When Are Stabilizations Delayed? Alesina-Drazen Revisited

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Abstract

In an influential article, Alesina and Drazen (1991) model delay of stabilization as the result of a struggle between political groups supporting reform plans with different distributional implications. In this paper we show that *ex ante* asymmetries in the costs of delay for the groups will reduce the probability of conflict and will lead to a shorter expected delay. Accurate common information about the cost of delay may lead to no delay at all. In an asymmetric conflict, a wider divergence in the distributional implications of reform will *reduce* the probability of conflict but will lead to a longer expected delay. We motivate the asymmetric model of delay by reference to Latin American episodes of the 1980s.

Keywords: Stabilization delay, economic reforms, war of attrition
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1 Introduction

In their (1991) article titled "Why are stabilizations delayed?", Alesina and Drazen provide a model where delay of economic reforms is the result of a distributional conflict between political groups uncertain about the capacity of their rivals to bear the cost of inflation and other distortions caused by delay. Although all political groups understand the need for reform, and although all suffer while reforms are delayed, each has an incentive to resist the adoption of reform in the hope that the others will capitulate first and agree to bear a disproportionate burden of the reform program. The model predicts that reform delay will be shorter the more similar are the distributional consequences of different reform plans, and the higher is the cost of delay for all groups. As shown by Drazen and Grilli (1993), this last result supports the common view that financial crises and other pains resulting from budgetary instability have the virtue of inducing earlier expected reform. Alesina and Drazen's (1991) analysis has been extended elsewhere by Alesina and Perotti (1995), Casella and Eichengreen (1996), Guidotti and Vegh (1999), Spolaore (2003), among others, and has achieved textbook status in the presentations by Persson and Tabellini (2000: 361-364) and Drazen (2000: 432-439).[1]

A key simplification in Alesina and Drazen's (1991) seminal contribution and the subsequent literature is the assumption that the political groups in conflict are identical *ex ante*, in the sense that the (privately known) cost of inflation for each group is independently drawn from the same distribution. *Ex ante* symmetry, however, is a very strong assumption. In general, the constituencies of rival political groups are not expected to be similarly affected by pre-stabilization distortions. For instance, inflation is commonly believed to be a regressive tax.[2] Thus, political groups representing on average lower income constituencies are likely to be the more affected by delaying the stabilization. Moreover, a symmetric setup precludes the consideration of (publicly observed) changes in the cost of inflation for one of the groups

[1] While Alesina and Drazen were the first authors to use the war of attrition model in a macroeconomic context, they build on the biological model of Maynard Smith (1974) and Riley (1980), and the public-good model of Bliss and Nalebuff (1984).

[2] Erosa and Ventura (2000) argue this point in a monetary economy with heterogenous household wealth composition and transaction patterns. Also, Romer and Romer (1999) find a negative correlation between the income of the poor and average inflation.

in conflict. An example is the more extensive use of foreign currency by the richer segments of the population, reducing their cost of inflation.[3]

In this paper, we consider a model of stabilization delay due to conflicting (and possibly asymmetric) political groups. We show that a political group more exposed to inflation costs will be likely to cave in immediately, leading to immediate reform. If the expected cost of inflation increases for the more exposed group, the probability of immediate reform increases and the expected delay of stabilization is reduced. If the expected cost of inflation increases for the less exposed group, the effects are exactly the reverse. Thus, in contrast to the predictions from Alesina and Drazen (1991), the effect of a reduction in the cost of inflation, benefitting mostly the less exposed group, may be a shorter delay. In agreement with the predictions from Alesina and Drazen (1991), if the distributive consequences of reform become more unequal, a longer expected delay follows. There is a surprising twist, though: the probability of immediate agreement also increases. Intuitively, if the more exposed group is nearly indifferent between conceding immediately or entering the conflict, it will be convinced to concede immediately by the expectation of a longer conflict.

Note that stabilization delay is less likely if one of the groups in conflict is better able than the other to shield itself from the costs of pre-stabilization distortions via financial adaptation–in particular, if financial adaptation is publicly observable. Stabilization delay is also less likely in a polarized society in which stabilization plans have widely divergent distributional consequences, because, say, different groups in the society have widely different asset structures. Polarized societies, however, may expect a longer delay of stabilization.

In terms of expected utility, we show that increasing the expected cost of inflation for the more exposed group will increase the (utilitarian) welfare of society, while increasing the expected cost for the least exposed group will reduce it. An increased divergence in the distributional implications of economic reform will reduce the expected utility of both groups. In synthesis, asymmetries in the losses due to stabilization delay will reduce the probability

[3]Financial adaptation to inflation is discussed by Labán and Sturzenegger (1994), who build on another influential contribution to the political economy of reform (Fernandez and Rodrik 1991). See also Sturzenegger (1997).

of conflict and increase (utilitarian) social welfare, while asymmetries in the distributional implications of reform will reduce the probability of conflict but decrease (unequivocally) social welfare.

We also explore systematically the relationship between economic crises (understood as increases in the costs of inflation for both groups) and social welfare. While Alesina and Drazen (1991) have shown that increasing the pains associated with inflation leads to a shorter delay of stabilization, this does not automatically translate into an increased expected welfare for the society. Drazen and Grilli (1993), in particular, illustrate by means of a simulation an inverted U-shape relationship between inflation and expected welfare for moderate to high levels of inflation. That is, they show that if some inflation is unavoidable before the stabilization, the optimal (second best) inflation is not necessarily low. We show, in addition, that the optimal inflation is decreasing in the degree of polarization of society. The reason is that the effect of economic crises in shortening the delay of stabilization is more pronounced in less polarized societies. In more polarized societies, a shorter expected delay does not compensate for the increased pains associated with high levels of inflation.

Examples for our model can be drawn from the Latin American experiences with economic reform in the second half of the 1980s and first half of the 1990s. In that interval, Bolivia, Mexico, Peru, Argentina and Brazil adopted reform programs that combined balancing the fiscal accounts with large-scale privatization and overhauling of trade and industrial policies. As Rodrik (1996) notes, this peculiar mix of policies was not inevitable–in fact, some of the policies adopted may have complicated the stabilization effort. If we think of reform delay as the result of a distributive conflict, we might conclude that in all those cases the groups favored by the policies eventually adopted emerged as winners of the conflict, and their favorite blueprint for reform was implemented. Strikingly, the reforms were implemented by formerly populist presidents, often belonging to parties that had shown a penchant for interventionism in the past. In our view, this accentuates the character of concession of the reforms.[4] Rather than by worsening conditions

[4] Cukierman and Tommasi (1998) propose a different, but not incompatible, explanation of the apparent paradox of populist politicians implementing right-wing reforms in terms of their credibility.

for everyone, reforms in Latin America may have been prompted by relative improvements in the ability to live with inflation and other distortions by the groups that eventually held the upper hand. At least from a utilitarian perspective, the lesson from our model is that financial adaptation by some groups in society may not have been bad for reform, contrary to what has been claimed in previous literature. Social polarization, in the sense of strong distributional consequences of different reform packages, may have been bad for reform though, as previously claimed by Alesina and Drazen (1991) and other authors. Looking at the future, our model predicts that the inconsistent policies characterizing stabilization delay are more likely to recur in countries with moderate to high–rather than extremely high–social polarization.

Formally, our model is an asymmetric war of attrition in the spirit of Nalebuff and Riley (1985) and Fudenberg and Tirole (1986).[5] The model exhibits many equilibria (indeed a continuum of them). However, only one equilibrium is robust to a small perturbation of the model suggested by Nalebuff and Riley. We show that, in all equilibria but the most favorable one, a political group would benefit from committing with some arbitrarily small probability to never give up–or at least having the other group believe it. We focus on the "commitment-proof" equilibrium obtained by allowing each group to be committed with a (vanishingly small) probability. Note that the uniqueness result depends upon each group making it credible that there is some possibility that it would never give in. In the context of the Latin American experience, that semblance of commitment may have been achieved by right-leaning governments by appointing ministers with long careers abroad and little at stake inside the country, who were presumably insensitive to the domestic costs of reform.[6] A semblance of commitment may also be achieved by the apparent delegation of policymaking to multilateral lending organi-

[5]Recent contributions such as those of Krishna and Morgan (1997) or Bulow and Klemperer (1999) have extended the incomplete information war of attrition model to affiliated costs or multiple combatants and prizes, but have stuck to the analysis of the symmetric case.

[6]Several finance ministers and prime ministers of Latin American countries during the period of reforms in the 1980s fit this pattern. While these appointments have been considered as a signal to foreign lenders, our point is that they may also be a signal to domestic audiences.

zations. Left-leaning unions may have been able to project a semblance of commitment by electing ideologically-motivated leaders apparently willing to fight it out to the bitter end. Delegation, communication problems with one's delegates, elimination of one's own capacity to act, and appeal to principles, are, of course, among the bargaining ploys classically described by Schelling (1956). The point is that these ploys may be effective even if far from convincing–it is enough that they cast the shadow of a doubt in a corner of the mind of the political opponents.[7]

Perraudin and Sibert (2000) and Hsieh (2000) have proposed other bargaining models of reform that allow for a positive probability of immediate agreement. They differ from our approach in that they consider a finite-horizon, one-sided incomplete information game with discrete time, with the uninformed party holding the ability to make reform proposals. Hsieh (2000) shows that increasing the costs of inflation proportionally for both parties leads to an increased probability of immediate agreement. Perraudin and Sibert (2000) show that increasing the cost of inflation only for the informed party may increase or decrease the probability of immediate agreement. This result is related in their case to the increased bargaining power of the uninformed party, for whom delay becomes a more attractive screening device. Neither of these two papers is concerned with the effects on stabilization delay of asymmetries in the expected costs of inflation to parties representing different segments of the domestic population. On another related contribution, Seddon Wallack (2003) has found evidence that countries with less accurate commonly accessible information tend to delay stabilization longer. We can note that in our setup better common information is likely to lead to a shorter delay or even no delay at all.

The remainder of the paper is organized as follows. The model is described in Section 2. Equilibrium selection is discussed in Section 3. Comparative statics results are presented in Section 4. Section 5 concludes with remarks on the role of institutions and information in delayed stabilizations.

[7] In the context of the cold war, Richard Nixon's famous "madman theory," expounded in detail by Kimball (1998), was an expression of the same idea.

2 The model

We consider a stripped-down version of the Alesina-Drazen model. At $t = 0$ an economy is hit by a shock reducing tax revenues. From then until the date of stabilization, the government deficit τ has to be covered by distortionary taxes (a proxy for inflation[8]). There are two political groups or parties ($i = 1, 2$). Before stabilization, (the representative consumer of) each party pays half of the distortionary taxes and in addition suffers some welfare loss θ_i that is private information to the party. For stabilization to occur, one of the two groups (which becomes the *loser*) has to agree to bear a fraction $\alpha > 1/2$ of the new, nondistortionary taxation while the remainder is borne by the other group (the *winner*). Note that α measures the divergence between the distributional implications of the reform plans favored by the two groups, or "degree of polarization" of society. Welfare losses disappear with stabilization.

Ignoring gross income, which plays no role in the model, the flow utility for group i before stabilization is: $U_i^D = -\tau/2 - \theta_i$. After stabilization, flow utility for the loser or conceding party becomes: $U_i^L = -\alpha\tau$. Flow utility for the winner becomes: $U_i^W = -(1-\alpha)\tau$. Groups are infinitely lived and discount the future according to r. The problem of each party is to maximize its expected lifetime utility by choosing a time to concede if the other party has not yet conceded.

We deviate from Alesina-Drazen by allowing (common) prior beliefs about θ_1 to differ from those about θ_2. We assume that prior beliefs are given by the distribution functions F_1 and F_2, with continuous densities f_1 and f_2. The densities f_1 and f_2 have common support $[\underline{\theta}, \bar{\theta}]$, and are bounded from above and away from zero from below. We also assume that $\bar{\theta} > \underline{\theta} > (\alpha - 1/2)\tau$; that is, even the conceding party expects to be better off after stabilization. In the language of Fudenberg and Tirole (1986), incomplete information is "small" in the sense that it is common knowledge that both groups are interested in stabilizing the economy.[9]

Group i's strategy is a (measurable) function $T_i : [\underline{\theta}, \bar{\theta}] \to [0, \infty]$, speci-

[8]Monetary versions of the model are considered by Drazen and Grilli (1993) and Guidotti and Vegh (1999).

[9]If either this or the boundedness assumption fail, there could be a unique solution to the system described by Theorem 1.

fying for each possible value of θ_i the time at which group i concedes if the other group has not yet given up. If it plans to concede at time t, and its opponent behaves according to T_j, group i's expected lifetime utility is:

$$
\begin{aligned}
V_i(t, T_j; \theta_i) = \Pr\{T_j(\theta_j) \geq t\} \times \left[\int_0^t U_i^D e^{-rx}\, dx + \int_t^\infty U_i^L e^{-rx}\, dx\right] \\
+ \int_{\{\theta_j : T(\theta_j) < t\}} \Bigg[\int_0^{T_j(\theta_j)} U_i^D e^{-rx}\, dx \\
+ \int_{T_j(\theta_j)}^\infty U_i^W e^{-rx}\, dx\Bigg]\, f_j(\theta_j)\, d\theta_j.
\end{aligned}
$$

The first term in brackets is group i's utility if group j continues to resist reform at time t; the second term in brackets is group i's utility if group j concedes at some time $T_j(\theta_j)$ before t.

A (Bayesian) equilibrium is a pair of strategies $\{T_1, T_2\}$ such that, if group 1 behaves according to T_1, group 2 finds it optimal to behave according to T_2 and vice versa. It is easy to see that there are equilibria without delay, in which either group 1 or group 2 concedes at time zero with probability one, while the other would wait long enough before doing so to deter the former one from deviating. The following lemma establishes some useful properties of equilibrium strategies for equilibria with delay.

Lemma 1 *If $\{T_1, T_2\}$ is an equilibrium with positive probability of delay,*

(1.1) $T_i(\theta_i) = 0$ *on* $[m_i, \bar{\theta}]$ *for some* $m_i \in (\underline{\theta}, \bar{\theta}]$,

(1.2) $T_i(\theta_i)$ *is continuous and strictly decreasing on* $(\tilde{\theta}_i, m_i]$ *for some* $\tilde{\theta}_i \in [\underline{\theta}, \bar{\theta}]$ *such that* $\min\{\tilde{\theta}_1, \tilde{\theta}_2\} = \underline{\theta}$ *and* $T(\tilde{\theta}_1) = T(\tilde{\theta}_2) = \bar{T}$ *for some* $\bar{T} > 0$ *(possibly infinite), and*

(1.3) *If* $\bar{T} < \infty$, $T_i(\theta_i) \geq \bar{T}$ *on* $[\underline{\theta}, \tilde{\theta}_i]$. *If* $\bar{T} = \infty$, $\tilde{\theta}_1 = \tilde{\theta}_2 = \underline{\theta}$.

(Proofs are contained in Appendix A.) Quite intuitively, Lemma 1 establishes that a political group will tend to concede earlier if it suffers more heavily from pre-stabilization distortions.

It is convenient to define the inverse functions

$$
\Phi_i(t) = \begin{cases} T_i^{-1}(t) & \text{if } 0 < t < \bar{T}, \\ \min\limits_{\theta_i} T_i^{-1}(0) & \text{if } t = 0. \end{cases}
$$

$\{\Phi_1(t), \Phi_2(t)\}$ represent the type of each group which concedes at time $t > 0$ along the equilibrium path, and the minimum type that concedes at time 0, where the type is given by the private cost of living with inflation. Then:

Theorem 1 *$\{T_1, T_2\}$ is an equilibrium with positive probability of delay if and only if $\{\Phi_1, \Phi_2\}$ is a solution to:*

$$\left[-\frac{f_j(\Phi_j(t))\Phi_j'(t)}{F_j(\Phi_j(t))}\right]\frac{2(\alpha-1/2)\tau}{r} = \Phi_i(t)-(\alpha-1/2)\tau \tag{2.1}$$

$(i, j = 1, 2$ and $i \neq j)$ such that:

$$\underline{\theta} < \min\{\Phi_1(0), \Phi_2(0)\} \leq \bar{\theta} \text{ and } \max\{\Phi_1(0), \Phi_2(0)\} = \bar{\theta}. \tag{2.2}$$

Moreover,

$$\bar{T} = \infty. \tag{2.3}$$

The RHS of equation (2.1) is the cost for group i of waiting another instant to concede $(U_i^L - U_i^D)$. The LHS is the expected gain for i from waiting another instant to concede, which is the product of the conditional probability that group j concedes at time t (the term in brackets), multiplied by the gain for i if j concedes $(\int_t^\infty (U_i^W - U_i^L)e^{-r(x-t)}\,dx)$. Equation (2.2) simply states that neither group concedes at time zero with probability one and at least one of the two groups concedes at time zero with probability zero. Equation (2.3) says that groups with smaller losses from inflation will wait for a very long time before conceding.

Since f_1 and f_2 are bounded from below, the system of ordinary differential equations (2.1) is Lipschitz continuous and therefore it has a unique solution for each boundary condition defined by (2.2). That is, there are many possible equilibria with delay. Fixing, say, $\Phi_1(0) = \bar{\theta}$, equilibria are indexed by $\Phi_2(0) \in (\underline{\theta}, \bar{\theta}]$. Worse, all equilibria with delay are Bayesian perfect, since concession can occur at any moment in time, and concession effectively finishes the game anyway. There are also equilibria without delay that are Bayesian perfect; an example is $T(\theta_1) = \infty$ for all θ_1 and $T(\theta_2) = 0$ for all θ_2 (or the opposite). An equilibrium like this is sustained by the following out-of-equilibrium beliefs: If group 2 has not conceded before any time $t > 0$, it will concede with probability one at t.

Intuitively, Theorem 1 tells us that there is a multiplicity of equilibria because equilibrium conditions cannot uniquely pin down the probability with which one of the two parties concedes immediately rather than facing a delayed stabilization. If the distribution of pre-stabilization losses is the same for both parties, symmetry suggests assuming that no party concedes at time zero–this is the assumption made implicitly by Alesina-Drazen. In general, however, we have no reason to expect the distribution of pre-stabilization losses to be exactly identical for both parties, and we need a more systematic way of dealing with the multiplicity of equilibria in order to make any kind of comparative statics prediction. Fortunately, as it turns out, all equilibria except one are not robust to the introduction of an arbitrarily small belief on the part of each group that they are facing an inflexible opponent. In the symmetric case, for instance, the Alesina-Drazen equilibrium is the only one surviving this refinement. In the next section we discuss why this refinement is appropriate in political bargaining contexts such as delayed stabilizations.

3 A commitment-proof equilibrium

Theorem 2 below shows that each political group stands to gain a lot if able to convince the other group that, with some arbitrarily small probability, it is either unable to concede or does not care about stabilization losses enough to consider conceding. A semblance of commitment may have been achieved in the Latin American experiences of the 1980s and 1990s via *strategic delegation.* Conservative governments appointed occasionally ministers with long careers abroad and who were suspected of insensitivity to domestic pains associated with economic policy. In the opposition, left-leaning unions elected "principled" leaders with strong ideological allegiances.[10] Left-leaning governments, in turn, stirred excitement and determination among their supporters against policies sponsored by multilateral lenders.[11] A semblance of

[10] Maoism made inroads in Latin America in the 1980s, among the conflicts associated with economic reforms. More recently, resistance to market-oriented economic reform in Ecuador and Bolivia has been associated with indigenist ideologies.

[11] This tactic seems to have been spoused recently by Kirchner's administration in Argentina since 2003. Kirchner has consistently unleashed scathing attacks on the IMF, implying that the fund had become captive to private lenders, financial firms and corporations.

commitment may have also been achieved via the deliberate (and public) *destruction of the state capacity* to implement the policies disliked.[12] As discussed by Schelling (1956), these and similar bargaining stratagems have pitfalls. Ministers can be fired, union leaders can be replaced, state capacity can be rebuilt, governments can tout the virtues of political or economic realism. These actions, however, can be made costly in themselves; conservative governments, for instance, may attempt to link the credibility of economic policies vis-a-vis foreign lenders to the presence of a specific person in the cabinet, while left-leaning governments may brand as "treason" the adoption of policies they oppose.

Rather than attempting–perhaps hopelessly–to make full justice to the strategic complexity of political bargaining, we introduce in Theorem 2 a slight perturbation of the model that takes into account the possible effect of bargaining ploys on the beliefs held by political groups in conflict. Theorem 2 strongly suggests that the multiplicity of equilibria of the model in the previous section is not itself realistic, but rather the result of not taking into account the opportunities of each group to, perhaps convincingly, tie their hands in front of the other.[13]

We proceed by "perturbing" the model with the introduction of some probability $p_i\epsilon$ that each group is "irrationally" committed to never give in, where $p_i \in [0,1]$ and ϵ is taken to be arbitrarily small. As before, the distribution of the cost of inflation for a "rational" group is given by F_i. Let $G_i(x) = (1 - p_i\epsilon)F_i(x) + p_i\epsilon$ and $g_i(x) = (1 - p_i\epsilon)f_i(x)$. Let also

$$K_i \equiv (\underline{\theta} - (\alpha - 1/2)\tau)\ln(p_j/p_i) + \int_{\underline{\theta}}^{\bar{\theta}} \ln\left(G_j(x)/G_i(x)\right) dx.$$

Then:

[12] The left-leaning government of Peru in the early 1990s intervened heavily in the operation of the Central Bank, while the successive conservative regime of Fujimori disbanded the Instituto Nacional de Planificación.

[13] The effects on bargaining of (one-sided) unobserved strategic delegation have been analyzed recently by Kockensen and Ok (2004), employing a "mistaken theories" refinement of a similar spirit to ours.

Theorem 2 *In the perturbed model, if $p_j > 0$ and $p_i = 0$, then in equilibrium group i concedes at time zero with probability one. If $p_1, p_2 > 0$, the (unique) equilibrium is characterized by an analogue to equation (2.1), with F_i and f_i replaced by G_i and g_i, and the following boundary condition: if $K_i \leq 0$, then $\Phi_i(0) = \bar{\theta}$; otherwise $\Phi_i(0)$ is given by*

$$\int_{\Phi_i(0)}^{\bar{\theta}} (g_i(x)/G_i(x))(x - (\alpha - 1/2)\tau)\, dx = K_i.$$

By committing unilaterally to never concede, even with an arbitrarily small probability, a group is able to extract an immediate concession from the other group.[14] If both groups are able to convince the other that they are "irrationally" committed to never give up with some positive probability, then we obtain a unique equilibrium that is similar to those described by Theorem 1. Now by letting ϵ go to zero for $p_1 = p_2 > 0$, we can in fact select a unique equilibrium in the unperturbed model. We refer to this as the *commitment-proof equilibrium*.[15]

Since f_1 and f_2 are bounded from above and away from zero from below,

$$\lim_{\epsilon \downarrow 0} \int_{\underline{\theta}}^{\bar{\theta}} \ln\left(G_i(x)/G_j(x)\right) dx = \int_{\underline{\theta}}^{\bar{\theta}} \ln\left(F_i(x)/F_j(x)\right) dx.$$

Thus, in the commitment-proof equilibrium,

$$\Phi_i(0) < \bar{\theta} \text{ if and only if } \int_{\underline{\theta}}^{\bar{\theta}} \ln\left(F_j(x)/F_i(x)\right) dx > 0;$$

in this case $\Phi_i(0)$ is given by

$$\int_{\Phi_i(0)}^{\bar{\theta}} (f_i(x)/F_i(x))(x - (\alpha - 1/2)\tau)\, dx = \int_{\underline{\theta}}^{\bar{\theta}} \ln\left(F_j(x)/F_i(x)\right) dx.$$

It follows that one party will concede at time zero with positive probability, unless pre-stabilization welfare losses are "very close" in stochastic terms

[14] As noted in the introduction, this provides a rationalization of the "madman theory" credited to Richard Nixon–even if you are perfectly sane, it helps if the others think that you are capable of anything. In Nixon's words, "We'll just slip the word ... that for God's sake, you know Nixon is obsessed about communism. We can't restrain him when he's angry, and he has his hand on the nuclear button" (Sagan and Suri 2003).

[15] Note that a unique selection can be made even if $p_1 \neq p_2$ is a more appropriate assumption; the boundary condition used to select an equilibrium changes continuously with p_1/p_2.

for the two groups, in the sense that $\int_{\underline{\theta}}^{\bar{\theta}} \ln\left(F_1(x)/F_2(x)\right) dx = 0$. Moreover, if pre-stabilization welfare losses of one party exhibit first-order stochastic dominance over the losses of the other, then the former party concedes at time zero with positive probability.

Inspecting the conditions satisfied by the commitment-proof equilibrium, we can see that, *ceteris paribus*, an outward shift of both distributions of losses to $\tilde{F}_1, \tilde{F}_2$ with $\tilde{F}_1(\theta_1 - \kappa) = F_1(\theta_1)$ and $\tilde{F}_2(\theta_2 - \kappa) = F_2(\theta_2)$ for some $\kappa > 0$ leads to an increase in $\min_i \Phi_i(0)$ (as long as $\min_i \Phi_i(0) < \overline{\theta}$). That is, if inflation becomes proportionally more painful for both parties, the probability of immediate reform increases. Finally, and rather surprisingly, if α increases, $\Phi_i(0)$ should decrease (as long as $\min_i \Phi_i(0) < \overline{\theta}$). That is, wider distributional implications of reform *increase* the probability of immediate reform.

This last result can be related to the increased "willingness to fight" of the party that does not concede at time 0 convincing the marginal type or types of the other party that it is not worth entering the conflict. This argument suggests that, if α increases, the expected time of stabilization may be delayed nonetheless due to the increased willingness to fight of the types of both parties that do enter the conflict. We explore this and other comparative static exercises in the next section.

4 Comparative statics

We consider the family of linear densities with support $[\underline{\theta}, \bar{\theta}] = [1, 2]$. Thus:

$$f_i(\theta_i) = 2\lambda_i(\theta_i - 1) + 1 - \lambda_i,$$

with $-1 < \lambda_i < 1$. Note that $\lambda_i = 0$ corresponds to the uniform density, and $\lambda_1 < \lambda_2$ implies that the losses of party 2 exhibit first order stochastic dominance over the losses of party 1. The expected instant cost of inflation for group i is, then $3/2 + \lambda_i/6$, and the total expected instant cost of inflation is $3 + (\lambda_1 + \lambda_2)/6$. In terms of interpretation, we consider values of $\lambda_1 + \lambda_2$ close to two as representative of very high inflation, and values of $\lambda_1 + \lambda_2$ close to minus two as representative of moderate inflation. We consider the ratio $\lambda_1/(\lambda_1 + \lambda_2)$ as representative of the exposure of group 1 to the inflation costs, caused by the weight of its holdings of domestic money balances in relation to its total assets. We normalize τ to one; this is equivalent to assuming that, if reform plans are very unequal (α close to one), a party with the lowest possible losses from inflation will gain almost nothing from conceding, while a party with the highest possible losses will cut its losses by more than half by conceding. Fixing the unit of time as years, we set the real interest rate and the discount rate r at 4 percent.

Using Theorem 1 and the boundary condition derived in Section 3, we have that, if $\lambda_1 \leq \lambda_2$,

$$-\left(\frac{2\gamma_j(\Phi_j(t)-1)+1}{\gamma_j(\Phi_j(t)-1)^2+(\Phi_j(t)-1)}\right)(50\alpha-25)\Phi_j'(t) \;=\; \Phi_i(t)-\alpha+1/2, \tag{3.1}$$

where $\gamma_j = \lambda_j/(1-\lambda_j)$, for $i = 1, 2$, $j \neq i$, with $\Phi_1(0) = 2$ and $\Phi_2(0)$ given by

$$\int_{\Phi_2(0)}^{2}\left(\frac{2\gamma_2(x-1)+1}{\gamma_2(x-1)^2+(x-1)}\right)(x-\alpha+1/2)\,dx = \int_1^2 \ln\left(\frac{\gamma_2(x-1)+1}{\gamma_1(x-1)+1}\right)dx. \tag{3.2}$$

Using $\Phi_2(0)$, we can calculate the probability of immediate agreement as

$$\Pr\{T_2(\theta_2)=0\} = 1-F_2(\Phi_2(0)) = 1-\lambda_2(\Phi_2(0)-1)^2-(1-\lambda_2)(\Phi_2(0)-1).$$

We use the system of differential equations given by (3.1) and the implicit boundary condition (3.2) to estimate also the expected time of stabilization and the expected welfare of both parties for six α values between 10/16 and 15/16 and for eleven by eleven (λ_1, λ_2) values between $(-1,-1)$ and $(1,1)$ (see Appendix B for a description of numerical methods). The estimations vary monotonically with respect to α so we report the results for the extreme cases 10/16 and 15/16.

4.1 The probability of immediate agreement

Figures 1 and 2 illustrate the probability of immediate agreement for different combinations of λ_1 and λ_2 for $\alpha = 10/16$ and $\alpha = 15/16$, respectively, by means of countour plots. Along the 45 degree line, with identical distributions

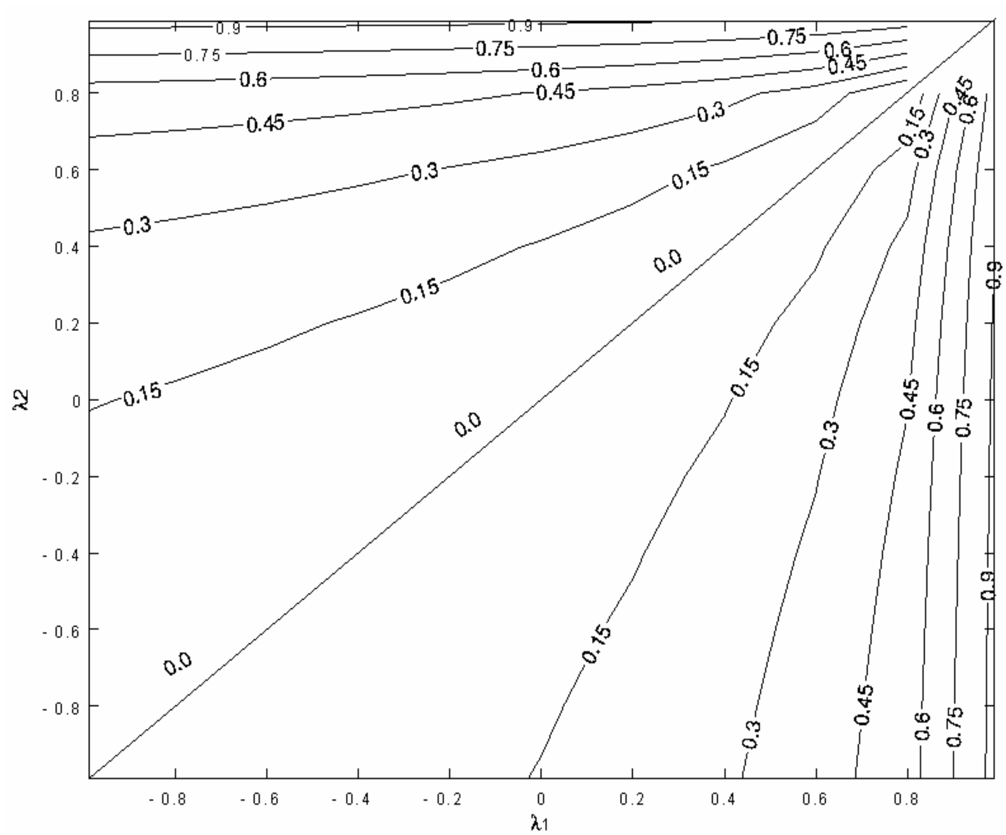

Figure 1: Probability of Immediate Agreement ($\alpha = 15/16$)

of inflation costs, the probability of immediate agreement is zero. Along any diagonal in the southeast direction, keeping the total expected cost of inflation constant but increasing the distance with respect to the 45 degree line, the probability of immediate agreement increases, reaching more than 90 percent if, say, λ_1 is close to one and λ_2 is close to minus one (or vice versa). With very high inflation (λ_1 and λ_2 close to one), minor movements in the distribution of inflation cost may lead to immediate agreement with probability close to one. Per contra, with moderate inflation (λ_1 and λ_2 close to minus one), the probability of immediate agreement is close to zero even in the presence of asymmetries in the cost of inflation.

Comparing Figures 1 and 2, we can see that the effects of an asymmetric

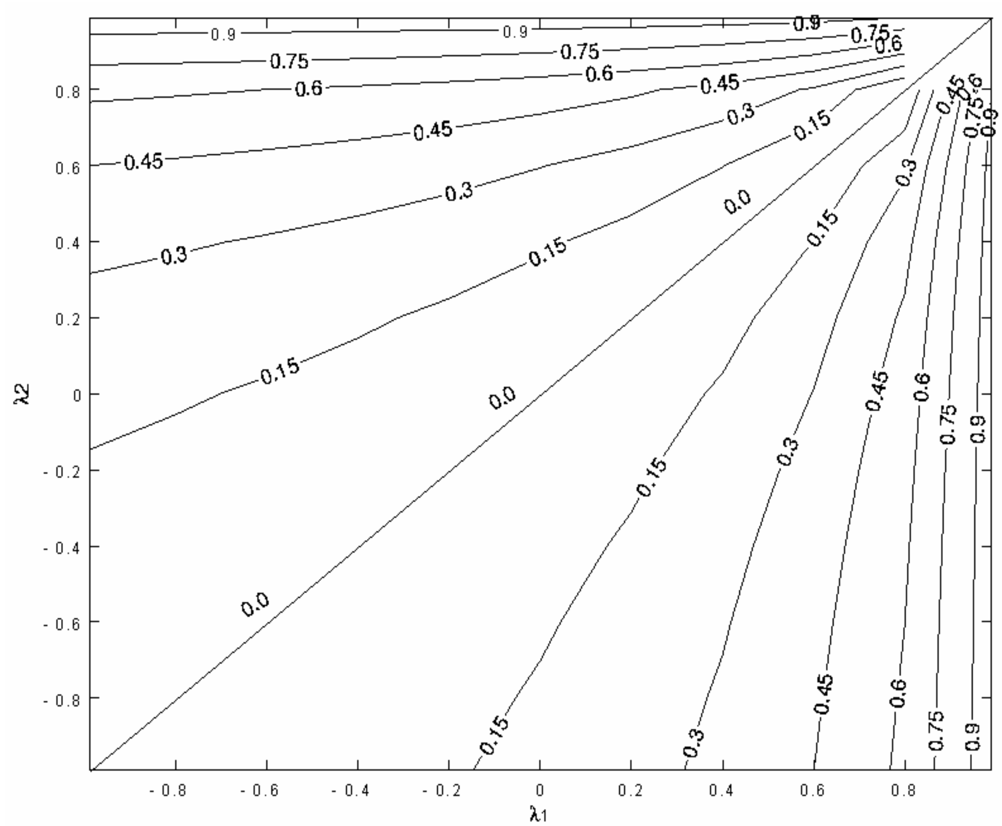

Figure 2: Probability of Immediate Agreement ($\alpha = 15/16$)

distribution of inflation costs on the probability of immediate agreement are larger in a more polarized society. In agreement with the results of the previous section, the probability of immediate agreement is increasing in α.

4.2 The expected time of stabilization

Figures 3 and 4 illustrate the expected time of stabilization for $\alpha = 10/16$ and $\alpha = 15/16$, respectively. Along any southeast diagonal, the expected time of stabilization is maximized along the 45 degree line. That is, asymmetries in the cost of inflation greatly reduce the delay of stabilization. In a society that is not very polarized, i.e. if α is equal to 10/16, the expected delay

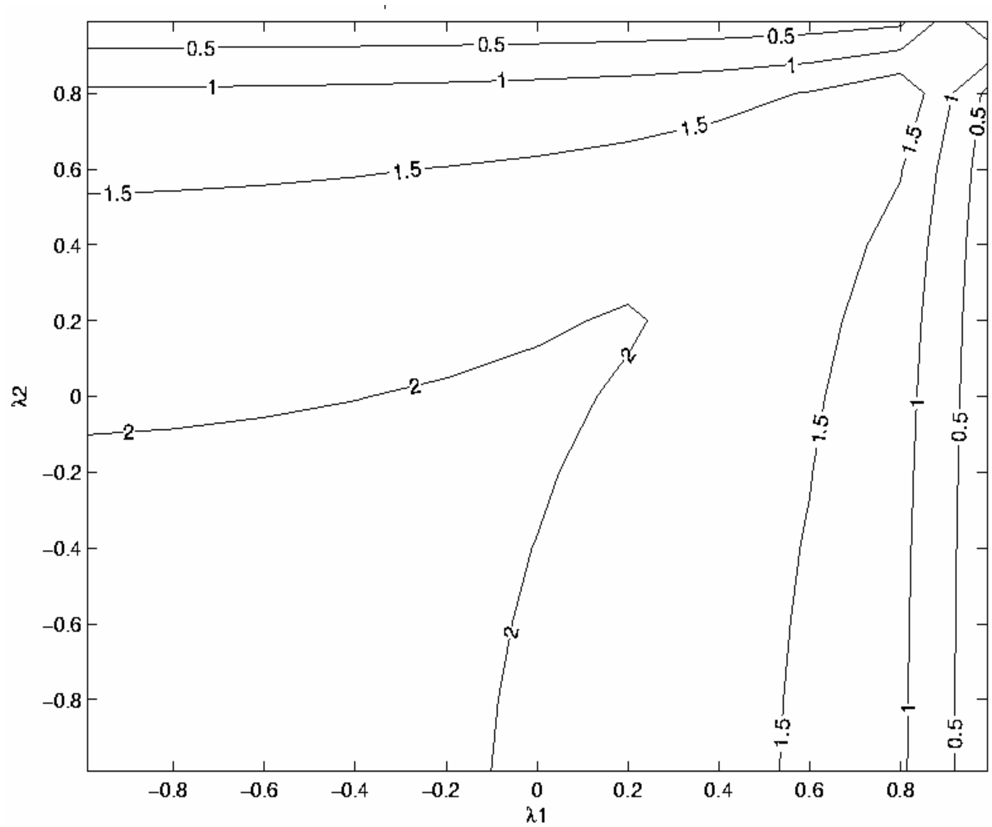

Figure 3: Expected Time of Stabilization ($\alpha = 10/16$)

stabilization is likely to be less than two years, at least assuming a uniform distribution over the values of λ_1 and λ_2. Per contra, in a very polarized society, i.e. if α is equal to 10/16, the expected delay of stabilization is likely to be more than seven years. In a very polarized society, moderate inflation (λ_1 and λ_2 close to minus one) may be expected to be sustained in equilibrium for ten years or more. Note that increasing polarization makes stabilization delay less likely but increases the expected delay. This provides support for the intuitive argument at the end of the previous section, namely, the reduction in the probability of delay occurs because the party most exposed to inflation costs may prefer to concede at time zero to avoid a protracted conflict.

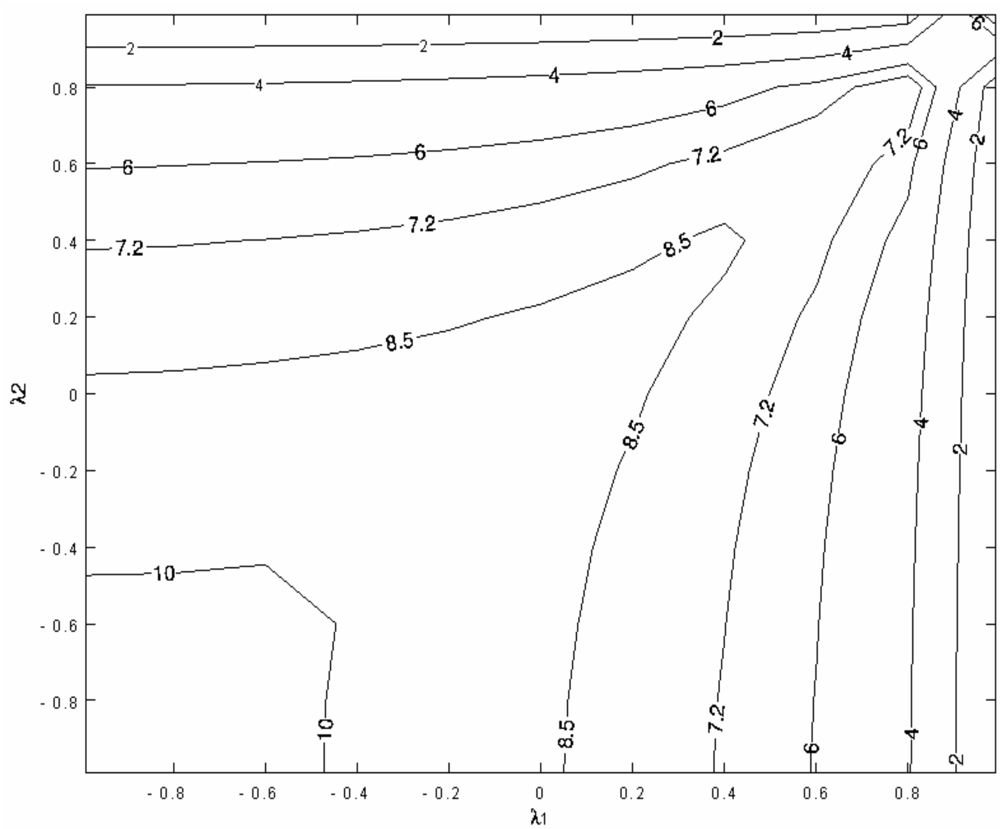

Figure 4: Expected Time of Stabilization ($\alpha = 15/16$)

4.3 The expected welfare of a political group

Figures 5 and 6 illustrate the expected welfare of group 1 for $\alpha = 10/16$ and $\alpha = 15/16$, respectively. Note that the welfare level corresponding to consecutive countour lines change very little to the right of the 45 degree line. This means that the welfare surface of group 1 is steeper if λ_1 is smaller than λ_2 than if λ_1 is larger than λ_2. That is, the group that is least exposed to inflation stands to gain more as a result of a further increase in the asymmetry in the distribution of inflation costs than what the most exposed party stands to lose. If the cost of inflation increases for the most exposed group and decreases *pari passu* for the least exposed group, the result will be an

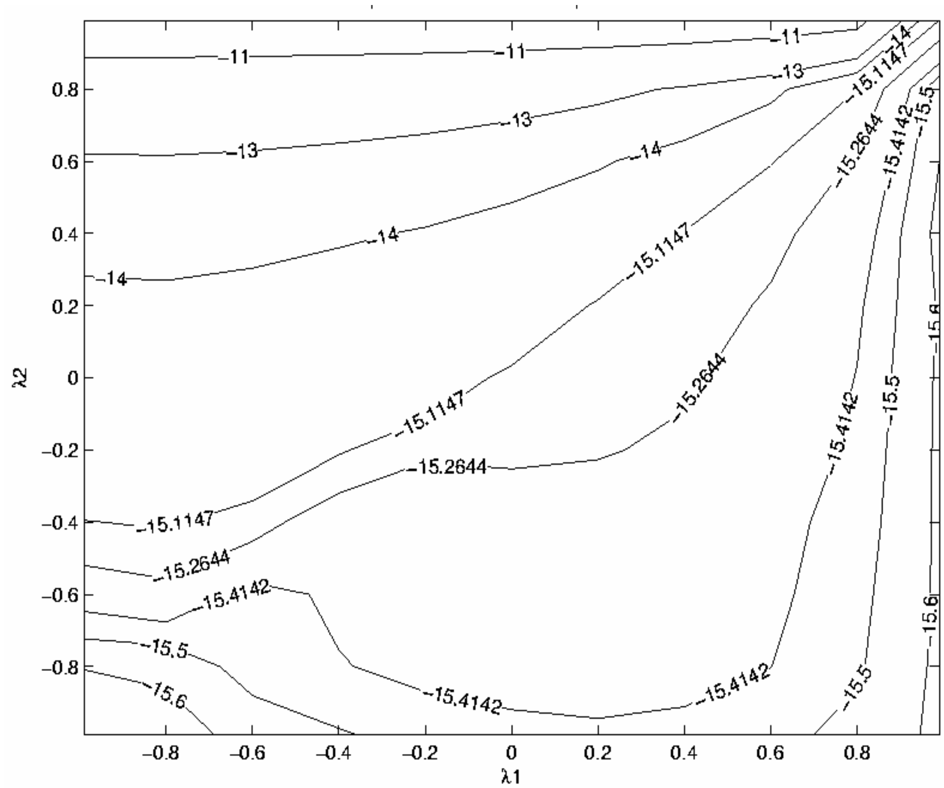

Figure 5: Expected Welfare of Group 1 ($\alpha = 10/16$)

increase in the sum of expected utilities. Thus, an increased asymmetry in the distribution of the inflation costs is beneficial for society, at least from a simple utilitarian perspective.

If the society is not very polarized and inflation is moderate, as in the southwest corner of Figure 5, paradoxically, even the more exposed group may benefit if its expected losses due to inflation increase, as illustrated by negatively sloped contour curves.

Comparing Figures 5 and 6, we can see that increasing polarization in the society is unequivocally bad for group 1, particularly to the right of the 45 degree line. That is, increasing polarization is particularly bad for the group most exposed to inflation costs. Since the welfare levels for group 2 can be obtained from the same figures through a permutation in the levels

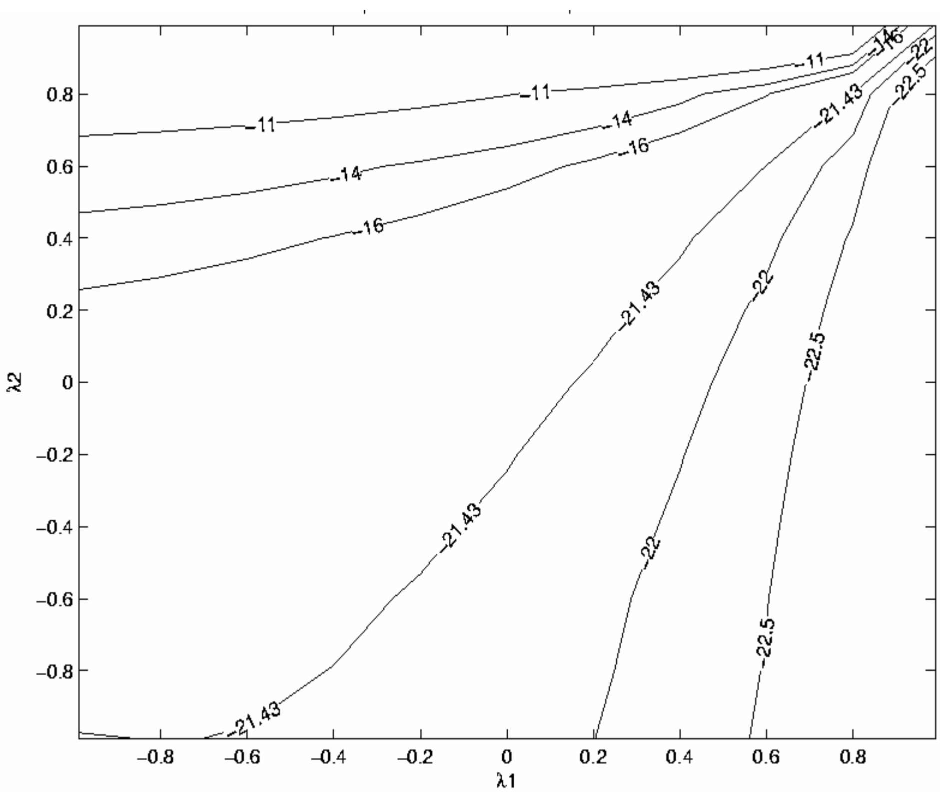

Figure 6: Expected Welfare of Group 1 ($\alpha = 15/16$)

of λ_1 and λ_2, it follows that an increase in polarization makes both groups worse off. This result holds as well for intermediate values of α between 10/16 and 15/16. In every case, increasing polarization makes both groups worse off in expected terms, due to the fact that stabilization is expected to be delayed longer in a more polarized society.

The lower bound for the expected welfare of group 1 is -25α, corresponding to the payoff of conceding at time 0. In the case depicted in Figure 6, that lower bound is $-23\frac{7}{16}$; we can see that the expected welfare of group 1 gets very close to its lower bound in the southeast corner of the picture.[16]

[16] For briefness, we omit figures with expected social welfare (that is, the sum of the expected welfare of both groups). As we can expect from the previous figures, the expected social welfare is minimized over the 45 degree line along any southeast diagonal.

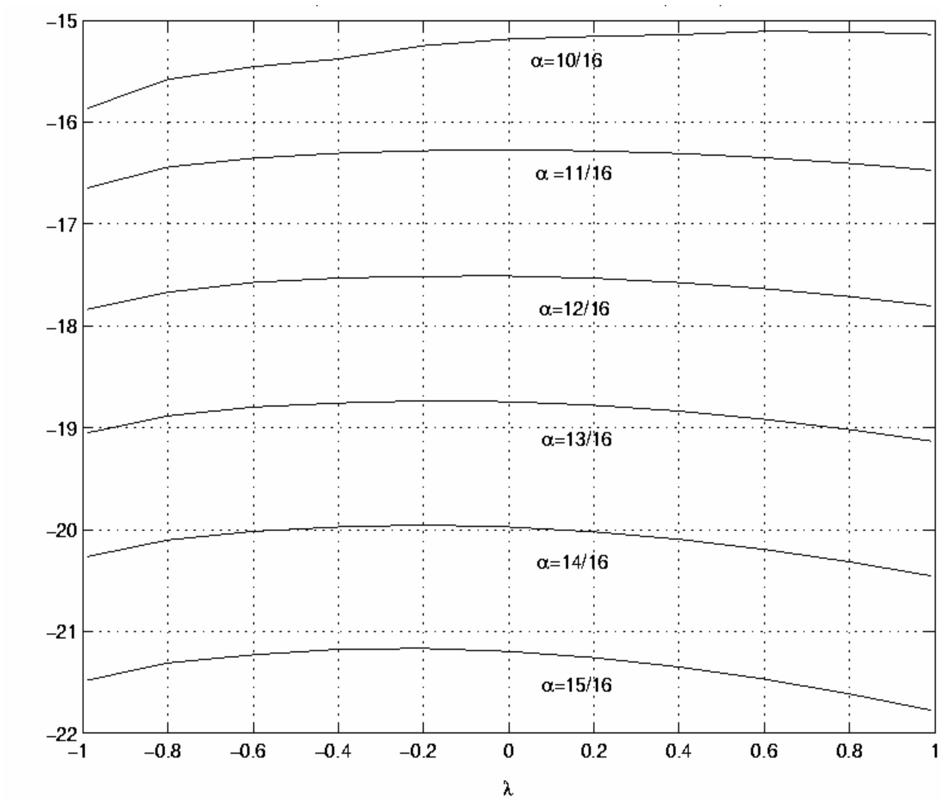

Figure 7: Expected Welfare of Each Group with Symmetric Inflation Costs

4.4 The benefits of crises for economic reforms

Figure 7 above illustrates the expected welfare of each group along the 45 degree line ($\lambda = \lambda_1 = \lambda_2$) for different values of α. Recall that the 45 degree line represents the original Alesina-Drazen model, with perfectly symmetric cost distributions. As we can see, the level of inflation costs maximizing the welfare of both groups is decreasing in the degree of polarization of society. If inflation costs are monotonically related to inflation rates, the conclusion is that the optimal (second best) inflation rate is decreasing in the degree of polarization in the society.

Drazen and Grilli (1993) show a similar inverted-U relationship between inflation costs and expected welfare, for moderate to high levels of inflation, in a simulation with $\alpha = 1$. In their case, assuming that inflation costs increase proportionally with inflation rates, the optimal inflation rate is 133 percent. Our simulations show that the optimal inflation rate is quite sensitive to assumptions with regard to the degree of polarization in society. The "benefits of crises for economic reforms" are more easily grasped by societies that are not very polarized because very high inflation rates in those societies readily prompt a political settlement.

Recall that in our model the expected total cost of inflation is $3 + (\lambda_1 + \lambda_2)/6$, or, in the symmetric case, $3 + \lambda/3$. The optimal expected cost of inflation is then $2\frac{14}{15}$ if $\alpha = 15/16$ and $3\frac{1}{5}$ if $\alpha = 10/16$. Assuming a linear relationship between expected costs and inflation rates, this means that if the optimal inflation rate with $\alpha = 15/16$ is about 133 percent, then the optimal inflation rate with $\alpha = 10/16$ is about 145 percent. These numbers are, of course, sensitive to changes in the relationship beween inflation rates and inflation costs, and to the distributive consequences of inflation.

5 Final remarks

We argue in this paper that asymmetries in the losses occasioned by pre-stabilization distortions to different political groups may lead to a sooner end of episodes of delayed stabilization. A number of economic reform episodes in Latin America in the last two decades seem to fit this pattern. In terms of understanding those episodes, the model points to the need of collecting evidence on the distribution of the cost of pre-stabilization distortions in those cases. We also argue that social polarization, in the sense of wider distributional implications of the available reform plans, makes conflicts over stabilization less likely, but contributes to a longer delay if a conflict breaks up. Moreover, social polarization reduces the benefit of crises for economic reforms, in the sense that the optimal second best inflation rate (taking into account that higher inflation costs may induce a sooner stabilization) is decreasing in social polarization. Intuitively, the reason is that the willingness to fight of the political groups is less sensitive to the cost of fighting when the prize (the difference between being the winner or the loser in the distributive conflict underlying inflation) is larger.

We model the delay of stabilization as a war-of-attrition game of incomplete information following Alesina and Drazen (1991). The war of attrition is known to exhibit a multiplicity of equilibria; we deal with this multiplicity appealing to a selection criterion suggested by the situation we model. There is a wealth of anecdotal evidence about the attempts of Latin American governments to tie-their-hands publicly or at least to pretend so, and similarly about the attempts of their domestic opponents. Our refinement is equivalent to assuming that these negotiation tactics may be somewhat effective in casting some doubt about the flexibility of the parties in conflict.

From a broader perspective, our paper, as well as related literature stemming from Alesina-Drazen (1991), emphasizes the role in stabilization delay of the absence or weakness of institutions of conflict management that allow fiscal shocks to develop into distributional conflicts. Recent contributions by Rodrik (1999) and by Acemoglu *et al.* (2003) show that in fact weak institutions account for a large fraction of the macroeconomic volatility and dismal growth performance of many countries in Latin America and elsewhere. The wave of economic reforms of the 1980s and 1990s does not seem to have done much in terms of strengthening institutions for conflict management. Consistent with the "seesaw hypothesis" of Acemoglu *et al.* (2003), market-oriented reforms were often accompanied by new ways to engage in traditional predatory and redistributive activities.[17] Thus, fiscal shocks occasioned by external circumstances may in the future trigger again the inconsistent policies that characterized the delayed stabilizations of the past.

A particular obstacle for conflict management emphasized in this paper is the absence of accurate information regarding the costs of delayed reform.[18] This paper, as a large part of the political economy literature, is silent on how the relevant agents acquire and aggregate information. Providing adequate microfoundations with respect to information acquisition and aggregation to this and other political economy models is a challenge for future research.

[17] In the case of Peru in the 1990s, for instance, Bowen and Hollinger (2003) provide some examples of creative use of the judicial system and the tax agency for extortion, predation and redistribution. In the same period, privatizations in Argentina and Mexico and bank bailouts in Mexico offered notorious redistribution opportunities.

[18] In fact, as shown in an earlier version of this paper, very accurate information about the costs of inflation (in the sense of different support of the distribution of inflation costs for the two groups) leads to immediate agreement in equilibrium. Hsieh (2000) offers a similar result for the full information case.

Appendix A: Proofs

A rigorous demonstration for most of the content of Lemma 1 and Theorem 1 is provided by Fudenberg and Tirole (1986); here the proof is only sketched. The proof of Theorem 2 follows Nalebuff and Riley (1985).

Proof of Lemma 1:

If there is positive probability of delay, there is some $\bar{T} > 0$ (possibly infinite) such that for every $t < \bar{T}$ there is some positive probability that neither party has conceded, and the probability that neither party has conceded at or before $\bar{T}$ is zero. T_i is nonincreasing for the set of types such that $T_i(\theta_i) < \bar{T}$, and this set must be some interval $(\tilde{\theta}_i, \bar{\theta}]$, because increasing θ_i decreases the payoff to keep fighting but does not change the payoff to conceding. T_i must also be gapless on $[0, \bar{T})$: If there is a gap $[\beta', \beta) \subset [0, \bar{T})$ in T_i (that is, an interval over which group i concedes with probability zero), then there must be a gap (β', β) in T_j because for any θ_j it would be preferable to concede at time β' than at (β', β). But then any type of group i planning to concede at or near β would be better off conceding at time $(\beta' + \beta)/2$. Furthermore, T_i must be atomless on $(0, \bar{T})$: If there is some nonnegligible probability of group i conceding at time $0 < \eta < \bar{T}$ (a mass of types θ_i conceding at time η), then there will be some interval $(\eta - \epsilon, \eta)$ such that in that interval group j will prefer to wait for the discontinuous jump in the probability of group i conceding. But this would create a gap on $(0, \bar{T})$. By the same reasoning, if $\bar{T}$ is finite, T_i must be atomless on $(0, \bar{T}]$.

The previous discussion establishes that T_i is continuous and strictly decreasing on $(\tilde{\theta}_i, m_i]$, where m_i is the lowest type that concedes at time 0. Moreover, if $\bar{T}$ is finite, it follows that at least one party concedes before $\bar{T}$ with probability one, so $\min\{\tilde{\theta}_1, \tilde{\theta}_2\} = \underline{\theta}$, and if one party does not concede with probability one before $\bar{T}$, then $T(\theta_i) \geq \bar{T}$ on $[\underline{\theta}, \tilde{\theta}_i]$. If $\bar{T}$ is infinite, then $\tilde{\theta}_1 = \tilde{\theta}_2 = \underline{\theta}$ because otherwise at least one party would concede at ∞ with positive probability. But then the probability of concession by this party after t would get arbitrarily close to zero as t increases, and there would be some time t' such that the other party would prefer to concede for any pre-stabilization welfare loss smaller than or equal to $\underline{\theta}$ rather than keep resisting for a very long time.

Proof of Theorem 1:

We prove necessity; the proof of sufficiency is straightforward. From the properties of T_i given by Lemma 1 it follows that its inverse Φ_i is continuous and strictly increasing. Everywhere differentiability can be established following Lemma 1(iv) in Fudenberg and Tirole (1986). Equation (2.1) then follows from differentiating $V_i(t, T_j; \theta_i)$ with respect to t and making the derivative equal to zero at $T_i(\theta_i) = t$ (or $\Phi_i(t) = \theta_i$). Where this derivative positive, group i would prefer to wait longer to concede, while were it negative, group i would prefer to concede before $T_i(\theta_i)$.

Equation (2.2) is proved by contradiction. If both groups were conceding at time 0 with positive probability, any group would be better off by waiting infinitesimally to see if its rival concedes immediately. If any group were conceding at time 0 with probability one, there would not be a positive probability of delay.

To show that the system of ordinary differential equations given by (2.1) has a (unique) solution for each boundary condition satisfying (2.2), note that the mapping $\phi : (\underline{\theta}, \bar{\theta})^2 \to \Re^2$ from $\Phi = (\Phi_1, \Phi_2)$ to $\dot{\Phi} = (\dot{\Phi}_1, \dot{\Phi}_2)$ (the time derivatives) given by (2.1) is Lipschitz continuous. Thus, it has a unique solution through every $\Phi \in (\underline{\theta}, \bar{\theta})^2$; that is, a function $\xi(\cdot, \Phi) : J \to \Re^2$ where J is an open interval containing $t = 0$ such that $\xi(0, \Phi) = \Phi$ and $D_t\xi(t, \Phi) = \phi(\xi(t, \Phi))$. Moreover, the solution is continuous in t and Φ (see e.g. Hirsch and Smale 1974). Since f_1, f_2 are bounded, we can easily extend the dominion of ϕ to include the endpoint $\bar{\theta}$, so we have a unique solution for every Φ satisfying (2.2). Finally, since $\dot{\Phi}_i < 0$ for $\Phi_i \in (\underline{\theta}, \bar{\theta}]$ and $\Phi_j \in [\underline{\theta}, \bar{\theta}]$, with $\lim_{\Phi_i \downarrow \underline{\theta}} \dot{\Phi}_i = 0$, and every solution must lie in the compact set $[\underline{\theta}, \bar{\theta}]^2$, then $\xi(t, \Phi)$ is defined for all $t \geq 0$, and in fact as t goes to ∞, $\xi(t, \Phi)$ goes to the point $(\underline{\theta}, \underline{\theta})$. That is, in equilibrium the last time of concession is the same for both parties and is infinite.

Proof of Theorem 2:

Note first that, if $p_i > 0$, there is no equilibrium in which party i concedes at time 0 with probability one (conditional on party i being rational). In any such equilibria, party j would be persuaded that party i is irrational if concession does not occur at time 0, and then, conditional on being rational, it would concede with probability one after some arbitrarily small interval.[19] But then party i would have an incentive to wait until rational types of party j concede. Thus, in the perturbed model, if $p_1, p_2 > 0$, there are no equilibria in which either type, conditional on being rational, concedes at time zero. Moreover, if $p_i = 0$ and $p_j > 0$, there is still an equilibrium without delay in which party i concedes at time zero with probability one and party j never concedes.

To investigate equilibria with delay, using arguments similar to those of Lemma 1 and Theorem 1, we obtain an expression similar to equation (2.1), that we can write as:

$$\text{(A.1)} \qquad -\left[\frac{g_j(\Phi_j(t))}{G_j(\Phi_j(t))}\right] \frac{2(\alpha - 1/2)\tau r^{-1}}{\Phi_i(t) - (\alpha - 1/2)\tau} \frac{\partial \Phi_j(t)}{\partial t} = 1.$$

Changing variables and integrating in θ_j, we obtain a condition on the last concession time for a rational type of party j:

$$\begin{aligned} T_j(\underline{\theta}) &= \int_{\underline{\theta}}^{\bar{\theta}} \left[\frac{g_j(x)}{G_j(x)}\right] \frac{2(\alpha - 1/2)\tau r^{-1}}{\Phi_i(T_j(x)) - (\alpha - 1/2)\tau}\, dx \\ &< \int_{\underline{\theta}}^{\bar{\theta}} \left[\frac{g_j(x)}{G_j(x)}\right] \frac{2(\alpha - 1/2)\tau r^{-1}}{\underline{\theta} - (\alpha - 1/2)\tau}\, dx = -\ln(p_i \epsilon) \times \frac{2(\alpha - 1/2)\tau r^{-1}}{\underline{\theta} - (\alpha - 1/2)\tau}. \end{aligned}$$

That is, if $p_i > 0$, $T_j(\bar{\theta}) < \infty$. Now, $T_j(\underline{\theta}) = T_i(\underline{\theta})$, because if group i will not concede after some finite time, then group j has nothing to gain by waiting any longer, and vice versa.

Using (A.1):

$$\left[\frac{g_2(\Phi_2(t))}{G_2(\Phi_2(t))}\right] (\Phi_2(t) - (\alpha - 1/2)\tau) \frac{\partial \Phi_2(t)}{\partial \Phi_1(t)} = \left[\frac{g_1(\Phi_1(t))}{G_1(\Phi_1(t))}\right] (\Phi_1(t) - (\alpha - 1/2)\tau).$$

This implicitly defines a first order differential equation for θ_2 as a function of θ_1. Consider the following, strictly decreasing function:

$$\text{(A.2)} \qquad H_i(\theta_i) = \int_{\theta_i}^{\sigma_i} (g_i(x)/G_i(x))(x - (\alpha - 1/2)\tau)\, dx,$$

[19] Strictly speaking, there is no best response for party j which is enough to prove nonexistence of equilibrium.

where σ_i is some fixed real number in $(\underline{\theta}, \bar{\theta})$. Using the definition of H and the previous equation, we obtain a mapping from the type of group 1 that concedes at a given time to the type of group 2 that concedes at the same time:

$$H_2(\theta_2) = H_1(\theta_1) + c.$$

where c is an integration constant. Since the last concession time is the same for both groups, we have $c = H_2(\underline{\theta}) - H_1(\underline{\theta})$. Thus

$$H_2(\Phi_2(0)) - H_2(\bar{\theta}) = H_1(\Phi_1(0)) - H_1(\bar{\theta}) + M, \tag{A.3}$$

where $M \equiv H_1(\bar{\theta}) - H_1(\underline{\theta}) - H_2(\bar{\theta}) + H_2(\underline{\theta})$. A condition similar to (2.2) still holds in the perturbed model. It follows that $\Phi_2(0) < \bar{\theta}$ and $\Phi_1(0) = \bar{\theta}$ if and only if $M > 0$, and $\Phi_1(0) < \bar{\theta}$ and $\Phi_2(0) = \bar{\theta}$ if and only if $M < 0$.

To find M, integrating by parts in (A.2) we get:

$$H_i(\theta_i) = \Big[(x - (\alpha - 1/2)\tau) \ln(G_i(x))\Big[_{x=\theta_i}^{x=\sigma_i} - \int_{\theta_i}^{\sigma_i} \ln(G_i(x))\, dx.$$

Thus, if $p_1, p_2 > 0$,

$$M = (\underline{\theta} - (\alpha - 1/2)\tau) \ln(p_1/p_2) + \textstyle\int_{\underline{\theta}}^{\bar{\theta}} \ln(G_1(x)/G_2(x))\, dx. \tag{A.4}$$

If, say, $M > 0$, using (A.2) and (A.3) we obtain an expression to compute $\Phi_2(0)$:

$$\int_{\Phi_2(0)}^{\bar{\theta}} (g_2(x)/G_2(x))(x - (\alpha - 1/2)\tau)\, dx = M,$$

and we can compute $\Phi_1(0)$ similarly if $M < 0$. (Note that the integral in the LHS is strictly decreasing in $\Phi_2(0)$, and that it grows without bound as $\Phi_2(0)$ approaches $\underline{\theta}$, which guarantees existence and uniqueness.) Finally, if $p_1 > 0$ and $p_2 = 0$, $M = \infty$ and then there is no solution to (A.3) for $\Phi_2(0) > \underline{\theta}$; that is, there is no equilibrium with delay. Similarly, if $p_1 = 0$ and $p_2 > 0$, $M = -\infty$ and an equivalent argument holds.

Appendix B: Numerical methods

In order to solve the system given by (3.1) and (3.2), we employ the fourth-order Runge-Kutta method[20] (see e.g. Robertson 1991). The step size is $h = 0.033$, the time span $[0, 300]$, and the number of steps $n = 300/h$. Rewriting (3.1) as

$$\phi_i'(t) = \frac{\left(\phi_j(t) - \alpha + \frac{1}{2}\right)\left((1 - \phi_i(t)) - \gamma_i(1 - \phi_i(t))^2\right)}{(2\gamma_i(\phi_i(t) - 1) + 1)(50\alpha - 25)} \equiv \psi_i\left(t, \phi_i, \phi_j\right),$$

for $i = 1, 2$, $j \neq i$, we implement the method in the following way:

$$\phi_{i(k+1)} = \phi_{ik} + \tfrac{1}{6}\mu_{ik1} + \tfrac{1}{3}\mu_{ik2} + \tfrac{1}{3}\mu_{ik3} + \tfrac{1}{6}\mu_{ik4},$$

where

$$\begin{aligned}
\mu_{ik1} &= h\,\psi_i\left(t_k, \phi_{ik}, \phi_{jk}\right),\\
\mu_{ik2} &= h\,\psi_i\left(t_k + \tfrac{1}{2}h, \phi_{ik} + \tfrac{1}{2}\mu_{ik1}, \phi_{jk} + \tfrac{1}{2}\mu_{jk1}\right),\\
\mu_{ik3} &= h\,\psi_i\left(t_k + \tfrac{1}{2}h, \phi_{ik} + \tfrac{1}{2}\mu_{ik2}, \phi_{jk} + \tfrac{1}{2}\mu_{jk2}\right),\\
\mu_{ik4} &= h\,\psi_i\left(t_k + h, \phi_{ik} + \mu_{ik3}, \phi_{jk} + \mu_{jk3}\right),
\end{aligned}$$

with $\phi_{10} = 2$ and ϕ_{20} given implicitly by (3.2). With this data we can approximate the expected time of stabilization and the expected welfare of both parties.

Expected time of stabilization

Let $S(T) \equiv \Pr\{\min(T_1(\theta_1), T_2(\theta_2)) \leq T\}$. Then, the expected time of stabilization is

$$E(T) \;=\; \int_0^\infty (1 - S(T))dT = \int_0^\infty F_1(\phi_1(T))\, F_2(\phi_2(T))\, dT.$$

We can approximate $E(T)$ using the trapezoidal rule as

$$h\left(\tfrac{1}{2}F_1(\phi_{10})\, F_2(\phi_{20}) + \tfrac{1}{2}F_1(\phi_{1n})\, F_2(\phi_{2n}) + \textstyle\sum_{k=1}^{n-1} F_1(\phi_{1k})\, F_2(\phi_{2k})\right).$$

Thus, $E(T)$ is approximated by h times

$$\begin{aligned}
&\tfrac{1}{2}\left(\lambda_1(\phi_{10} - 1)^2 + (1 - \lambda_1)(\phi_{10} - 1)\right)\left(\lambda_2(\phi_{20} - 1)^2 + (1 - \lambda_2)(\phi_{20} - 1)\right)\\
&+\tfrac{1}{2}\left(\lambda_1(\phi_{1n} - 1)^2 + (1 - \lambda_1)(\phi_{1n} - 1)\right)\left(\lambda_2(\phi_{2n} - 1)^2 + (1 - \lambda_2)(\phi_{2n} - 1)\right)\\
&\qquad + \textstyle\sum_{k=1}^{n-1}\left(\lambda_1(\phi_{1k} - 1)^2 + (1 - \lambda_1)(\phi_{1k} - 1)\right)\\
&\qquad\qquad\qquad \left(\lambda_2(\phi_{2k} - 1)^2 + (1 - \lambda_2)(\phi_{2k} - 1)\right).
\end{aligned}$$

[20] At each step, the local truncation error is of the order $O\left(h^5\right)$, and the overall global truncation error e_k is of the order $|e_k| = O\left(h^4\right)$, for $k = 1, 2, \ldots, n$.

Expected welfare

Group i's expected welfare is

$$E_i\left[V_i\left(t, T_j\left(\cdot\right); \theta_i\right)\right]$$

$$= \int_{\underline{\theta}}^{\overline{\theta}} V_i\left(t, T_j\left(\cdot\right); \theta_i\right) dF_i\left(\theta_i\right)$$

$$= \int_{\underline{\theta}}^{\overline{\theta}} \left\{\Pr\left\{T_j\left(\theta_j\right) \geq t\right\} \times \left[\int_{x=0}^{x=t} U_i^D e^{-rx} dx + \int_{x=t}^{x=\infty} U_i^L e^{-rx} dx\right] \right.$$
$$+ \int_{\left\{\theta_j : T_j\left(\theta_j\right) < t\right\}} \left[\int_{x=0}^{x=T_j\left(\theta_j\right)} U_i^D e^{-rx} dx \right.$$
$$\left.\left. + \int_{x=T_j\left(\theta_j\right)}^{x=\infty} U_i^W e^{-rx} dx\right] dF_j\left(\theta_j\right)\right\} dF_i\left(\theta_i\right)$$

$$= \int_0^{\infty} \left[F_j\left(\phi_j\left(t\right)\right)\left(-\left(\tfrac{\tau}{2} + \phi_i\left(t\right)\right)\left(\left(1 - e^{-rt}\right)/r\right) - \alpha\tau e^{-rt}/r\right)\right.$$
$$+ \int_0^t \left(-\left(\tfrac{\tau}{2} + \phi_i\left(t\right)\right)\left(\left(1 - e^{-rx}\right)/r\right) - \left(1 - \alpha\right)\tau e^{-rx}/r\right)$$
$$\left. F_j'\left(\phi_j\left(x\right)\right)\left|\phi_j'\left(x\right)\right| dx\right] F_i'\left(\phi_i\left(t\right)\right)\left|\phi_i'\left(t\right)\right| dt.$$

We can approximate the expected welfare as

$$\left[1 - F_i\left(\phi_{i0}\right)\right]\left(\left(-\alpha\right)/r\right) + \left[1 - F_j\left(\phi_{j0}\right)\right]\left(\left(-\left(1 - \alpha\right)\right)/r\right)$$
$$+ \sum_{k=1}^n \left[F_j\left(\phi_{jk}\right)\left(-\left(\tfrac{\tau}{2} + \phi_{ik}\right)\left(\left(1 - e^{-rkh}\right)/r\right) - \alpha\tau e^{-rkh}/r\right)\right.$$
$$+ \sum_{l=1}^k \left(-\left(\tfrac{\tau}{2} + \phi_{ik}\right)\left(\left(1 - e^{-rlh}\right)/r\right) - \left(1 - \alpha\right)\tau e^{-rlh}/r\right)$$
$$\left. F_j'\left(\phi_{jl}\right)\left|\phi_{jl} - \phi_{j(l-1)}\right|\right] F_i'\left(\phi_{ik}\right)\left|\phi_{ik} - \phi_{i(k-1)}\right|.$$

Thus, group i's expected welfare is approximated by

$$\left[1 - \left(\lambda_i\left(\phi_{i0} - 1\right)^2 + \left(1 - \lambda_i\right)\left(\phi_{i0} - 1\right)\right)\right]\left(\left(-\alpha\right)/r\right)$$
$$+ \left[1 - \left(\lambda_j\left(\phi_{j0} - 1\right)^2 + \left(1 - \lambda_j\right)\left(\phi_{j0} - 1\right)\right)\right]\left(\left(-\left(1 - \alpha\right)\right)/r\right)$$
$$+ \sum_{k=1}^n \left[\left(\lambda_j\left(\phi_{jk} - 1\right)^2 + \left(1 - \lambda_j\right)\left(\phi_{jk} - 1\right)\right)\right.$$
$$\left(-\left(\tfrac{\tau}{2} + \phi_{ik}\right)\left(\left(1 - e^{-rkh}\right)/r\right) - \alpha\tau e^{-rkh}/r\right)$$
$$+ \sum_{l=1}^k \left(-\left(\tfrac{\tau}{2} + \phi_{ik}\right)\left(\left(1 - e^{-rlh}\right)/r\right) - \left(1 - \alpha\right)\tau e^{-rlh}/r\right)$$
$$\left.\left(2\lambda_j\left(\phi_{jl} - 1\right) + \left(1 - \lambda_j\right)\right)\left|\phi_{jl} - \phi_{j(l-1)}\right|\right]$$
$$\times \left(2\lambda_i\left(\phi_{ik} - 1\right) + \left(1 - \lambda_i\right)\right) F_i'\left(\phi_{ik}\right)\left|\phi_{ik} - \phi_{i(k-1)}\right|.$$

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