the interaction of the degree of structural reform implemented by GH with GL 's decision whether or not to admit H to join the

¹¹The result that a stricter monetary policy implies a less stringent fiscal and/or structural policy because the effect on future inflation is reduced, features in many other models though; see Jensen (1994), van der Ploeg (1995), Beetsma and Bovenberg (1997) and Beetsma and Uhlig (1999) for examples.

union. This is the objective of the remainder of this section. In Section 4.2 we assume that monetary unification is reversible, while in Section 4.3 we assume that it is irreversible.

4.2. Equilibrium structural policy and reversible monetary unification

In order to characterize a (subgame-perfect Nash) equilibrium we first state the conditions that determine whether H will be admitted to form a union or not. When unification is reversible these conditions merely involve a comparison of GL 's single-period utility under either regime for a given structural policy in H . The reason is that the regime choice in period t does not affect the state in period $t + 1$ (which is solely determined by φ_{t+1}) and, hence, does not affect structural policy in period $t + 1$. Hence, next period, “bygones are bygones” and the regime choices follow again through comparison of GL 's single-period utilities under the two alternatives.

If monetary unification is reversible, H will be admitted to form a union in period t if and only if $u^{GL,U}(\bar{y}_t) \geq u^{GL,I}$.¹² Let \bar{y}^* be the level of structural distortions in country H for which GL is indifferent between admitting and not admitting H . Hence, using (8) and (12), \bar{y}^* is implicitly defined by

$$b = \left(\frac{\lambda\psi}{1+\lambda}\bar{y}^* \right)^2. \quad (16)$$

If $0 \leq \bar{y}_t \leq \bar{y}^*$ there will be monetary unification as the gain b outweighs the loss associated with the increase in inflation in L . If $\bar{y}_t > \bar{y}^*$, independent monetary policymaking will prevail.¹³ Having established the decision rule of GL , we now turn to the determination of the equilibrium path of \bar{y}_t , and, hence, the endogenous timing of monetary unification.

First, note that given the exogenous process (3) for φ_t , it is clear that from period T and onwards there will be monetary unification because $\varphi_t = 0$, for all $t \geq T$. Irrespective of the expected monetary regime, GH then sets $k_t = 0$ for all $t \geq T$, cf. (14) and (15) and, hence, $\bar{y}_t = 0$ for all $t \geq T$. Therefore, GL loses nothing from admitting H to form a union, but gains b .

This result suggests that for sufficiently small values of φ_t also, there will be monetary unification in equilibrium. This will indeed turn out to be the case and to prove this formally, we start by characterizing the first period, say \tilde{T} , in which the choice $\bar{y}_{\tilde{T}}^U$ induces monetary unification. Because \bar{y}_t^U is falling over time, \tilde{T} is implicitly defined by

¹²Note that we assume that GL has a “marginal preference” for monetary unification, as it invites country H in the case of indifference. This, however, has no implications for our results.

¹³Because GH 's policy always implies that $\bar{y}_t \geq 0$, we ignore the negative solution for \bar{y}^* in (16).

$$\begin{aligned}\bar{y}_T^U &\leq \bar{y}^*, \\ \bar{y}_{T-j}^U &> \bar{y}^*, \quad \tilde{T} \leq T, \quad j = 1, 2, \dots\end{aligned}\tag{17}$$

We summarize the above arguments in the following proposition:

Proposition 1. *Let \tilde{T} be defined by (17). For $t \geq \tilde{T}$, there will be reversible monetary unification in equilibrium, and \bar{y}_t evolves according to $\bar{y}_t = \bar{y}_t^U$ [cf. (15)] for $\tilde{T} \leq t < T$ and is given by $\bar{y}_t = 0$ for $t \geq T$.*

Proof. See Appendix B. ■

Proposition 1 confirms that for relatively low levels of exogenous structural distortions, it is optimal for GH to conduct a structural policy that induces monetary unification. Moreover, its policy is such that total structural distortions gradually decline over time. In other words, over time there is structural convergence between the countries. There will be no period in which it is optimal for GH to conduct lax structural policies in order to reduce the utility loss from structural adjustment. Because φ_t is relatively small, structural measures are relatively limited in any case, while the losses for H (in terms of higher average inflation and not receiving b) from being excluded from the monetary union are too large.

We show now that if φ_t is sufficiently large, it is too costly for GH to reduce total distortions to a level that induces monetary unification. Denote by $T^{ru} - 1$ the last period t such that $\bar{y}_t^I > \bar{y}^*$ in equilibrium induces independent monetary policymaking. However, to characterize $T^{ru} - 1$ formally we need to know the properties of the equilibrium in period T^{ru} . For the moment, assume that in period T^{ru} the equilibrium features a structural policy such that $\bar{y}_{T^{ru}} = \bar{y}^*$, thereby leading to monetary unification. This assumption — which will be validated as a fact below — implies that $T^{ru} - 1$ is defined by

$$\begin{aligned}u_{T^{ru}-1-j}^{GH,I}(\bar{y}_{T^{ru}-j-1}^I) &> u_{T^{ru}-j-1}^{GH,U}(\bar{y}^*), \\ u_{T^{ru}}^{GH,I}(\bar{y}_{T^{ru}}^I) &\leq u_{T^{ru}}^{GH,U}(\bar{y}^*), \quad j = 0, 1, 2, \dots\end{aligned}\tag{18}$$

Note that by Lemma 1, $\bar{y}_{T^{ru}-1}^I \geq \bar{y}^*$. The following proposition characterizes the equilibrium for periods up to and including $T^{ru} - 1$:

Proposition 2. *Assume that the equilibrium in period T^{ru} is characterized by $\bar{y}_{T^{ru}} = \bar{y}^*$. Then, for $t \leq T^{ru} - 1$, there will be no monetary unification in equilibrium, and \bar{y}_t evolves according to $\bar{y}_t = \bar{y}_t^I$, cf. (14).*

Proof. See Appendix C. ■

Hence, Proposition 2 shows that as long as the exogenous component of the structural distortion is relatively large, the amount of structural adjustment needed to induce monetary unification is too costly for GH . Structural convergence in the direction of L 's zero level of distortions does take place, but not within the context of monetary unification.

The question now is what will happen in periods $T^{ru} \leq t < \tilde{T}$?¹⁴ Will there be monetary unification or independent monetary policymaking and how will structural distortions evolve? In the proof of Proposition 2 we conjectured that the equilibrium in period T^{ru} will be characterized by $\bar{y}_t = \bar{y}^*$ and monetary unification. We now show that this is indeed the case, not only for period T^{ru} , but actually for all of the periods $T^{ru}, \dots, \tilde{T} - 1$. To obtain some intuition for this result, it is helpful to consider what is *not* equilibrium behavior. For example, it is suboptimal for GH to follow (15) for $t < \tilde{T}$. This would imply a policy in anticipation of monetary unification, but is characterized by $\bar{y}_t > \bar{y}^*$, cf. (17). Therefore, GL would not admit H . Similarly, it is suboptimal for GH to follow (14) for $t = T^{ru}$ as it follows from (18) that GH could obtain a higher utility from merely delivering \bar{y}^* and inducing monetary unification. Hence, the equilibrium structural policy in period $t = T^{ru}$ will neither be given by (15), nor by (14). Instead, we have the following result for all $T^{ru} \leq t < \tilde{T}$:

Proposition 3. *For all $T^{ru} \leq t < \tilde{T} \leq T$ there will be monetary unification in equilibrium, and \bar{y}_t “evolves” according to $\bar{y}_t = \bar{y}^*$.*

Proof. See Appendix D. ■

Figure 1 around here

Combining Propositions 1-3 we can now summarize the process of monetary unification as well as the associated equilibrium path of \bar{y}_t . Figure 1 provides a graphical representation. Before T^{ru} , there will be independent monetary policymaking, as H 's level of structural distortions has not converged sufficiently towards that of L . But although H has not been allowed into the union, its economy is still undergoing structural reform, cf. Proposition 2. Going from period $T^{ru} - 1$ to period T^{ru} exogenous structural distortions have become sufficiently small that it is optimal for GH to make a rapid one-time adjustment so as to reap the gains from monetary unification. However, from then on further

¹⁴Note that we cannot be sure that this set is non-empty. For example, if κ is a sufficiently large number, it could be the case that $\tilde{T} = T$ and $T^{ru} = T - 1$ implying monetary unification for $t \geq T$ and independent monetary policymaking for $t < T$. We assume, however, that κ is sufficiently small that $T^{ru} < \tilde{T} - 1$.

structural convergence is delayed for a while: further adjustment is relatively costly and does not provide sufficient benefits in terms of reduced inflation and higher output. Divergence, however, is costly too as it implies exclusion from the monetary union. Hence, GH selects its degree of structural reform to be just sufficient to make sure that H is not forced to leave the union. As a result, cf. Proposition 3, further convergence is delayed until \tilde{T} . Convergence resumes at \tilde{T} and continues until T , when it is complete, cf. Proposition 1.¹⁵

4.3. Equilibrium structural policy and irreversible monetary unification

The characterization of the equilibrium under irreversible monetary unification is not as simple as in the case of reversible unification. The reason is that admitting H into the union now precludes the possibility of making a different choice in the future. Hence, a simple time-invariant decision rule as derived from (16) no longer suffices as a guidance for GL .

In order to limit our attention to subgame-perfect strategies, we solve the model through backward induction. First, we consider the periods $t \geq T$, for which $\varphi_t = 0$. Suppose that the equilibrium in period $T + 1$ will be characterized by monetary unification, even if the alternative of monetary independence is still available by then. We show that this implies that the equilibrium in period T is characterized by monetary unification. GH 's dominant strategy is to set $\bar{y}_T = 0$. If period $T - 1$ was already characterized by monetary unification, then so will period T be. If period $T - 1$ was characterized by monetary independence and because monetary unification will prevail in period $T + 1$, by assumption, GL only needs to compare the single-period utilities under the two alternatives. By (8) and (12), $u_t^{GL,U}(0) \geq u^{GL,I}$. Hence, irrespective of the regime in period $T - 1$, it is optimal for GL to admit H to form a union.¹⁶ The same argument applies for any period $t > T$.

Now we consider the periods $\tilde{T} \leq t < T$, with \tilde{T} defined by (17). Again, with the discussion of the previous subsection in mind, it seems natural to conjecture a subgame-perfect Nash equilibrium characterized by monetary unification and $\bar{y}_t = \bar{y}_t^U$, just as in the case of reversible unification. In fact, this conjecture turns out to be correct. To see this, consider first whether it pays for GL to deviate from the prescribed strategy. In period

¹⁵It should now be clear that the assumption about GL having a ‘‘marginal preference’’ for monetary unification is inessential (as claimed in Footnote 12). Had we assumed a ‘‘marginal preference’’ for monetary independence, then in periods $T^{ru} \leq t < \tilde{T}$ government GH would conduct a policy $\bar{y}_t = \bar{y}^* - \xi$, with $\xi > 0$ arbitrarily small, so as to induce monetary unification. Hence, the only difference would be that \bar{y}_t in Proposition 3 should be replaced with $\bar{y}_t = \bar{y}^* - \xi$.

¹⁶Note that we explicitly consider optimal behavior also in response to out-of-equilibrium events to ensure subgame perfection.

$T-1 \geq \tilde{T}$ there is only a regime choice if there was monetary independence in period $T-2$; because there is monetary unification as of T , GL again only needs to compare the single-period utilities under the two alternatives, given $\bar{y}_{T-1} = \bar{y}_{T-1}^U$. However, $\bar{y}_{T-1}^U \leq \bar{y}_{\tilde{T}}^U \leq \bar{y}^*$. Hence, $u^{GL,U}(\bar{y}_{T-1}^U) \geq u^{GL,I}$ and, hence, it is optimal for GL to admit H . The same type of argument applies for any period t , $\tilde{T} \leq t < T$. Also, by the arguments of the previous subsection, GH would never deviate from proposed equilibrium: choosing \bar{y}_t^U when monetary unification is expected is optimal.

The next proposition summarizes the equilibrium path as of period \tilde{T} and onwards:

Proposition 4. *There exists a subgame-perfect Nash equilibrium for which there is irreversible monetary unification as of period \tilde{T} , with \bar{y}_t evolving according to $\bar{y}_t = \bar{y}_t^U$ [cf. (15)] for $\tilde{T} \leq t < T$ and $\bar{y}_t = 0$ for $t \geq T$.*

Hence, from \tilde{T} and onwards, equilibrium structural distortions coincide with those under reversible monetary unification; cf. Proposition 1. This is not surprising, because after period \tilde{T} economies have converged sufficiently that the question about monetary independence or monetary unification is trivial.

Now, we turn to the periods $t < \tilde{T}$, for which we will see that equilibrium behavior differs markedly from that in the case of reversible monetary unification. Before characterizing equilibrium behavior in periods before \tilde{T} , we need to introduce some additional notation. Let $j \geq 1$. Denote by $U_{\tilde{T}-j} (I_{\tilde{T}-j})$ the situation of monetary unification (monetary independence) at the end of period $\tilde{T}-j$. Denote by $W_{I,\tilde{T}-j}^i (W_{U,\tilde{T}-j}^i)$ the discounted sum of equilibrium utility flows at the start of $\tilde{T}-j$ for i ($i = GL, GH$) up to and including period $\tilde{T}-1$ if $I_{\tilde{T}-j-1} (U_{\tilde{T}-j-1})$ describes the relevant state.

Define $\bar{y}_{\tilde{T}-j}^* \geq 0$ as the level of structural distortions (if it exists) that leaves GL indifferent between admitting and not admitting country H to form the monetary union. Hence, for $j > 1$, $\bar{y}_{\tilde{T}-j}^*$ is the solution to

$$u^{GL,U}(\bar{y}_{\tilde{T}-j}^*) + \beta_L W_{U,\tilde{T}-j+1}^{GL} = u^{GL,I} + \beta_L W_{I,\tilde{T}-j+1}^{GL}. \quad (19)$$

If (19) does not have a solution $\bar{y}_{\tilde{T}-j}^* \geq 0$, we follow the convention of setting $\bar{y}_{\tilde{T}-j}^* = 0$.¹⁷ Then note that because monetary unification will always occur in \tilde{T} , $\bar{y}_{\tilde{T}-1}^*$ is the solution to

$$u^{GL,U}(\bar{y}_{\tilde{T}-1}^*) = u^{GL,I}.$$

¹⁷Hence, $\bar{y}_{\tilde{T}-j}^* = 0$ includes all the cases in which there is no possibility for GH to choose structural distortions in such a way that it will be admitted to form a union (remember that total structural distortions are bounded from below at zero).

Hence, $\bar{y}_{\tilde{T}-1}^* = \bar{y}^*$. Furthermore, because it can be shown that $W_{I,\tilde{T}-j+1}^{GL} \geq W_{U,\tilde{T}-j+1}^{GL}$,¹⁸ it follows from (19) that $\bar{y}_{\tilde{T}-j}^* \leq \bar{y}^*$ for $j > 1$.

We can now characterize a subgame-perfect equilibrium for $t \leq \tilde{T} - 1$:

Lemma 3. *For $j \geq 0$ the following strategies characterize a subgame-perfect equilibrium:*

GH plays:

If $U_{\tilde{T}-j-1}$, it sets $\bar{y}_{\tilde{T}-j} = \bar{y}_{\tilde{T}-j}^U$.

If $I_{\tilde{T}-j-1}$, it sets

$$\begin{aligned} \bar{y}_{\tilde{T}-j} &= \bar{y}_{\tilde{T}-j}^L, \text{ if } \bar{y}_{\tilde{T}-j}^* = 0, \\ \bar{y}_{\tilde{T}-j} &= \operatorname{argmax} \left[u^{GH,I} \left(\bar{y}_{\tilde{T}-j}^L \right) + \beta_H W_{I,\tilde{T}-j+1}^{GH}, \quad u^{GH,U} \left(\bar{y}_{\tilde{T}-j}^* \right) + \beta_H W_{U,\tilde{T}-j+1}^{GH} \right], \\ &\quad \text{if } \bar{y}_{\tilde{T}-j}^* > 0. \end{aligned}$$

GL plays:

If $U_{\tilde{T}-j-1}$, then it “selects” $U_{\tilde{T}-j}$.

If $I_{\tilde{T}-j-1}$, then it selects:

$I_{\tilde{T}-j}$, if $\bar{y}_{\tilde{T}-j}^ = 0$ or if $\bar{y}_{\tilde{T}-j} > \bar{y}_{\tilde{T}-j}^* > 0$,*

$U_{\tilde{T}-j}$, if $\bar{y}_{\tilde{T}-j} \leq \bar{y}_{\tilde{T}-j}^$ and $\bar{y}_{\tilde{T}-j}^* > 0$.*

Proof. See Appendix E. ■

The equilibrium is characterized by working back in time and checking the relevant conditions in Lemma 3, so as to determine the date when irreversible monetary unification takes place. To be more precise, we will establish that, for $j \geq 1$, $\bar{y}_{\tilde{T}-j-1}^* < \bar{y}_{\tilde{T}-j}^*$, if $\bar{y}_{\tilde{T}-j}^* > 0$. Before doing this, note that, if $\bar{y}_{\tilde{T}-j}^* > 0$, one can write $W_{I,\tilde{T}-j}^{GL} = u^{GL,U} \left(\bar{y}_{\tilde{T}-j}^* \right) + \beta_L W_{U,\tilde{T}-j+1}^{GL}$. To see this, realize that $W_{I,\tilde{T}-j}^{GL}$ is the discounted utility assuming that both players subsequently act optimally, *given* each other’s strategy. Hence, *GL* will subsequently admit country *H* only if $\bar{y}_{\tilde{T}-j} \leq \bar{y}_{\tilde{T}-j}^*$. *GH*, knowing that *GL* follows this policy, either sets $\bar{y}_{\tilde{T}-j} = \bar{y}_{\tilde{T}-j}^*$ or $\bar{y}_{\tilde{T}-j} = \bar{y}_{\tilde{T}-j}^L$; cf. Lemma 3. In both cases, by definition of $\bar{y}_{\tilde{T}-j}^*$, (19), *GL*’s utility is given by

$$\begin{aligned} W_{I,\tilde{T}-j}^{GL} &= u^{GL,U} \left(\bar{y}_{\tilde{T}-j}^* \right) + \beta_L W_{U,\tilde{T}-j+1}^{GL} \\ &= u^{GL,I} + \beta_L W_{I,\tilde{T}-j+1}^{GL}, \quad j \geq 1. \end{aligned} \tag{20}$$

¹⁸Here is a sketch of the proof. Note that, if $I_{\tilde{T}-j}$, the equilibrium outcome for $\bar{y}_{\tilde{T}-j+1}$ equals $\bar{y}_{\tilde{T}-j+1}^*$ or $\bar{y}_{\tilde{T}-j+1}^L$. In either case, it is less than the equilibrium outcome $\bar{y}_{\tilde{T}-j+1}^U$ if $U_{\tilde{T}-j}$. Hence, *GL*’s utility flow for period $\tilde{T} - j + 1$ under $I_{\tilde{T}-j}$ is at least as high as under $U_{\tilde{T}-j}$. *GL* always has the *possibility* to invite *H* to form a union on the basis of the outcome for $\bar{y}_{\tilde{T}-j+1}$ if $I_{\tilde{T}-j}$. If it does so, then the discounted sum of utility flows from $\tilde{T} - j + 2$ and onwards equals that under $U_{\tilde{T}-j}$.

Expand the left-hand side of (19), forward equation (20) by one period and substitute the result into the right-hand side of (19), which then becomes:

$$u^{GL,U}(\bar{y}_{\tilde{T}-j}^*) + \beta_L u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^U) + \beta_L^2 W_{U,\tilde{T}-j+2}^{GL} = u^{GL,I} + \beta_L u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^*) + \beta_L^2 W_{U,\tilde{T}-j+2}^{GL},$$

or

$$u^{GL,U}(\bar{y}_{\tilde{T}-j}^*) + \beta_L u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^U) = u^{GL,I} + \beta_L u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^*), \quad j \geq 2. \quad (21)$$

Using (21), we can establish:

Lemma 4. For $j \geq 2$, $\bar{y}_{\tilde{T}-j}^* < \bar{y}_{\tilde{T}-j+1}^*$, if $\bar{y}_{\tilde{T}-j+1}^* > 0$.

Proof. See Appendix F. ■

Lemma 4 indicates that the condition that GL imposes in order for H to be admitted becomes stricter the further we move back in time.¹⁹ The reason is that once H is in the union, GH has no incentive to implement sufficient structural reform, because it is no longer disciplined by the prospect of being excluded from the union in the next period(s). This disciplining force was what deterred GH from structural divergence under reversible unification. Instead, under irreversible unification GH can “switch to” $\bar{y}_t^U > \bar{y}_t^*$ without fear of being excluded from the union, cf. Lemma 3. This is precisely what relatively disciplined countries in Europe fear now that monetary unification has become a reality: once in, traditionally less-disciplined countries no longer have an incentive to follow disciplined policies. We summarize this result in the following proposition, whose proof is trivial by now:

Proposition 5. Suppose that irreversible monetary unification takes place at $\tilde{T} - 2$ or earlier. The period immediately after is characterized by structural divergence.

The result of Proposition 5 is illustrated in Figure 2, which shows how structural distortions evolve over time both for irreversible and reversible monetary unification. Under irreversibility, the period in which monetary unification takes place, T^{iu} , is characterized by a fall in structural distortions. This reduction in distortions is then followed by an increase in structural distortions in the following period. Subsequently, distortions fall monotonically over time, but remain higher than under reversibility until period \tilde{T} is reached. Note that irreversible unification occurs *later* than reversible unification, which is what

¹⁹Only for $\beta_L = 1$, we have been able to show formally that $\bar{y}_{\tilde{T}-j+1}^* = 0$ implies $\bar{y}_{\tilde{T}-j}^* = 0$ ($j \geq 2$). The proof is given in Appendix G.

one would also generally expect as the entrance requirement is stricter under irreversible unification.

Figure 2 around here

To see whether this finding is robust, we resort to numerical analysis. Table 1 gives, for a selection of parameter combinations, T^{ru} , T^{iu} , and \tilde{T} as well as the entry requirements \bar{y}^* and $\bar{y}_{T^{iu}}^*$ under, respectively, reversible and irreversible unification. The baseline parameter combination is $\lambda = 1$, $\psi = 2$, $\delta = 1$, $\kappa = 0.15$, $\beta_L = \beta_H = 0.9$, $b = 0.2$ and $T = 100$. Rather arbitrarily, the first period in the computations is set at $t = 1$. In each of the cases reported in Table 1, we vary one of the parameters, while keeping all the others at their baseline values. It turns out that in all but one of the reported cases, monetary unification *does* occur later under irreversibility than under reversibility (i.e., $T^{iu} > T^{ru}$). Moreover, irreversible unification always takes place before $\tilde{T} - 1$. Hence, the pattern of structural distortions exhibited in Figure 2 is representative for all except one of the parameter combinations considered in Table 1 (this is the case of $\beta_L = 0$, which is discussed below).

To further check the robustness of these results, we compute the same figures for the entire set of parameter combinations formed by the cartesian product of $\lambda \in \{0.5, 1, 2\}$, $\psi \in \{1, 2, 4\}$, $\delta \in \{0.5, 1, 2\}$, $\beta_L \in \{0, 0.5, 0.9, 1\}$, $\beta_H \in \{0, 0.5, 0.9, 1\}$ and $b \in \{0.1, 0.2, 0.4\}$, a total of 1296 combinations, covering a wide range within the relevant part of the parameter space. In virtually all of the cases, $T^{iu} < \tilde{T} - 1$, implying that structural divergence is likely to occur in the short run after unification has taken place.

An increase in either λ or ψ has two effects working in opposite directions. A higher λ gives country H a larger influence in the determination of the common monetary policy and would lead to higher inflation, *ceteris paribus*. Similarly, an increase in the cost ψ of output being different from its natural rate raises inflation. The higher inflation induces country L to tighten the entrance requirement, which delays unification. However, higher inflation also gives country H an incentive to speed up reform. The overall effect of an increase in λ or ψ on the timing of unification is therefore ambiguous. An increase in δ implies that reform becomes more costly for GH , thereby delaying both reversible and irreversible monetary unification.

The effects of varying the players' discount factors are intricate. Note that the entry requirement and, thus, the timing of reversible unification is independent of variations in the discount factors as both GH and GL under reversibility take decisions on a period-by-period basis. In the extreme case with $\beta_L = \beta_H = 0$ (not reported), $\bar{y}_{T^{ru}}^* = \dots = \bar{y}_{\tilde{T}-1}^* = \bar{y}^*$

Table 1. WHEN DOES UNIFICATION OCCUR?

Deviations from baseline	T^{ru}	T^{iu}	\tilde{T}	\bar{y}^*	$\bar{y}_{T^{iu}}^*$
None	64	85	89	0.45	0.32
$\lambda = 2$	73	86	90	0.34	0.19
$\psi = 1$	72	83	87	0.89	0.53
$\psi = 4$	42	83	87	0.22	0.13
$\delta = 0.5$	31	74	80	0.45	0.15
$\delta = 2$	80	90	93	0.45	0.31
$\beta_L = 0$	64	1	89	0.45	0.45
$\beta_L = 0.5$	64	82	89	0.45	0.19
$\beta_L = 1.0$	64	85	89	0.45	0.29
$\beta_H = 0$	64	85	89	0.45	0.32
$\beta_H = 0.5$	64	85	89	0.45	0.32
$\beta_H = 1.0$	14	35	39	0.45	0.32
$b = 0.1$	75	89	92	0.32	0.23
$b = 0.4$	49	79	84	0.63	0.35

[this follows by the proof of Lemma 4; cf. (F.2)], and the moments at which irreversible and reversible unification take place coincide. Since neither player attaches any value to what happens in future periods, GL decides whether to admit H or not, and GH whether to “trigger” an invitation or not, exclusively on grounds of current structural distortions, i.e., just as under reversible unification.

When only GL is extremely myopic, while GH is not (i.e., $\beta_L = 0$ and $\beta_H > 0$), irreversible unification may actually happen *earlier* than reversible unification. The reason is that GL 's myopia makes it possible for H to enter a union on the same terms under irreversibility as under reversibility. Not surprisingly, H will then enter earlier as that involves a number of periods during which GH can act according to its best strategy under monetary unification, \bar{y}_t^U . This contrasts with reversible unification, where GH needs to keep distortions at \bar{y}^* for some time after entry. In the more reasonable cases in which GL is not extremely myopic, however, the entry requirement under irreversibility is stricter in anticipation of structural divergence, and unification takes place later than under reversibility. An increase in β_L tends to slow down unification, because GL 's disutility arising from future structural divergence in country H weighs more heavily, while an increase in β_H tends to speed up unification, because GH 's future benefits arising from a current one-time adjustment to get into the union weigh more heavily.²⁰

²⁰From Table 1, it seems that changes in β_H have no effect on T^{iu} . This is due to an integer constraint. For many other parameter combinations that are not reported in Table 1 we see that an increase in β_H speeds up unification, while the opposite never happens.

5. Summary and conclusions

Many fear that, now that they have made it into EMU, some countries might relax their efforts to follow disciplined fiscal and structural policies. Such developments would inhibit the independence of the ECB and potentially put it under pressure to relax monetary policy. In this paper we have explored this issue in a model in which monetary unification is endogenously determined and conditional upon sufficient structural convergence. Our analysis predicts that structural policies will be relaxed again once irreversible monetary unification has taken place. This leads monetary unification to take place later than would be the case under reversible unification. Knowing how costly it will be to change monetary arrangements once EMU had taken off, the insistence on structural convergence for countries to be eligible for EMU participation should not be surprising.

For clarity we have kept our model as simple as possible. However, a number of extensions would be worthwhile to investigate. First, we assumed that the exogenous component of structural distortions followed a downward sloping trend. If, instead, this component follows some autoregressive stochastic process, a reversible monetary union may be broken up in the future. For example, various (economic as well as political) shocks could at some point make it too costly to maintain a structural policy that is compatible with unification.²¹ Under irreversibility, one would expect such an autoregressive process to induce the low-inflation country to impose a tighter entrance criterion (to lower the chance of being stuck in the union with a country hit by persistent, bad structural shocks).

A second extension is to allow the benefits from unification to depend on the type of unification. If the benefits under irreversibility were larger than under reversibility (for example due to the complete elimination of any exchange rate risk) then this would tend to speed up irreversible unification relative to reversible unification.

Finally, the bargaining position of the high-inflation country in the formulation of monetary policy could be imagined to depend upon the type of unification. It would seem natural that the implicit threat of being excluded at a future date under reversible unification would weaken its position relative to the case of irreversibility. But this would just reinforce our result that under irreversibility, unification is likely to occur later than under reversibility (because the entry requirement is likely to be tightened further under irreversibility).

²¹Such a scenario could fit well with some countries' deliberate decision to leave the Exchange Rate Mechanism of the European Monetary System in the early 1990s. The costs of maintaining a policy stance compatible with participation apparently became too high.

Appendix

A. Benefits of unification through efficient shock stabilization

In this appendix we present a model in which there are benefits from monetary unification arising from efficiency gains in terms of shock stabilization. The output schedules, (1), are replaced with

$$\begin{aligned} y_t^H &= \pi_t^H - \mathbb{E}_{t-1} [\pi_t^H] - \alpha (\pi_t^L - \mathbb{E}_{t-1} [\pi_t^L]) - \bar{y}_t - \epsilon_t, & 0 < \alpha < 1, \\ y_t^L &= \pi_t^L - \mathbb{E}_{t-1} [\pi_t^L] - \alpha (\pi_t^H - \mathbb{E}_{t-1} [\pi_t^H]) - \epsilon_t, \end{aligned} \quad (\text{A.1})$$

where ϵ_t is an i.i.d. supply shock with $\mathbb{E}_{t-1} [\epsilon_t] = 0$ and $\mathbb{E}_{t-1} [\epsilon_t^2] = \sigma_\epsilon^2$. There are international spill-overs, because an unexpected increase in inflation in country i lowers i 's real wage rate relative to j 's real wage ($j \neq i$) and, hence, causes a diversion of economic activity from j ($j \neq i$) to i (cf. Martin, 1995).²² Both countries are hit by a common supply-shock ϵ_t . We could also allow for country-specific shocks, but the results would be qualitatively unaffected if their variance is not too large compared with the variance of ϵ_t . As in the main text, we assume that L and H are not two arbitrary countries, but two countries that could, in principle, form a monetary union were it not for differences in structural distortions.

The utilities of GL and GH are now given by the expectations of (4) and (5), respectively, conditional on period $t - 1$ information and with $b = 0$, while the utilities of the central banks are now given by the expectation of the right-hand side of (6), conditional on period $t - 1$ information.

The outcomes for inflation and output under monetary policy independence are now given by

$$\begin{aligned} \pi_t^H &= \psi \bar{y}_t + \mu^I \epsilon_t, & \pi_t^L &= \mu^I \epsilon_t, \\ y_t^H &= -\bar{y}_t - [1 - (1 - \alpha) \mu^I] \epsilon_t, & y_t^L &= -[1 - (1 - \alpha) \mu^I] \epsilon_t, \end{aligned}$$

where $\mu^I \equiv \psi [1 + \psi (1 + \alpha)] / \Lambda$, $\Lambda \equiv (1 + \psi)^2 - \psi^2 \alpha^2 > 0$, and GL 's and GH 's per-period pay-offs consequently become, respectively,

$$\begin{aligned} u^{GL,I} &= -\Omega^I \sigma_\epsilon^2, \\ u_t^{GH,I} (\bar{y}_t) &= -\psi (1 + \psi) (\bar{y}_t)^2 - \Omega^I \sigma_\epsilon^2 - \delta (\bar{y}_t - \varphi_t)^2, \end{aligned}$$

²²These spill-overs are ignored in the main text, as they would, qualitatively speaking, have no effect on the results. They are important, however, in the presence of supply-shocks as will become clear.

with $\Omega^I \equiv \psi(1 + \psi)[1 + \psi(1 + \alpha)]^2 / \Lambda^2 > 0$.

Under monetary unification, the outcomes for inflation and output are

$$\begin{aligned}\pi_t &= \frac{\psi\lambda(1 - \alpha)}{1 + \lambda}\bar{y}_t + \mu^U \epsilon_t, \\ y_t^H &= -\bar{y}_t - [1 - (1 - \alpha)\mu^U] \epsilon_t, \quad y_t^L = -[1 - (1 - \alpha)\mu^U] \epsilon_t,\end{aligned}$$

where $\mu^U \equiv \psi(1 - \alpha) / [1 + \psi(1 - \alpha)^2]$, leading to the following per-period pay-offs:

$$\begin{aligned}u^{GL,U}(\bar{y}_t) &= -\left[\frac{\psi\lambda(1 - \alpha)}{1 + \lambda}\bar{y}_t\right]^2 - \Omega^U \sigma_\epsilon^2, \\ u_t^{GH,U}(\bar{y}_t) &= -\psi\left[1 + \frac{\psi\lambda^2(1 - \alpha)^2}{(1 + \lambda)^2}\right](\bar{y}_t)^2 - \Omega^U \sigma_\epsilon^2 - \delta(\bar{y}_t - \varphi_t)^2,\end{aligned}$$

with $\Omega^U \equiv \psi / (1 + \psi(1 - \alpha)^2)$. Under independent monetary policymaking, each of the central banks neglects the negative externality on the other country of its own response to shocks. As a result, the countries' responses to disturbances are too active. These externalities, however, are internalized under monetary unification, thereby leading to an efficient trade-off between output and inflation variability. More specifically, it is easy to verify that $\Omega^U < \Omega^I$, which demonstrates that the utility loss from supply shock variability is smallest under monetary unification.

B. Proof of Proposition 1

By the definition of \tilde{T} , (17), $\bar{y}_t^U \leq \bar{y}^*$, for all $t \geq \tilde{T}$ and, hence, for all $t \geq \tilde{T}$, it is optimal for GL to admit country H . Now, consider GH 's incentives for all $t \geq \tilde{T}$. Any deviation $\bar{y}_t = \bar{y}_t^d < \bar{y}_t^U$ is suboptimal: it does not lead to a change in the monetary regime, and \bar{y}_t^U is optimal under monetary unification, cf. (15). Any deviation $\bar{y}_t^U < \bar{y}_t^d \leq \bar{y}^*$ is suboptimal for the same reason. Finally, consider a deviation $\bar{y}_t^d > \bar{y}^*$. This induces independent monetary policymaking. By Lemma 1, $u_t^{GH,U}(\bar{y}_t^d) > u_t^{GH,I}(\bar{y}_t^d)$. Because \bar{y}_t^U is the optimal level of distortions under monetary unification, $u_t^{GH,U}(\bar{y}_t^U) \geq u_t^{GH,U}(\bar{y}_t^d) > u_t^{GH,I}(\bar{y}_t^d)$. Hence, \bar{y}_t^U is preferred to any $\bar{y}_t^d > \bar{y}^*$.

C. Proof of Proposition 2

Suppose that for all $t < T^{ru}$, $\bar{y}_t = \bar{y}_t^I$. Then, because $\bar{y}_{T^{ru}-1}^I \geq \bar{y}^*$ and because \bar{y}_t^I is decreasing over time, it is suboptimal for GL to admit country H to join the union if $t < T^{ru}$. Now, consider GH 's incentives to deviate from $\bar{y}_t = \bar{y}_t^I$ for all $t < T^{ru}$. A

deviation $\bar{y}_t^d > \bar{y}_t^I$ is suboptimal as it will not induce a different monetary regime, while under monetary independence, \bar{y}_t^I is optimal, cf. (14). A deviation $\bar{y}^* < \bar{y}_t^d < \bar{y}_t^I$ is ruled out by a similar argument. Finally, consider a deviation $\bar{y}_t^d \leq \bar{y}^*$. Although this induces monetary unification, it is suboptimal because $u_t^{GH,I}(\bar{y}_t^d) > u_t^{GH,U}(\bar{y}^*)$ [by (18)] and $u_t^{GH,U}(\bar{y}^*) \geq u_t^{GH,U}(\bar{y}_t^d)$. The latter follows because $u_t^{GH,U}$ is strictly concave with a unique maximum at \bar{y}_t^U , $\bar{y}_t^U > \bar{y}_t^I \geq \bar{y}^*$, for all $t < T^{ru}$.

D. Proof of Proposition 3

Given that $\bar{y}_t = \bar{y}^*$ and given GL 's decision rule, it is optimal to admit country H to join the union. Now consider GH 's incentives for all $T^{ru} \leq t < \tilde{T}$. A deviation $\bar{y}_t^d < \bar{y}^*$ is clearly suboptimal: it does not lead to a change in the monetary regime and because $\bar{y}^* < \bar{y}_t^U$ ($t < \tilde{T}$), $u_t^{GH,U}(\bar{y}_t^d) < u_t^{GH,U}(\bar{y}^*)$ because $u_t^{GH,U}$ is strictly concave with a unique maximum at $\bar{y}_t^U > \bar{y}^*$. Now, consider a deviation $\bar{y}_t^d > \bar{y}^*$, thereby inducing independent monetary policymaking. We can rule this out as follows. First, consider the case in which $\bar{y}_t^I > \bar{y}^*$. Clearly, the optimal deviation is $y_t^d = \bar{y}_t^I$. Because $u_{T^{ru}}^{GH,I}(\bar{y}_{T^{ru}}^I) \leq u_{T^{ru}}^{GH,U}(\bar{y}^*)$, this deviation is ruled out if $\partial [u_t^{GH,I}(\bar{y}_t^I) - u_t^{GH,U}(\bar{y}^*)] / \partial t < 0$. We have

$$\begin{aligned} \partial u_t^{GH,I}(\bar{y}_t^I) / \partial t &= [-2\psi(\bar{y}_t^I) - 2\delta(\bar{y}_t^I - (T-t)\kappa) - 2\psi^2\bar{y}_t^I] (\partial \bar{y}_t^I / \partial t) \\ &\quad - 2\delta(\bar{y}_t^I - (T-t)\kappa)\kappa, \end{aligned}$$

which by use of (14) reduces to $\partial u_t^{GH,I}(\bar{y}_t^I) / \partial t = -2\delta[\bar{y}_t^I - (T-t)\kappa]\kappa$. Furthermore, we have $\partial u_t^{GH,U}(\bar{y}^*) / \partial t = -2\delta[\bar{y}^* - (T-t)\kappa]\kappa$. Hence, $\partial [u_t^{GH,I}(\bar{y}_t^I) - u_t^{GH,U}(\bar{y}^*)] / \partial t = 2\delta(\bar{y}^* - \bar{y}_t^I)$, which is negative (as required) because $\bar{y}_t^I > \bar{y}_t = \bar{y}^*$. Finally, consider the deviation $\bar{y}_t^d > \bar{y}^*$ when $\bar{y}_t^I < \bar{y}^*$. Because $\partial u_t^{GH,I}(\bar{y}_t^d) / \partial \bar{y}_t^d < 0$ if $\bar{y}_t^I < \bar{y}^*$, the optimal deviation is $\bar{y}_t^d = \bar{y}^* + \xi$, where $\xi > 0$ is arbitrarily small. However, this deviation is suboptimal as Lemma 1 implies that $u_t^{GH,U}(\bar{y}^*) > u_t^{GH,I}(\bar{y}^* + \xi)$ when ξ is arbitrarily small.

E. Proof of Lemma 3

Almost by construction these are the optimal strategies of the two players, for any given history of the game. For GH , deviating from \bar{y}_{T-j}^I , while still inducing I_{T-j}^* , is suboptimal. Similarly, deviating from \bar{y}_{T-j}^* , while still inducing U_{T-j}^* , is suboptimal (remember that $\bar{y}_{T-j}^* \leq \bar{y}^* < \bar{y}_{T-j}^U$) as $u_{T-j}^{GH,U}(y)$ is a strictly concave function of y reaching a maximum at $y = \bar{y}_{T-j}^U$. If U_{T-j-1}^* , GL has no alternative, but to set U_{T-j}^* (because unification is

irreversible), while GH 's dominant strategy is to set $\bar{y}_{\tilde{T}-j} = \bar{y}_{\tilde{T}-j}^U$. If $I_{\tilde{T}-j-1}$, then, by definition of $\bar{y}_{\tilde{T}-j}^*$, (19), GL has no incentive to deviate from the prescribed choice.

F. Proof of Lemma 4

The proof is by induction. For $j = 2$, (21) can be written as:

$$u^{GL,U}(\bar{y}_{\tilde{T}-2}^*) = u^{GL,I} + \beta_L \left[u^{GL,U}(\bar{y}_{\tilde{T}-1}^*) - u^{GL,U}(\bar{y}_{\tilde{T}-1}^U) \right]. \quad (\text{F.1})$$

The second term on the right-hand side is positive (because $\bar{y}_{\tilde{T}-1}^* = \bar{y}^* > 0$ and by definition of \tilde{T}). Hence, because $u^{GL,I} = u^{GL,U}(\bar{y}_{\tilde{T}-1}^*)$, $\bar{y}_{\tilde{T}-2}^* < \bar{y}_{\tilde{T}-1}^*$ [remember that if a solution $\bar{y}_{\tilde{T}-2}^*$ to (F.1) does not exist, $\bar{y}_{\tilde{T}-2}^* = 0$]. Now, suppose that $0 < \bar{y}_{\tilde{T}-j}^* < \bar{y}_{\tilde{T}-j+1}^*$, $j \geq 2$. Lag (21) by one period and subtract (21) from the resulting equation. This yields:

$$\begin{aligned} & \beta_L \left[u^{GL,U}(\bar{y}_{\tilde{T}-j}^*) - u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^*) \right] \\ = & \left[u^{GL,U}(\bar{y}_{\tilde{T}-j-1}^*) - u^{GL,U}(\bar{y}_{\tilde{T}-j}^*) \right] + \beta_L \left[u^{GL,U}(\bar{y}_{\tilde{T}-j}^U) - u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^U) \right]. \end{aligned} \quad (\text{F.2})$$

By assumption, the term on the left-hand side is positive. Because $\bar{y}_{\tilde{T}-j}^U > \bar{y}_{\tilde{T}-j+1}^U$, the second term on the right-hand side is negative. Hence, $\bar{y}_{\tilde{T}-j-1}^* < \bar{y}_{\tilde{T}-j}^*$.

G. Proof that, for $\beta_L = 1$, $\bar{y}_{\tilde{T}-j+1}^* = 0$ implies $\bar{y}_{\tilde{T}-j}^* = 0$ ($j \geq 2$)

If $\beta_L = 1$ and $\bar{y}_{\tilde{T}-j+1}^* = 0$, then $u^{GL,I} + W_{I,\tilde{T}-j+2}^{GL} \geq u^{GL,U}(0) + W_{U,\tilde{T}-j+2}^{GL}$. We need to show that this implies that $u^{GL,I} + W_{I,\tilde{T}-j+1}^{GL} \geq u^{GL,U}(0) + W_{U,\tilde{T}-j+1}^{GL}$. With the help of (20), one can write $u^{GL,I} + W_{I,\tilde{T}-j+1}^{GL} = u^{GL,I} + u^{GL,I} + W_{I,\tilde{T}-j+2}^{GL} \geq u^{GL,I} + u^{GL,U}(0) + W_{U,\tilde{T}-j+2}^{GL} > u^{GL,U}(0) + u^{GL,U}(\bar{y}_{\tilde{T}-j+1}^U) + W_{U,\tilde{T}-j+2}^{GL} = u^{GL,U}(0) + W_{U,\tilde{T}-j+1}^{GL}$.

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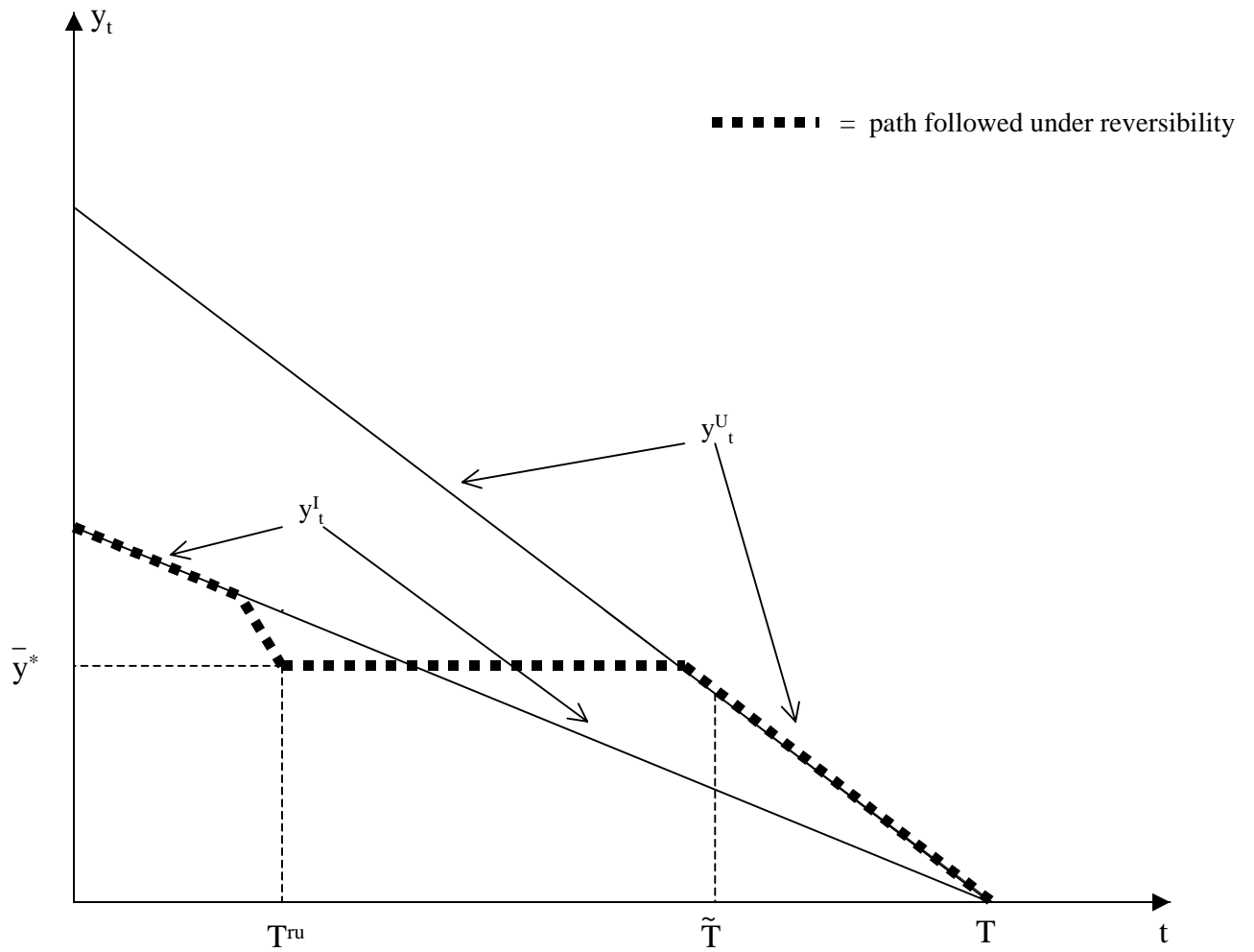


Figure 1: Path of structural distortions under reversible unification.

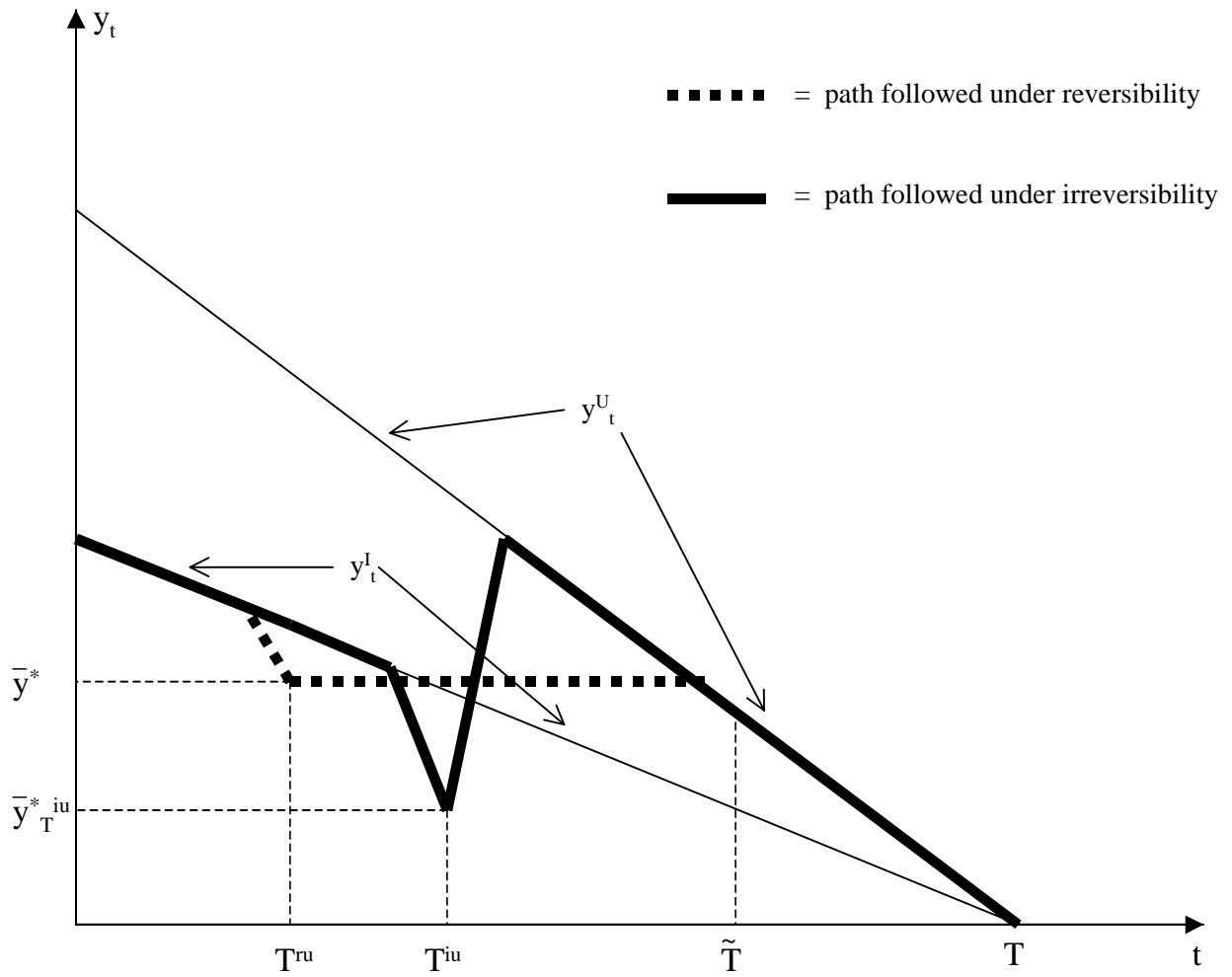


Figure 2: Path of structural distortions under irreversible unification.