CESifo WORKING PAPERS

7607
2019

April 2019

Tax decentralization notwithstanding regional disparities

Antonio Andrés Bellofatto, Martín Besfamille

CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editor: Clemens Fuest
www.cesifo-group.org/wp

An electronic version of the paper may be downloaded
· from the SSRN website: www.SSRN.com
· from the RePEc website: www.RePEc.org
· from the CESifo website: www.CESifo-group.org/wp

CESifo *Working Paper No. 7607*
Category 1: Public Finance

Tax decentralization notwithstanding regional disparities

Abstract

In assessing the desirability for tax decentralization reforms, a dilemma between efficiency and redistribution emerges. By limiting the ability of the central government to redistribute resources towards regions in financial needs, decentralization curbs incentives for excessive subnational spending and enhances fiscal discipline, but may also widen interregional disparities by triggering tax competition for mobile tax bases. We provide a formal treatment of this trade-off, and shed light on the optimal degree of fiscal decentralization. We find that tax decentralization can be optimal even under Rawlsian social preferences which only weight the welfare of the poorest region in the federation.

JEL-Codes: H770.

Keywords: fiscal federalism, tax competition, regional disparities.

Antonio Andrés Bellofatto
School of Economics
University of Queensland
Australia - Brisbane St Lucia, QLD 4072
a.bellofatto@uq.edu.au

Martín Besfamille
Instituto de Economía
Pontificia Universidad Católica de Chile
Macul / Santiago / Chile
mbesfamille@uc.cl

January 7, 2019
N. Pastrián provided outstanding research assistance. We also thank A. Aguirre, E. Appelbaum, P. Azar, L. Basso, M. Bérgolo, R. Bojilov, W. Boning, G. Brusco, S. Bucovetsky, A. Corvalan, B. Domínguez, P. Egger, A. Esteller-Moré, N. Figueroa, D. Foremny, U. Glogowsky, S. Grant, N. Grau, A. Haufler, M. Hayashi, S. Heinsalu, J. Hines, Y. Iwamoto, J. Joffre-Monseny, T. Kam, I. King, A. Klemm, M. Köthenbürger, N.-P. Lagerlöf, M. Mansour, M. Mardan, E. Mattos, D. Montolio, L. Muinelo, M. Nose, H. Ogawa, E. Pasten, M. Risch, E. Silva, J. Slemrod, A. Solé-Ollé, J.P. Montero, H. Silva, P. Sorribas-Navarro, K. Staal, G. Stefanidis, M. Stimmelmayr, M. Stuart, D. Suverato, T. Velayudhan, Y.Waki, G.Wamser, C. Yamaguchi, G. Zhu, and E. Zilberman for their comments, as well as participants of the 72nd Annual Congress of the IIPF (2016), 49as Jornadas Internaciones de Finanzas Públicas (2016), Mini TOI (2016), SECHI (2017), Workshop on Fiscal Federalism (2018), and seminars at ANU, Banco Central de Chile, DII-Universidad de Chile, IMF, IECONUdelaR, Institut d'Economia de Barcelona, KOF-ETH (Zürich), Ludwig-Maximilians Universität, Michigan, Pontificia Universidad Católica de Chile, UQ, Univ. of Tokyo and York Univ. M. Besfamille acknowledges financial support from FONDECYT Grant #1150170 and from the Complex Engineering Systems Institute (CONICYT-PIA-FB0816). The usual disclaimer applies.

1 Introduction

In the unitary state of Chile, fiscal decentralization reforms—broadly defined as the devolution of tax and expenditure powers to subnational governments—rank high in the policy agenda.[1] At the same time, this country has one of the highest degrees of regional disparities among the OECD world.[2] Should Chile's regional configuration be regarded as a case *for* or *against* decentralization policies?

This paper aims to contribute to these sorts of discussions. We do so by focusing on a common dilemma between efficiency and redistribution when assessing the desirability for decentralization reforms. On the one hand, by limiting the ability of the central government to redistribute resources towards regions in financial needs, decentralization curbs incentives for excessive subnational spending and enhances fiscal discipline (see, e.g., Qian and Roland (1998)). On the other hand, by triggering tax competition for mobile tax bases, decentralized systems may widen interregional disparities. In a famous essay, Rémy Prud'homme puts forward this distributional issue:[3]

> *"Is a decentralized system likely to be more effective at reducing interjurisdictional disparities than a centralized system? The answer is no.* (A decentralized system) *is likely to induce a vicious circle; richer jurisdictions will have large tax bases (whatever tax bases are chosen), with tax rates that are either the same or lower than other, less rich jurisdictions. In the first instance, they will collect more taxes and therefore will be able to provide more local public services. In the second, they will offer the same services at lower tax rates. In both cases, these localities will be preferred by businesses and households, which will choose to settle there, enlarging the tax base and increasing the gap in income between regions. Decentralization can therefore be the mother of segregation."* (Prud'homme (1995), p. 203)

In this paper we provide a formal treatment of this trade-off balancing equity and efficiency and, through those lens, we shed light on the optimal degree of fiscal decentralization. Our main result is that fiscal decentralization, despite increasing regional

[1] For example, president Bachelet's second administration (2014-2018) put forward a "Decentralization Agenda" aiming at transferring power to lower level governments (see https://chile.gob.cl/ocde).

[2] In 2013, the level of regional GDP concentration in Chile was the second highest in the OECD. See OECD (2017).

[3] Empirical evidence on the impact of fiscal decentralization on regional disparities is mixed (see Martinez-Vazquez et al. (2017) for a survey). For example, Rodríguez-Pose and Gill (2004) find a positive link between decentralization and regional divergence, while Lessmann (2012) and Kyriacou et al. (2015) argue that the sign of the effect depends on the level of economic development and on government quality, respectively.

disparities, can be optimal even under Rawlsian social preferences which only weight the welfare of the poorest region in the federation. Accordingly, the inherent inefficiencies of centralization may dwarf one of the key "dangers" of decentralization articulated by Prud'homme (1995).

We develop a model of a federation with benevolent governments at all levels, i.e., central and regional. The federation is composed of two regions which are heterogeneous across their capital endowment: the "rich" region has a larger capital endowment than the "poor" region. Capital serves as the tax base, and it is imperfectly mobile across regions. Regional governments decide upon the provision of a binary local public good, or project. If the project is initiated, it may or may not require an additional round of financing to be completed. Each regional government has just enough resources to initiate a local project, but needs additional tax revenue—either from local tax collections or from the central government—if the project is to be refinanced. In this sense, public expenditure is already fully decentralized, and our analysis concentrates on whether taxation authority should be decentralized or not.[4]

We consider two institutional regimes, *tax decentralization* and *tax centralization*, depending on whether regional governments or the central authority make the decision on refinancing projects.[5] Under tax decentralization, each regional government decides upon continuing projects in financial needs by raising local capital taxes. Under tax centralization, instead, the central government decides whether or not to bailout incomplete projects by means of a uniform national capital tax.

Our model formalizes the aforementioned trade-off between interregional inequality and efficiency of subnational spending. Namely, tax centralization dampens regional disparities, but can lead to overprovision of local projects. Tax decentralization, in contrast, amplifies the gap between the rich and the poor region, but eliminates excessive local spending. Additionally, our model singles out other types of inefficiencies emerging from the decentralized regime. That is, local projects can in fact be underprovided with respect to the first best, and initiated projects are subject to refinancing distortions and deadweight losses associated with tax competition.

We focus on how the optimal regime choice is shaped by the interplay of three fundamentals: the difference in initial capital endowments across regions, the social aversion to interregional inequalities, and the probability of experiencing a refinancing shock. The

[4]Our focus on tax decentralization is motivated by the fact that tax autonomy is much less decentralized than expenditure authority in the data. See, e.g., OECD/KIPF (2016).

[5]Brueckner (2009) refers to these regimes as full and partial decentralization, respectively.

first two parameters drive, respectively, the degree of ex ante interregional disparities, and the social welfare weight on regional convergence. The third parameter determines the expected completion time of a project and, thus, the likelihood with which centralization and decentralization generate different outcomes ex post (recall that the rules of our decentralization regimes only differ at the refinancing stage).

The analysis starts by characterizing the optimal regime under a utilitarian criterion, and over the entire range of refinancing shock probabilities. Two major results are drawn. First, small initial disparities can *favor* tax decentralization vis-à-vis centralization. Essentially, thanks to a larger tax base, a higher capital endowment in the hands of the rich region allows it to lower tax distortions in its jurisdiction. We show that, for low levels of regional heterogeneity, this effect is first-order relative to other distortions, and makes expected welfare under tax decentralization increasing in the degree of regional disparities. Second, large disparities do not necessarily eliminate decentralization optimality. We pin down a plausible necessary and sufficient condition for that to be the case, which is tied to the relative net expected return on initiated projects under each regime in the poor region.

We then evaluate the optimal regime choice under different welfare criteria. Since tax centralization reduces ex ante inequalities, higher social aversion for interregional disparities typically favors tax centralization over decentralization (all else equal). But somewhat paradoxically, even a Rawlsian planner would adopt the decentralized regime under some conditions. More precisely, as long as regions are relatively homogeneous and the refinancing probability is high enough, tax decentralization dominates for *any* welfare criterion, including one which only weights welfare of the poorest region in the federation.

The reason for this result is twofold. First, a high probability of refinancing brings down the net expected return of a local project. Hence, overinvestment inefficiencies under centralization are severe relative to underinvestment issues under decentralization. Second, when regions are sufficiently homogeneous, the poor region would need to fund a large fraction of central bailouts, while facing small tax competition distortions (as regions levy similar tax rates). Therefore, small disparities also favor the decentralized regime from the perspective of the poor.

Related Literature. Our paper contributes to the vast theoretical literature on optimal fiscal federalism initated by Musgrave (1959) and Oates (1972).[6] Recent strands of this literature studied how different types of interregional externalities shape the optimal allocation of tax and expenditure powers across government levels. For example, Lockwood (2002) and Besley and Coate (2003) focus on the role of interregional spillovers, while Janeba and Wilson (2011) and Hatfield and Padró i Miquel (2012) look at fiscal externalities associated with tax competition. In this paper, the optimal degree of decentralization is determined by the social concern for regional disparities, and by the inefficiencies emerging from two types of externalities: tax competition (under tax decentralization) and a *common pool* fiscal externality due to central bailouts (under tax centralization).[7] Moreover, differently from the works just cited, we study optimal *tax* rather than *expenditure* decentralization, and we provide a purely normative contribution by abstracting from political economy constraints.

Technically, our model builds on Bellofatto and Besfamille (2018), where we study the optimal degree of fiscal decentralization in the presence of regional state capacity imperfections. Three main differences are worth highlighting. First, in this paper we introduce interregional heterogeneity. Second, here we consider a richer normative criteria that explicitly accounts for equity considerations. Third, we abstract from regional state capacity imperfections to focus on the impact of regional disparities on the optimal decentralization regime.

By featuring potential bailouts from the central government, this paper also relates to the literature on the optimality of soft vs. hard budget constraints in federations, including Qian and Roland (1998), Köthenbürger (2004), and Besfamille and Lockwood (2008), among others. All of these works focus on environments with identical regions.

Our paper also connects with the literature on asymmetric capital tax competition, following the line of the seminal contributions of Bucovetsky (1991) and Wilson (1991).[8] A central result in those papers is the so-called "advantage of smallness." Namely, "small" regions levy lower taxes than "large" regions in equilibrium, which ultimately leads to higher welfare for the residents of the small region. One notable difference with Bucovetsky (1991) and Wilson (1991) is that regional asymmetries in those works come from differences in population sizes, and not from differences in capital endowments per capita as in this paper (for this reason, we prefer employing the "rich-poor" rather than the "large-

[6] See Oates (1999) for a survey.
[7] See Wildasin (1997) and Goodspeed (2002).
[8] Wilson (1999) provides a thorough survey of the tax competition literature.

small" taxonomy).[9] DePater and Myers (1994) and Peralta and van Ypersele (2005) consider capital tax competition environments in which regions not only differ across population sizes, but also across capital endowments per resident. A central feature of these models is the presence of a "pecuniary externality" (or "terms of trade effect") through which regions can manipulate the price of capital. In our environment, though, such pecuniary externality is absent because the marginal productivity of capital is constant.

Another key difference with the bulk of the literature on tax competition is that, in our framework, public expenditure does not adjust residually. Rather, the level of public spending is *fixed* at the tax competition stage. Hence, when regions engage in tax competition in our model, the poor region ends up setting a higher tax rate than the rich, simply because the tax base of the latter is larger. This rationalizes the mechanism hypothesized by Prud'homme (1995), which goes against the "advantage of smallness" result.[10]

Finally, Cai and Treisman (2005) show that regional competition (over infrastructure spending and taxes) to attract mobile capital can exacerbate initial disparities across regions. Janeba and Todtenhaupt (2018) evaluate how such polarization effect is influenced by the levels of initial government debt. Unlike in those papers, we compare the relative merits of centralized and decentralized regimes.

Layout of the paper. The layout of the remainder of the paper is as follows. Section 2 lays out the model. In Sections 3 and 4 we focus the tax centralization and the tax decentralization regimes, respectively, by analyzing equilibrium outcomes and inefficiencies under each regime. Section 5 characterizes the optimal regime, Section 6 presents numerical simulations of the model, and Section 7 concludes. Most proofs are relegated to the Appendix.

2 The Model

2.1 Preliminaries

The economy lasts for four periods, $t = \{0, 1, 2, 3\}$, and is composed of two regions indexed by $\ell \in \{p, r\}$. Each region is populated by a representative agent, or resident,

[9] In the recent work of Mongrain and Wilson (2018), regional size differences are driven by the number of domestic firms ex ante. The authors focus on the relative merits of preferential tax treatment of different types of firms.

[10] Similarly, Itaya et al. (2008) find that, via pecuniary externalities, small regions can end up setting tax rates above the taxes set by large regions.

which is endowed with κ_ℓ units of capital. Regions only differ across the capital endowments of their residents. Specifically, we assume that $\kappa_r \geq \kappa_p > 0$, and henceforth refer to region p and r as the "poor" and the "rich" region, respectively. Residents are immobile, but capital is imperfectly mobile across regions: in the lines of Persson and Tabellini (1992), a resident of a region that invests f units of capital in the other region incurs a mobility cost $f^2/2$ in terms of utils. The national stock of capital is denoted by $\kappa \equiv \kappa_p + \kappa_r$, and the ex ante level of heterogeneity in the economy is measured by $\Delta\kappa \equiv \kappa_r - \kappa_p$.

The economy should be thought of as a federation with two levels of government, namely, a central government, and two regional governments. Each level of government is benevolent and chooses policies to maximize the utility of its resident over the four periods. Residents are risk-neutral, do not discount future payoffs, and derive utility from the consumption of two types of goods: a private good, and a local public good provided by the regional government. The private good is the numéraire and it is produced in the last period by competitive firms. Capital is the only production input and units are chosen so that one unit of capital produces one unit of the private good.

Local public goods, or "projects," are binary in nature, i.e., they are either provided at a predetermined scale or they are not provided (reasonable examples encompass large infrastructure projects, such as bridges, roads, or tunnels). A project carries an initiation cost $c_0 \geq 1$ in terms of the numéraire, and with probability $(1-\pi) \in [0,1]$ requires an additional cost c to be completed. The refinancing cost c not only incorporates the technical cost of completion, but also other utility costs associated with the delay of the project. If no refinancing is needed, a project launched in region ℓ yields social benefit b within that region at the end of the initiation period. If refinancing is needed and met, the project also yields b to the region, but once the economy ends. Otherwise, the social benefit of the project is nil. We refer to $(1-\pi)$ as the probability of experiencing a negative *refinancing shock*.

The refinancing cost c is distributed according to the probability density function $h(c)$ with full support on $[0, b]$. By construction, $c \leq b$; otherwise, continuation would never be optimal. The realizations of the refinancing shocks (i.e., whether projects are completed or not at the end of the initiation period) are independent and observable across regions.

2.2 Tax Regimes

Regional governments have just enough resources to pay for the initiation cost c_0. The continuation cost c should be financed via tax revenues. We consider two institutional regimes, depending on which level of government makes the refinancing decision (if needed) and funds the continuation cost. Under *tax centralization*, TC, the central government decides upon refinancing incomplete projects through a uniform tax τ on the national stock of capital.[11] Under *tax decentralization*, TD, continuation decisions are made by regional governments. To refinance, local authorities use a per unit tax levied on capital invested in their regions at the rate τ_ℓ. We assume that the choice of the tax regime is taken by a national Congress.

2.3 Timing

Decisions unfold as summarized in Figure 1. Given a preexisting level of regional heterogeneity (captured by $\Delta\kappa$), the Congress chooses between tax centralization and tax decentralization at the beginning of $t = 0$. At the end of that period, the refinancing cost c (common across regions) is realized. Period $t = 1$ is also divided into two subperiods: first, regional governments simultaneously decide whether or not to initiate projects, and subsequently the refinancing shock is realized. With probability π, projects generate payoff b at the end of $t = 1$.

At $t = 2$, central or regional governments (depending on the institutional regime in place) decide whether to shut down or continue projects in financing needs, and taxes are set accordingly at $t = 3$. Once taxes are set, capital owners invest in the region(s) with the highest net return(s), central or regional governments raise their taxes, production takes place, and private consumption occurs. Projects which are completed late yield social benefit b at the end of period $t = 3$.

It is worth highlighting that uncertainty around refinancing needs is unraveled sequentially: at the end $t = 0$ the size of the refinancing cost is realized, and at the end of $t = 1$ the outcome of the refinancing shock materializes. This modeling choice generates a realistic feature. Namely, that the Congress faces more uncertainty than local governments regarding the returns of local projects.

2.4 Welfare Criteria

The Congress chooses the tax regime that maximizes a measure of social welfare across regions. Specifically, let $W^{\mathcal{I}}_{\ell,t}$ denote the equilibrium level of expected welfare of region

[11] Our formulation of tax centralization is equivalent to a framework in which accepting or not a central bailout is an option for the regions. The reason is that accepting a bailout would be a dominant strategy.

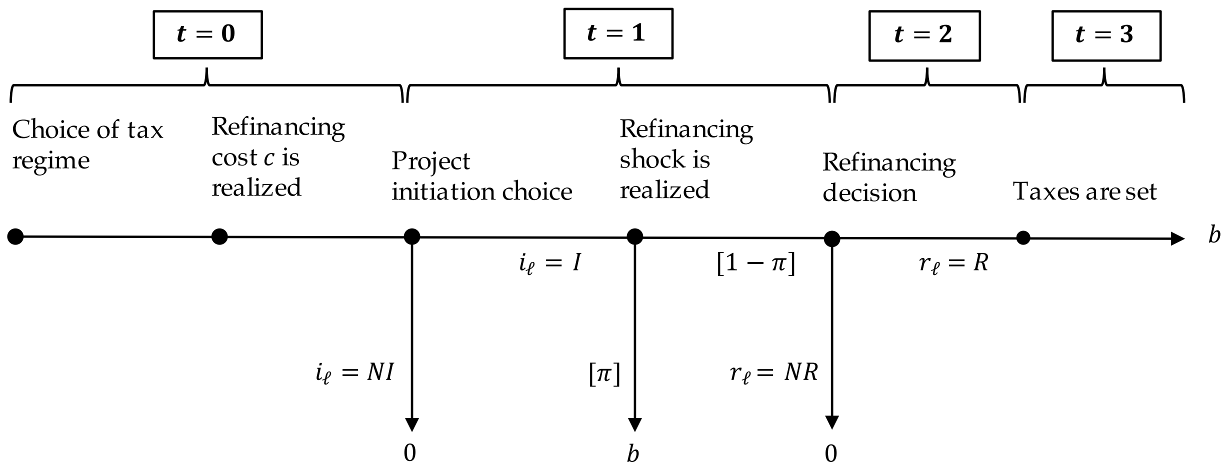


Figure 1: Timing in the model. Values in terminal nodes represent the benefit of the project. $i_\ell = I$ $(= NI)$ if region ℓ initiates (does not initiate the project). $r_\ell = R$ $(= NR)$ if region ℓ refinances (does not refinance the project).

$\ell \in \{p, r\}$ at period t under the tax regime $\mathcal{I} \in \{TC, TD\}$. The Congress at $t = 0$ chooses the institutional regime $\mathcal{I} \in \{TC, TD\}$ that maximizes

$$U_0^{\mathcal{I}} = \frac{\alpha}{2} W_{r,0}^{\mathcal{I}} + \left(1 - \frac{\alpha}{2}\right) W_{p,0}^{\mathcal{I}}, \tag{1}$$

where $\alpha \in [0, 1]$.

The social preference for redistribution towards the poor is inversely related to α. Two values of this parameter will be of particular interest for our analysis. First, under $\alpha = 1$, the Congress is utilitarian and, given risk neutrality, is only concerned about efficiency. Second, $\alpha = 0$ gives rise to a Rawlsian Congress which only values the welfare of the poor region in the federation.

3 Tax Centralization

This section studies the outcomes and inefficiencies of the centralized tax regime. We start by analyzing the decisions of the central government in the last two periods, i.e., when the central government decides upon marginally financing local projects via uniform capital taxes. Given that central taxation is non-distortionary (because taxation is uniform and moving capital is costly), and that $c \leq b$, at $t = 2$ the central government will fund all projects in refinancing needs, henceforth denoted by $n \in \{0, 1, 2\}$. Therefore, in the last period the central government sets a uniform tax $\tau(n)$ so that $\tau(n)\kappa = nc$.

Since taxation is uniform, the project initiation decision of a given region may ultimately impact the welfare of the other region in the federation. Thus, when making the project initiation choice at $t = 1$, a simultaneous game between regions arises. Region ℓ's expected welfare at the beginning of $t = 1$ is given by

$$W_{\ell,1}^{TC}(i_\ell, i_m) = \kappa_\ell \left(1 - \mathbb{E}_n \tau(n)\right) + \mathbb{1}_{\{i_\ell = I\}}[b - c_0], \tag{2}$$

where $\mathbb{E}_n$ is the expectation over n, i_m is the investment decision chosen by region $m \neq \ell$, and $\mathbb{1}_{\{i_\ell = I\}}$ is an indicator function which equals 1 if region ℓ has initiated the project. Using that

$$\mathbb{E}_n \tau(n) = \frac{c}{\kappa}(1 - \pi)\left(\mathbb{1}_{\{i_\ell = I\}} + \mathbb{1}_{\{i_m = I\}}\right),$$

equation (2) can be written as

$$W_{\ell,1}^{TC}(i_\ell, i_m) = \kappa_\ell + \mathbb{1}_{\{i_\ell = I\}}\left[b - c_0 - (1 - \pi)\frac{\kappa_\ell}{\kappa}c\right] - \mathbb{1}_{\{i_m = I\}}(1 - \pi)\frac{\kappa_\ell}{\kappa}c\cdot \tag{3}$$

By (3), we can define the refinancing cost threshold

$$c_\ell^{TC}(\kappa_\ell, \pi) \equiv \frac{\kappa}{\kappa_\ell}\frac{b - c_0}{1 - \pi}, \tag{4}$$

which makes region ℓ's net expected welfare from initiating a project equal to zero, given the probability of a negative refinancing shock $(1 - \pi)$, and given regional capital κ_ℓ. The following proposition characterizes the project initiation decision of the region, and follows naturally from the definition of c_ℓ^{TC}.

Proposition 1. *Consider the project initiation game under TC. Given (c, κ_ℓ, π), project initiation takes place in region ℓ if and only if $c \leq c_\ell^{TC}(\kappa_\ell, \pi)$.*

National taxation generates a *common-pool fiscal externality*:[12] any given region is negatively affected by the possibility of an incomplete project in the other region. The impact of this externality across regions is asymmetric, due to differences in tax bases. That is, as evident from (3), region ℓ only pays a fraction κ_ℓ/κ of the cost of refinancing any incomplete project. As a consequence, the rich region follows a tighter investment rule than the poor, which is reflected by $c_r^{TC} \leq c_p^{TC}$. Initiation equilibria is shown in Figure 2.

[12]See Wildasin (1997) and Goodspeed (2002).

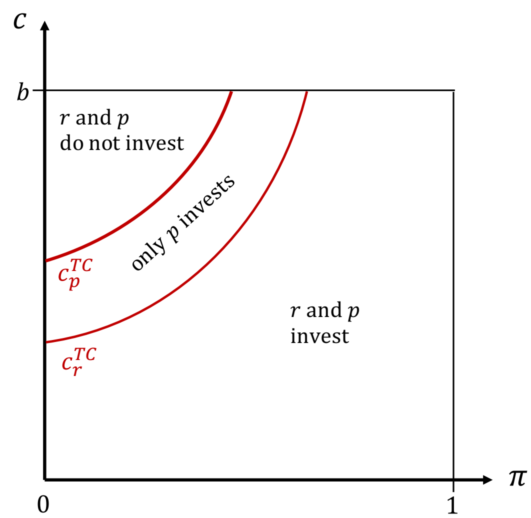


Figure 2: Initiation equilibria under TC.

3.1 Inefficiencies

To isolate the sources of inefficiencies emerging under tax centralization, we begin by characterizing the outcomes of a "first best," which serves as our benchmark for efficiency. Suppose that each region fully internalizes the cost of refinancing an incomplete project, and that it meets refinancing costs without generating distortions. Under this first best scenario, region ℓ's expected welfare at $t = 1$ is given by

$$W^*_{\ell,1}(i_\ell) = \kappa_\ell + \mathbb{1}_{\{i_\ell = I\}}\left[b - c_0 - (1-\pi)c\right],$$

where we used that refinancing is always optimal under the first best. It follows that region ℓ would initiate a project at $t = 1$ if and only if (c, π) satisfy $c \leq c^*(\pi)$, where

$$c^*(\pi) \equiv \frac{b - c_0}{1 - \pi}.$$

Clearly, $c^* \leq c_\ell^{TC}$ for all (κ_ℓ, π) and $\ell \in \{p, r\}$. This fact combined with $c_r^{TC} \leq c_p^{TC}$ prove the next corollary:

Corollary 1. *Under TC, equilibrium outcomes can be inefficient for two reasons:*

1. *Both regions invest in equilibrium when it is inefficient to do so.*
2. *Only the poor region invests in equilibrium when it is inefficient to do so.*

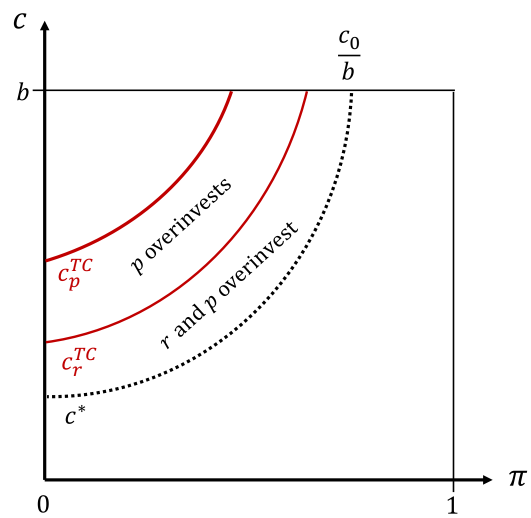


Figure 3: Inefficiencies under TC.

Due to the common-pool fiscal externality, inefficiencies under TC involve two types of overinvestment distortions. Such inefficiencies are shown in Figure 3. When the refinancing cost is relatively low, both regions initiate too many projects. When the refinancing cost is relatively high, the rich region does not initiate: this way, the rich can, at least, avoid the cost of refinancing a large fraction of its own potential bailout. Investment inefficiencies require that π be sufficiently low; if $\pi \geq c_0/b$, TC replicates the first best for all c.

We should also note that when $\kappa_r \to \infty$, $c_r^{TC} \to c^*$, and initiation decisions become efficient for the rich. The reason is that, as the share of national capital in the hands of the rich converges to one, this region fully internalizes the cost of its bailout for all (c, π). Conversely, initiation decisions become more distorted for the poor, because its share on the cost of bailouts converges to zero.

4 Tax Decentralization

In this section we analyze the regime of tax decentralization. In this case, a three-stage simultaneous game between regions emerges. At $t = 1$, regional governments take the initial investment decision. At $t = 2$, the refinancing decision is made, given the realization of the refinancing shocks. Finally, at $t = 3$, refinancing is achieved by levying taxes on regional capital. Next we solve this game by backwards induction, and characterize the tax decentralization regime in terms of outcomes and inefficiencies.

4.1 Equilibrium in Tax Rates

Given a profile of regional tax rates (τ_p, τ_r), a resident of region $\ell \in \{p, r\}$ allocates her capital endowment across regions by solving the following problem:

$$\max_{h_\ell, f_{\ell m}} \; h_\ell \,(1 - \tau_\ell) + f_{\ell m}\,(1 - \tau_m) - \frac{1}{2}(f_{\ell m})^2 \tag{5}$$

subject to

$$h_\ell + f_{\ell m} = \kappa_\ell, \quad \text{and} \quad f_{\ell m} \geq 0,$$

where h_ℓ is the level of capital invested in region ℓ, and $f_{\ell m}$ is the capital flow from region ℓ to region $m \neq \ell$. It is straightforward to show that the solution to (5) gives

$$f_{\ell m} = \max\{0, \tau_\ell - \tau_m\}, \tag{6}$$

so that the size of capital flows across regions is being pinned down by the tax differential. Based on (6), we can now characterize Nash equilibria of the tax determination subgame in period $t = 3$.

Proposition 2. *Consider the tax determination subgame under TD. Nash equilibria are as follows:*

1. *If only region ℓ refinances an incomplete project, it sets the tax rate $\hat{\tau}^I_\ell \equiv \frac{1}{2}\left[\kappa_\ell - \sqrt{\kappa_\ell^2 - 4c}\right]$.*
2. *If both regions refinance incomplete projects, the unique symmetric Nash equilibrium in pure strategies $(\hat{\tau}^{II}_p, \hat{\tau}^{II}_r)$ is such that $\hat{\tau}^{II}_r < \hat{\tau}^{II}_p$.*

Proof. See Appendix A.1. □

Figure 4 illustrates the possible equilibria in tax rates, depending on the profile of refinancing decisions across regions. In this plot, we use that the reaction function of region ℓ when seeking refinancing is given by

$$\tau_\ell(\tau_m) = \frac{1}{2}\left[\kappa_\ell + \tau_m - \sqrt{(\kappa_\ell + \tau_m)^2 - 4c}\right], \tag{7}$$

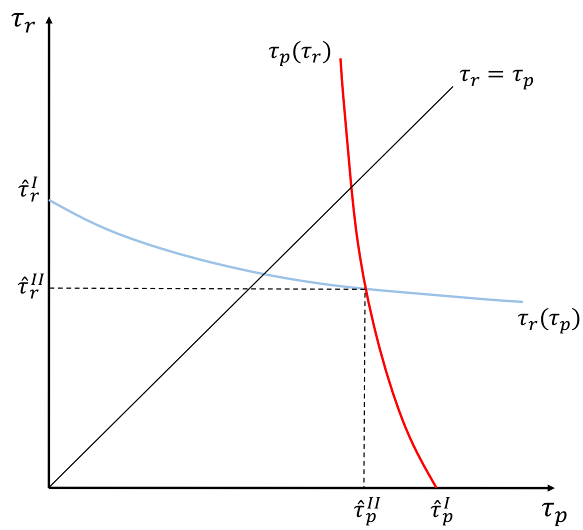


Figure 4: Equilibrium in tax rates. If only region $\ell \in \{p, r\}$ refinances, it sets the tax rate $\hat{\tau}_\ell^I$. If both regions refinance, they set $(\hat{\tau}_p^{II}, \hat{\tau}_r^{II})$ in equilibrium.

which is continuous, convex, and strictly decreasing, implying that local taxes are strategic substitutes (see Appendix A.1).[13] If only region ℓ is refinancing an incomplete project, then $\tau_m = 0$ on the right hand side of (7), and this yields $\hat{\tau}_\ell^I$. If both regions are seeking funds to refinance incomplete projects, they engage in tax competition, and the rich region sets a lower tax rate in equilibrium than the poor.

The intuition behind $\hat{\tau}_r^{II} < \hat{\tau}_p^{II}$ is as follows. Suppose we abstracted from capital mobility. Then the rich region could meet any predetermined revenue requirement by levying lower tax rates than poor, due to its larger tax base (i.e., because $\kappa_r > \kappa_p$). Allowing for capital mobility only reinforces this effect on tax differentials. The reason is that capital flows from the poor to the rich in search for the highest after-tax yield, which exacerbates the disparities in tax bases.

This mechanism formalizes the verbal description of Prud'homme (1995) quoted in the introduction. Interestingly, the form of tax asymmetry in our model differs from the one emerging in Bucovetsky (1991) and Wilson (1991), where the poor end up setting lower taxes than the rich. The difference comes from the fact that, unlike in those environments, in our model public expenditures do not adjust residually: both regions need to raise tax revenues in the amount c, which is fixed at $t = 3$.

It is also worth highlighting that taxation is asymmetric in both of the cases described

[13] Parchet (2018), for example, finds empirical evidence supporting strategic substitutability in local tax rates in Switzerland.

in Proposition 2. As a consequence, refinancing under the TD regime always triggers capital mobility costs and, hence, carries deadweight losses. The magnitude of these deadweight losses will be an essential determinant of the refinancing decisions described in the next subsection.

4.2 Refinancing

Let $W_{\ell,2}^{TD}(r_\ell, r_m)$ denote region ℓ's welfare at $t = 2$ if the region initiated a project, given refinancing decisions $(r_\ell, r_m) \in \{R, NR\}^2$. R and NR denote "refinancing" and "not refinancing", respectively, and $m \neq \ell$. Using the results from the previous section, and applying the local government's budget constraint, we can write $W_{\ell,2}^{TD}(R, NR)$ as

$$W_{\ell,2}^{TD}(R, NR) = \kappa_\ell - c_0 + b - RC_\ell^I(c),$$

where

$$RC_\ell^I(c) \equiv c + \frac{1}{2}\left(\hat{f}_{\ell m}^I\right)^2,$$

and $\hat{f}_{\ell m}^I = \hat{\tau}_\ell^I$ is the equilibrium level of capital outflows from ℓ to m. $RC_\ell^I(c)$ is region ℓ's welfare cost of refinancing when the other region is not refinancing. This welfare cost comprises the continuation cost c, *and* the deadweight loss from funding the continuation of the project through distortionary taxation due to capital mobility.

Similarly, if both regions refinance we have

$$W_{\ell,2}^{TD}(R, R) = \kappa_\ell - c_0 + b - RC_\ell^{II}(c),$$

with

$$RC_\ell^{II}(c) \equiv c - \hat{\tau}_\ell \hat{f}_{m\ell}^{II} + \hat{\tau}_m \hat{f}_{\ell m}^{II} + \frac{1}{2}\left(\hat{f}_{\ell m}^{II}\right)^2$$

denoting region ℓ's welfare cost of refinancing when both regions choose to continue incomplete projects, and where $\hat{f}_{\ell m}^{II}$ ($\hat{f}_{m\ell}^{II}$) are the equilibrium capital outflows (inflows) from (to) region ℓ. Capital inflows $\hat{f}_{m\ell}^{II}$ decrease the welfare cost of refinancing by alleviating the tax burden on local residents. Capital outflows $\hat{f}_{\ell m}^{II}$ raise $RC_\ell^{II}(c)$ in two ways: they increase the tax due in region m, and they trigger capital mobility costs.[14]

To characterize the equilibrium of the refinancing subgame, it will be useful to define

[14]To simplify notation, we leave implicit the dependency of RC_ℓ^I and RC_ℓ^{II} on (κ_ℓ, κ_m).

the cost thresholds c_ℓ^i by

$$RC_\ell^i(c_\ell^i) = b,$$

for $\ell \in \{p, r\}$ and $i = \{I, II\}$.[15] In words, c_ℓ^i is the continuation cost that makes region ℓ indifferent between refinancing and not refinancing an incomplete project, whenever i regions refinance (including region ℓ).

The fact that the rich region is endowed with a larger tax base implies that $c_r^i > c_p^i$, so that the rich follows a looser criterion for refinancing projects, all else equal. Moreover, in the Appendix we prove that there exists a threshold κ^{ref} such that $c_r^I \leq c_p^{II}$ when $\kappa_r \leq \kappa^{ref}$, and $c_r^I > c_p^{II}$ otherwise. Based on these relationships, we can show that when initial regional disparities are large enough, the rich region refinances more projects in equilibrium than the poor.

Proposition 3. *Consider the refinancing subgame under TD. Nash equilibria are as follows:*

1. *Suppose that only region ℓ is facing an incomplete project. Then region ℓ refinances if and only if $c \leq c_\ell^I$.*
2. *Suppose that both regions face incomplete projects, and $\kappa_r \leq \kappa^{ref}$. Then both regions refinance if $c \leq c_p^{II}$, and no region refinances otherwise.*
3. *Suppose that both regions face incomplete projects, and $\kappa_r > \kappa^{ref}$. Then both regions refinance if $c \leq c_p^{II}$, only region r refinances if $c_p^{II} < c \leq c_r^I$, and no region refinances otherwise.*

Proof. See Appendix A.2. □

Nash equilibria of the refinancing subgame depend upon the capital endowment κ_r and on the refinancing cost c. Part 1 is almost immediate, given the definition of c_ℓ^I. Now suppose that both regions face incomplete projects. When $\kappa_r \leq \kappa^{ref}$, the difference in capital endowments is relatively small, and both regions refinance their incomplete project with fairly similar tax rates. Consequently, the Nash equilibrium is symmetric: either both regions refinance their incomplete project, or no region does. However, when $\kappa_r > \kappa^{ref}$, region r has a much larger tax base than the poor. So for moderate levels of the refinancing cost, Nash equilibria become asymmetric. Specifically, not refinancing is a dominant strategy for region p, while the opposite holds for region r.

[15] The existence of c_ℓ^i follows by continuity and monotonicity of $RC_\ell^i(c)$.

4.3 Project Initiation

We now turn to discussing the project initiation decision under TD.

Proposition 4. *Consider the project initiation game under TD. Given (c, κ_r, π), there exists a threshold $c_\ell^{TD}(\kappa_r, \pi)$ such that region $\ell \in \{p, r\}$ initiates a project if an only if $c \leq c_\ell^{TD}(\kappa_r, \pi)$. Moreover, there exists a cutoff $\kappa^{init} < \kappa^{ref}$ such that if $\kappa_r \leq \kappa^{init}$, $c_p^{TD}(\kappa_r, \pi) = c_r^{TD}(\kappa_r, \pi)$ for all π, and $c_p^{TD}(\kappa_r, \pi) \leq c_r^{TD}(\kappa_r, \pi)$ otherwise.*

Proof. See Appendix A.3. □

Figure 5 summarizes project initiation as well as refinancing equilibria (characterized in Proposition 3) under the TD regime given (c, κ_r, π). Naturally, initiation becomes more attractive for low c and high π. For low values of κ_r, initiation equilibria is symmetric, and both regions either initiate or do not initiate projects. When κ_r is above κ^{init}, initiation equilibrium can be asymmetric for intermediate values of c and π. In that parametric area—highlighted in the second panel of Figure 5—the rich region initiates but the poor region does not, which *overturns* the project initiation outcome under the TC regime (refer to Figure 3). Essentially, due to uniform national taxation, under TC differences in capital endowments imply that the rich faces a higher refinancing cost than the poor. With TD, on the other, the rich can exploit its larger tax base to its own advantage by lowering taxes. As a consequence, the expected cost of initiating a project is lower (higher) for the rich (poor) under TD than under TC.

In the the second row of Figure 5, κ_r exceeds κ^{ref}. For those values of κ_r, not only initiation but also refinancing outcomes can be asymmetric for any realization of refinancing shocks. This occurs for $c \in [c_p^{II}, c_r^{I}]$, as explained in Proposition 3.

4.4 Inefficiencies

To close this section, we study inefficiencies arising from the TC regime. Our efficiency benchmark is still the first best introduced in Section 3.1. In the Appendix we show that, for all (κ_r, π), the initiation thresholds c_ℓ^{TD} are below c^*. Hence, we can establish the types of inefficiencies that emerge under this institutional regime, as follows.

Corollary 2. *Under TD, equilibrium outcomes can be inefficient for three reasons:*

1. *Regions do not make initial investments in equilibrium when it is efficient to do so.*

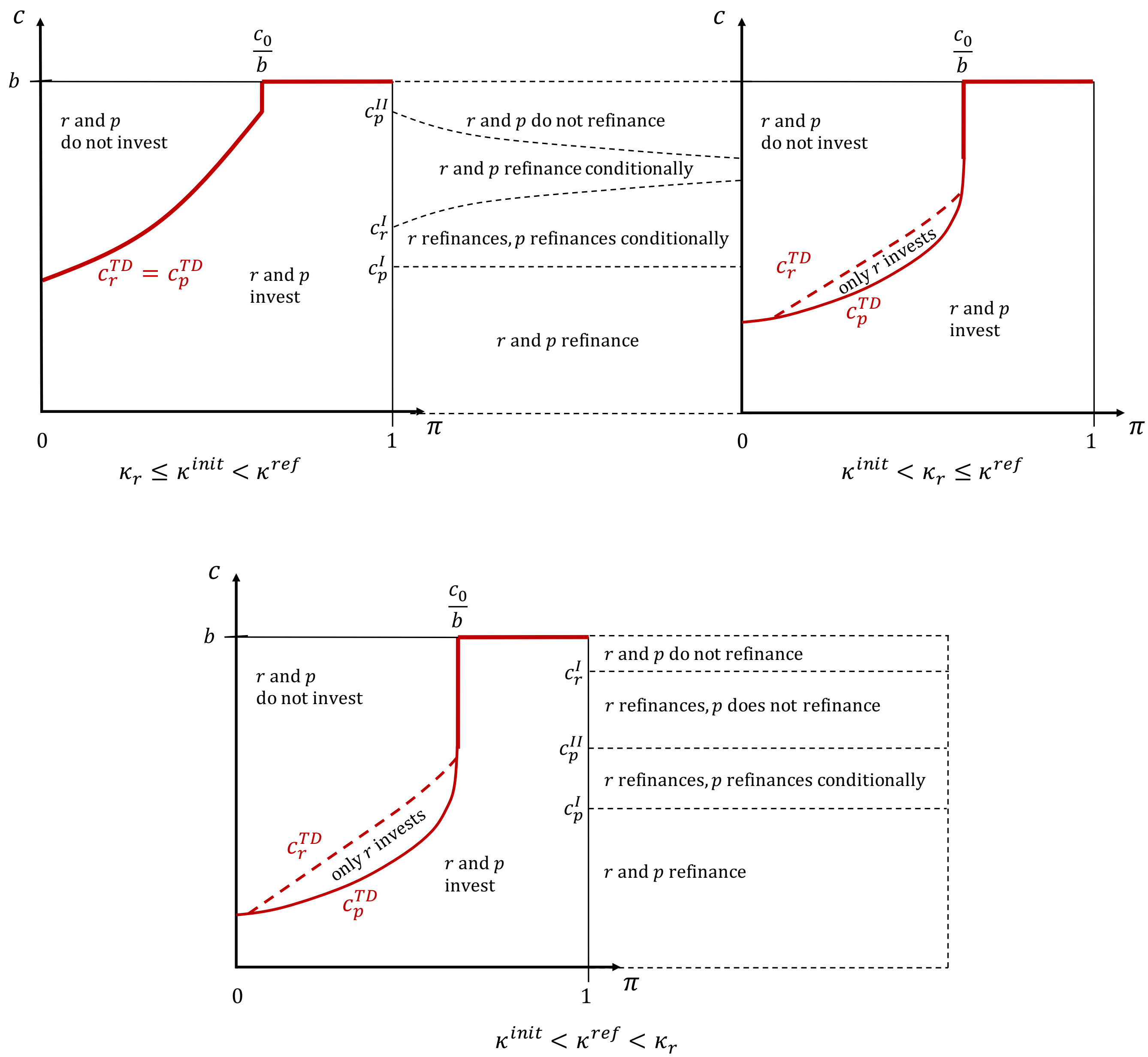


Figure 5: Initiation and refinancing equilibria under TD. Region $\ell \in \{p, r\}$ is said to refinance "conditionally" when it refinances only if region $m \neq \ell$ faces an incomplete project.

2. *Incomplete projects are not refinanced in equilibrium when it is efficient to do so.*

3. *Incomplete projects are refinanced using distortionary capital taxes.*

Proof. See Appendix A.4. □

Figure 6 illustrates these results. We only focus on scenarios in which $\kappa_r \leq \kappa^{ref}$, as these already comprise all possible types of inefficiencies. Consider the first panel, in which $\kappa_r \leq \kappa^{init}$. To the northwest of c^* efficient decisions are adopted in both regions, while in all other areas inefficiencies arise. Particularly, regions underinvest for (c, κ_r, π) such that $c \in [c_p^{TD}(\kappa_r, \pi), c^*(\pi)]$. To the southeast of c_p^{TD} initiation is optimal, but refinancing (if it occurs) is achieved bearing deadweight losses, as capital taxation is distortionary. Moreover, for $c > c_p^I$, incomplete projects are either shut down in some terminal nodes of the tax competition game, or they are never finished. The second panel of Figure 6 illustrates the case in which regional disparities are sufficiently large so that a new type of initiation inefficiency appears: when (c, κ_r, π) satisfy $c \in [c_p^{TD}(\kappa_r, \pi), c_r^{TD}(\kappa_r, \pi)]$, only the poor region underinvests.

In general, the higher the capital endowment differential, the lower the distortions in region r. In fact, as $\kappa_r \to \infty$, $(\hat{\tau}_r^I, \hat{\tau}_r^{II}) \to (0, 0)$ and $c_r^{TD} \to c^*$, and both initiation and refinancing decisions of the rich region converge to the first best ones. On the other hand, when κ_r increases, $\hat{\tau}_p^{II}$ increases and converges to the highest tax rate $\hat{\tau}_p^I$. This implies that, when both regions refinance, refinancing becomes costlier to region p. In turn, c_p^{TD} moves towards the southeast of the (c, π) plane, which amplifies underinvestment distortions for region p.

5 Optimal Institutional Regime

The institutional choice between tax centralization and tax decentralization is made by the Congress at $t = 0$, when the realization of the refinancing cost c is still unknown. As a reminder, the Congress chooses $\mathcal{I} \in \{TC, TD\}$ by maximizing the welfare criterion $U_0^{\mathcal{I}}$ in (1):

$$U_0^{\mathcal{I}} = \frac{\alpha}{2} W_{r,0}^{\mathcal{I}} + \left(1 - \frac{\alpha}{2}\right) W_{p,0}^{\mathcal{I}},$$

with $\alpha \in [0, 1]$.

In this section we study how the optimal regime choice is shaped by the interplay of three fundamentals: the difference in initial capital endowments across regions (indexed

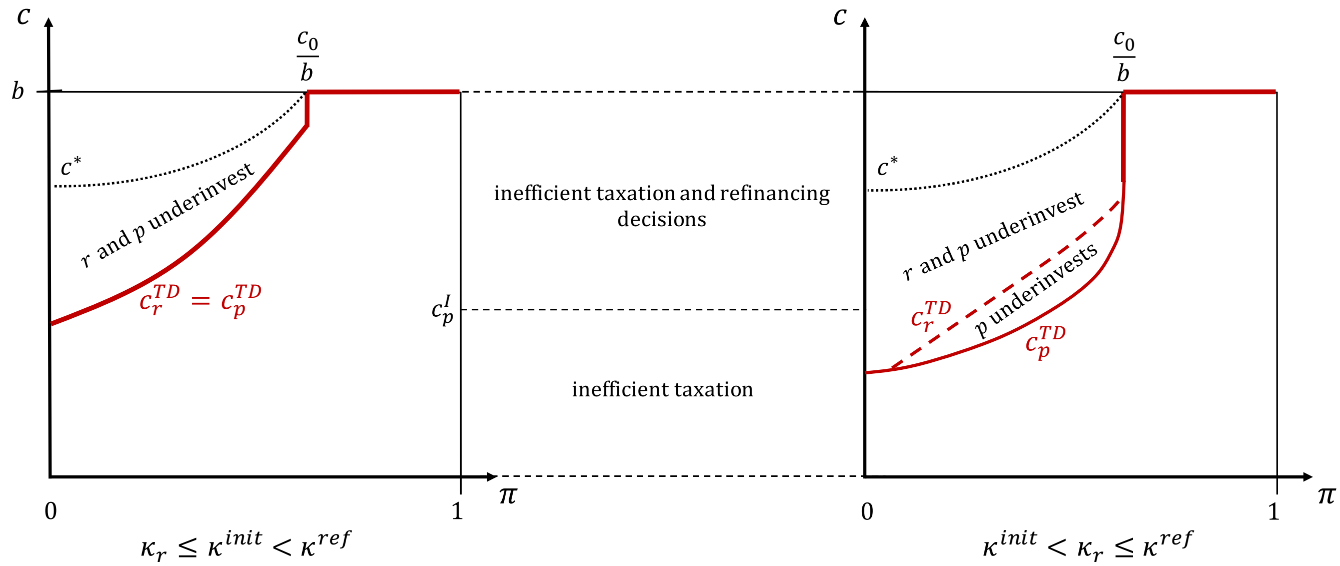


Figure 6: Inefficiencies under TD.

by κ_r), the social aversion to interregional inequalities (which is decreasing in α), and the distribution of refinancing shocks (determined by π). Until stated otherwise, we adopt two parametric assumptions which permit an analytical characterization of the optimal regime for different configurations of (κ_r, α, π):

Assumption 1. *The refinancing cost is uniformly distributed over* $[0, b]$.

Assumption 2. $\frac{b-c_0}{c_0} \geq 2$.

Assumption 1 simplifies the algebra around welfare comparisons. Assumption 2 imposes a lower bound on the profitability of the project, as measured by the net benefit-to-cost ratio (before refinancing costs). Taken together, these are sufficient conditions to ensure a single-crossing between U_0^{TC} and U_0^{TD} across $\pi \in [0, 1)$ given (κ_r, α).[16] We first establish how the regime comparison is determined by π:

Proposition 5. *Given* (κ_r, α), *there exists a unique threshold* $\hat{\pi}(\kappa_r, \alpha)$ *such that TD dominates if and only if* $\pi \leq \hat{\pi}(\kappa_r, \alpha)$.

Proof. See Appendix A.5. □

[16]The existence of such single-crossing when violating Assumptions 1-2 has been verified extensively though numerical simulations. In Section 6 we provide a sample of those simulations.

By Proposition 5, low π favors TD over TC. Essentially, given a refinancing cost, an increase in the probability of experiencing a negative refinancing shock (i.e., a reduction in π) decreases the net expected return on the local project. As projects become less profitable, overinvestment distortions under TC exacerbate, while underinvestment distortions under TD are dampened (see Corollaries 1 and 2). Hence, a reduction in π lowers the relative inefficiencies of TD.[17]

In the remainder of this section, we characterize the optimal regime across (κ_r, α) by evaluating the behavior of the frontier $\hat{\pi}(\kappa_r, \alpha)$ when changing those fundamentals. We proceed in two steps. First, we isolate the impact of changes in κ_r when $\alpha = 1$, i.e., assuming that the Congress follows a utilitarian criterion. Next, we generalize those results and compare the relative performance of centralization and decentralization under different welfare criteria.

5.1 A Utilitarian Congress

Consider the case of a purely utilitarian Congress, in which $\alpha = 1$. In this environment, the Congress is only guided by efficiency considerations. We begin by looking at how initial disparities shape the regime comparison, conditional on regions being sufficiently homogeneous.

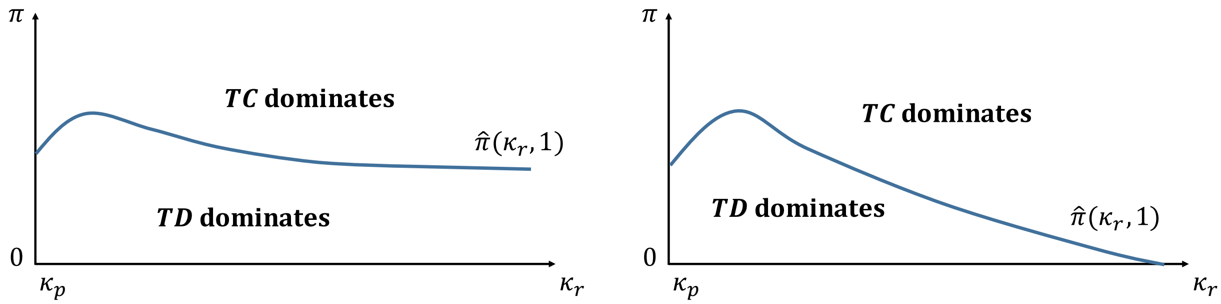
Proposition 6. *Suppose that κ_r is close to κ_p. Then the frontier $\hat{\pi}(\kappa_r, 1)$ increases with κ_r .*

Proof. See Appendix A.6. □

Verbally, small disparities favor tax decentralization vis-á-vis centralization. Why? Consider the centralized framework. By Assumption 2, the profitability of local projects is high. If, in addition, κ_r is close to κ_p, the rich region would initiate all projects as its share on the cost of bailouts is low (i.e., close to 1/2). Under TC the initiation rule is looser for the poor (see Section 3) and, hence, both regions would initiate all projects.[18] This situation would not change by increasing $(\kappa_r - \kappa_p)$ slightly, and social welfare would not be affected either (because only the regional shares on bailouts are changing and the government is utilitarian).

[17] The result in the proposition extends one of the normative prescriptions in Bellofatto and Besfamille (2018) to an environment with asymmetric regions. A key difference with that paper is that, in the current environment, capital mobility distortions are present even when all regions need to refinance.

[18] Technically, under Assumption 2 and for $\kappa_r = \kappa_p$, we have $c_p^{TC} = c_r^{TC} > b$.



(a) Equation (8) holds. **(b)** Equation (8) does not hold.

Figure 7: The frontier $\hat{\pi}(\kappa_r, 1)$.

Conversely, welfare in the decentralized regime does change for *any* variation in κ_r. Two offsetting effects should be taken into consideration. First, under TD, the welfare cost of the tax distortions arising when both regions refinance an incomplete project *increases*. This is because $(\hat{\tau}_p^{II} - \hat{\tau}_r^{II})$ rises with κ_r. Second, the distortions arising if only region r refinances *decrease*, since $\hat{\tau}_r^{I}$ is a decreasing function of κ_r. In a neighborhood of $\kappa_r = \kappa_p$ this last effect dominates and, therefore, welfare under TD increases.

We now compare tax regimes in highly unequal federations.

Proposition 7. *Suppose that $\kappa_r \to \infty$. Then TD can dominate TC (i.e., $\hat{\pi}(\kappa_r, 1) > 0$) if and only if*

$$\lim_{\kappa_r \to \infty} \int_0^{c_p^{TD}(\kappa_r, 0)} \left[b - c_0 - RC_p^I(c) \right] h(c) dc > b - c_0 - \bar{c}. \tag{8}$$

Proof. See Appendix A.7. □

According to Proposition 7, when regions are too heterogeneous tax decentralization can still dominate centralization. The necessary and sufficient condition for this result has an intuitive meaning. The left hand side of (8) is the net benefit of initiated projects in the poor region under TD when refinancing is a certain event (i.e., under $\pi = 0$). The right hand side is the corresponding net benefit under TC. As the former exceeds the latter, decentralization becomes beneficial for the poor region even under extreme disparities and in the worst case scenario in which all projects should be refinanced. Notably, condition (8) does not involve net benefits under either regime for the rich region. This is because welfare of the rich converges to the first best level as $\kappa_r \to \infty$, no matter what tax regime is in place.

Propositions 6 and 7 portray how initial disparities shape the optimal tax regime (on efficiency grounds) in opposite sides of the spectrum of κ_r. Figure 7 illustrates these results. (As shown in Section 6 below, the shape of the frontier for intermediate values of κ_r is in line with typical numerical simulations of the model.)

5.2 Equity Considerations

To facilitate the interpretation of the upcoming analysis, we first establish a precursory result which illustrates how regional disparities are affected by each regime.

Lemma 1. *Let $D_0^{\mathcal{I}} \equiv W_{r,0}^{\mathcal{I}} - W_{p,0}^{\mathcal{I}}$ be the expected welfare disparity across regions under regime $\mathcal{I} \in \{TC, TD\}$. Then*

$$D_0^{TC} < \kappa_r - \kappa_p < D_0^{TD}.$$

Proof. See Appendix A.8. □

Lemma 1 shows that tax decentralization worsens regional disparities relative to centralization. This is intuitive, since under TC the rich region pays a higher fraction of central bailouts. On the other hand, under TD it is more likely that capital flows from region p to region r, thus widening the welfare differences between the rich and the poor. It is worth noting that $(\kappa_r - \kappa_p)$, the benchmark for comparing expected disparities in Lemma 1, can be interpreted as the expected degree of regional disparities under autarky.[19]

The previous lemma allows us to show the following result:

Proposition 8. *The frontier $\hat{\pi}(\kappa_r, \alpha)$ satisfies three properties:*

1. *It increases with α.*

2. *There exists a $\underline{\alpha}$ such that for $\alpha \geq \underline{\alpha}$ the frontier $\hat{\pi}(\kappa_r, \alpha)$ increases with κ_r in a neighborhood of $\kappa_r = \kappa_p$.*

3. *There exists a threshold $\overline{\alpha}$ such that for $\alpha > \overline{\alpha}$ we have $\lim_{\kappa_r \to \infty} \hat{\pi}(\kappa_r, \alpha) > 0$ if and only if (8) holds.*

Proof. See Appendix A.9. □

[19] Under autarky, capital is immobile because regions are isolated from each other. This implies that local taxation is lump-sum. Moreover, as utilities are linear, regions follow the same decisions in terms of initiation and refinancing public projects.

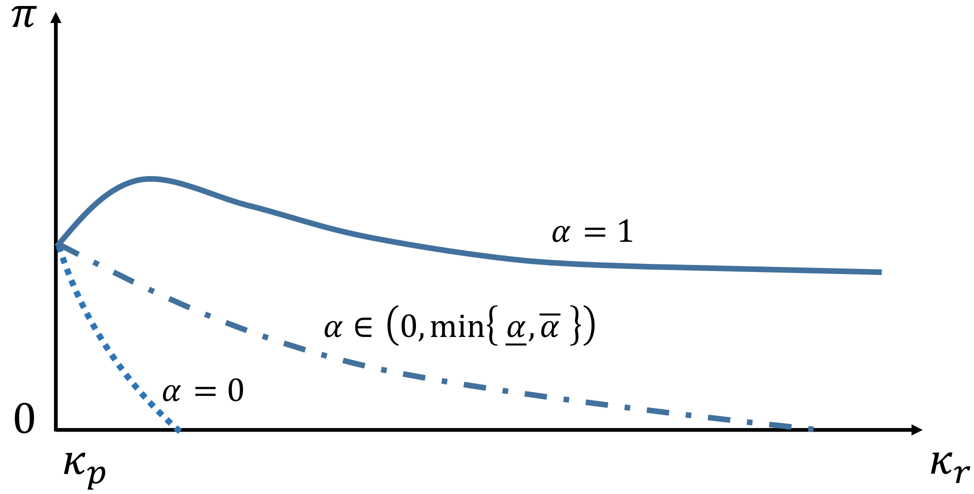


Figure 8: The frontier $\hat{\pi}(\kappa_r, \alpha)$ for different values of α. $\hat{\pi}(\kappa_p, \alpha)$ is independent of α. As α decreases, $\hat{\pi}(\kappa_r, \alpha)$ intersects the horizontal axis closer to the origin.

Using the definition of $D_0^{\mathcal{I}}$, we can write the welfare criterion in (1) as

$$U_0^{\mathcal{I}} = \frac{1}{2} W_{r,0}^{\mathcal{I}} + \frac{1}{2} W_{p,0}^{\mathcal{I}} - \frac{1}{2}(1-\alpha) D_0^{\mathcal{I}}, \tag{9}$$

so that $(1-\alpha)$ gauges the negative impact of expected disparities on social welfare, given a surplus $(W_{r,0}^{\mathcal{I}} + W_{p,0}^{\mathcal{I}})$. Part 1 of the proposition, by which TD dominance increases with α, is then immediate from Lemma 1 and equation (9). Put differently, $\alpha < 1$ creates a bias towards TC dominance.

Parts 2 and 3 generalize our previous results of Propositions 6 and 7, respectively, on the limiting behavior of the frontier $\hat{\pi}$. Naturally, the corresponding results on how TD dominance changes with κ_r go through as long as the bias against TD (which is proportional to $(1-\alpha)$) is not too large. For high concerns for regional inequality, though, the frontier decreases with κ_r, implying that higher regional disparities favor TC.[20]

5.2.1 A Rawlsian Congress

As shown previously, decentralization exacerbates initial disparities across regions which, in turn, provides a case for centralization on equity grounds. Next, we evaluate the sever-

[20]In line with this normative prescription, Arzaghi and Henderson (2005), Stegarescu (2009) and Sacchi and Salotti (2014) empirically find that high regional economic disparities negatively affect the level of decentralization.

ity of such a bias against decentralization. We do so by comparing regimes under Rawlsian social preferences, i.e., by only weighting the welfare of the poor region.

Proposition 9. *Suppose that $\alpha = 0$ and that κ_r is sufficiently low. Then $\hat{\pi}(\kappa_r, 0) > 0$, so that there exist combinations of (κ_r, π) such that TD strictly dominates TC.*

Proof. See Appendix A.10. □

Figure 8 summarizes the results of Propositions 8 and 9 on how the frontier $\pi(\kappa_r, \alpha)$ changes with the normative parameter α. Even when $\alpha = 0$, the Congress chooses TD in a non-empty parametric area of the plane (κ_r, π). This result is surprising: even a Congress who is extremely averse to inequality would choose the decentralization regime which widens disparities the most.[21]

As shown in the south west of Figure 8, TD is optimal under Rawlsian preferences when both $(\kappa_r - \kappa_p)$ and π are small. To elucidate the underlying mechanism, we only need to compare the relative efficiency of each regime for the poor region—this is the only jurisdiction with positive weight when $\alpha = 0$. Consider the TC regime first. If π is small, the net expected return on a project is tiny. Moreover, if regions are sufficiently homogeneous, the poor needs to fund a large share of the bailouts from the central government (close to $1/2$). Overall, the poor faces acute overinvestment inefficiencies under TC in the south west of Figure 8.

Decentralization essentially protects the poor against its own incentives to overinvest, at the cost of generating other distortions. In fact, under TD the poor underinvests relative to the first best, and taxes in a distortionary fashion, given that $\tau_p > \tau_r$ in equilibrium (regardless of the refinancing outcome). But these inefficiencies are not too severe when the probability π is low, and when κ_r is close to κ_p: for those parameters, projects are not too profitable, and in equilibrium τ_p is closer to τ_r. In sum, the distortions faced by the poor under TD are smaller than those under TC.

6 Numerical Illustration

In this section we complement our previous analytical results with numerical simulations. Our main goal is twofold: to verify the robustness of our results, and to look at comparative statics with respect to some key parameters.

[21] It is worth emphasizing that taxation is uniform under TC, and that the Congress abides by this restriction when choosing the decentralization regime.

The baseline parameterization is as follows. We normalize κ_p to 1, set $c_0 = 0.01\kappa_p$, $b = 4c_0$, and assume that the distribution of c is uniform (obviously, Assumptions 1-2 hold for these parameter values). The maximum value of κ_r is $4\kappa_p$, which is in line with US data.[22] The frontier $\hat{\pi}(\kappa_r, \alpha)$ corresponding to the baseline scenario is shown in solid blue in Figures 9 and 10. In each figure, the first panel shows the frontier when the Congress is Utilitarian (i.e., $\alpha = 1$), while the second panel focuses on the Rawlsian case with $\alpha = 0$.

Figure 9 analyzes the impact on the frontier $\hat{\pi}(\kappa_r, \alpha)$ when relaxing Assumption 1, by which the distribution of c is uniform (or, equivalently, a $Beta(1,1)$). We numerically solve the model under two additional distributions for the refinancing cost: a $Beta(3,1)$ and a $Beta(1,3)$. The former is negatively skewed and concentrates much more mass on high values for c than a uniform distribution. The opposite holds for the latter. In Figure 10 we focus on the consequences of relaxing Assumption 2. We do so by bringing down the net benefit-to-cost ratio $(b - c_0)/c_0$ below 2.

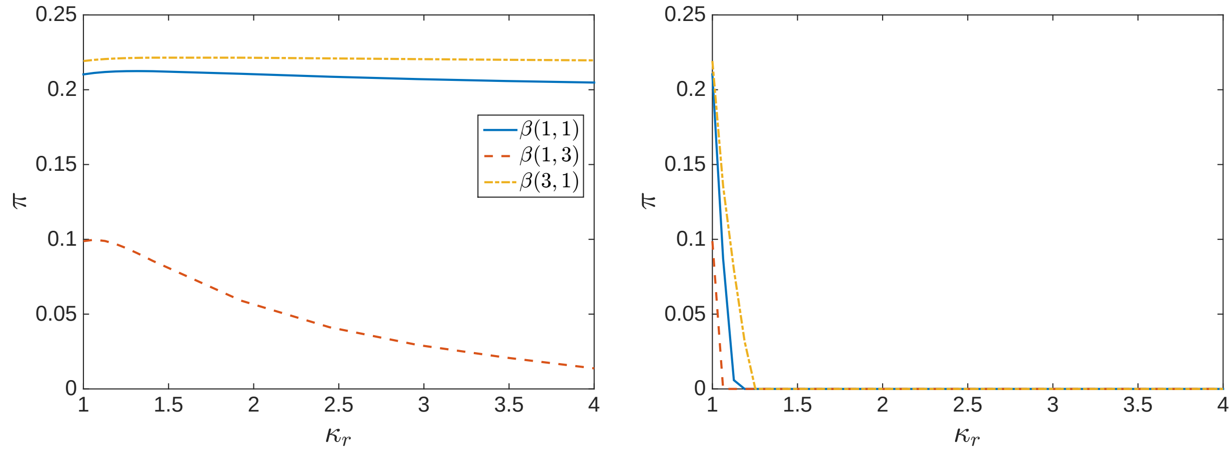
The numerical simulations yield, at least, two important lessons. First, and most importantly, our analytical characterization of the optimal regime contained in Section 5 can hold more generally under less restrictive parametric specifications.

Second, TD dominates in a larger parametric area as $h(c)$ concentrates more mass on high c, or as b decreases. Essentially, in either case the expected return on local projects decreases. As a consequence, overinvestment distortions under TC become relatively more severe than the underinvestment inefficiencies of TD.

7 Conclusion

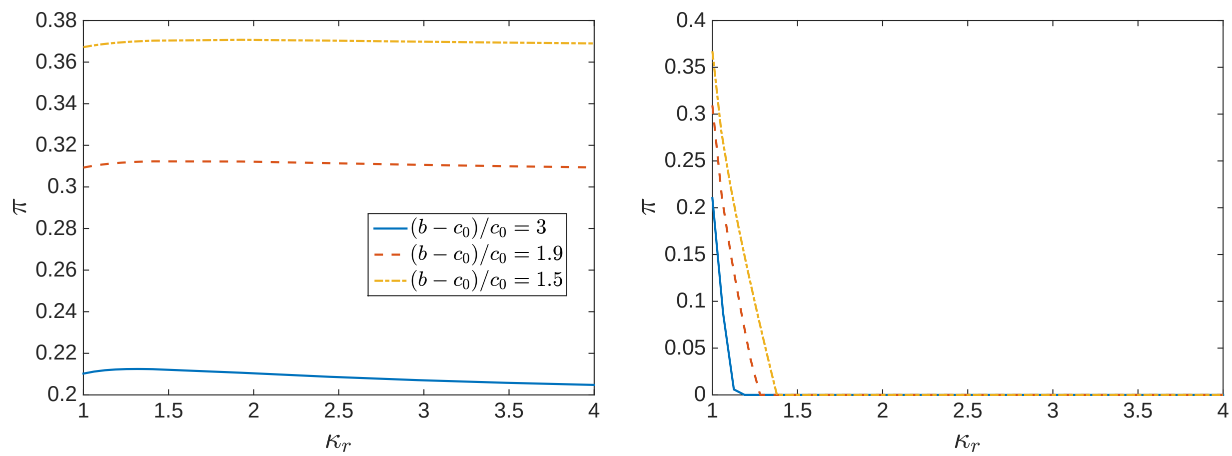
In this paper we analyze the relative merits of tax decentralization in the face of regional disparities. We build a model of a federation with two government layers, and two regions differing across a mobile tax base, i.e., capital. We focus on whether tax powers should be transferred or not to the regional governments by comparing two polar regimes on efficiency and on equity grounds. Under tax decentralization, local public projects are entirely funded by the regional governments. Under tax centralization, local public projects are partially funded by the central government via bailouts. Our model formalizes the following trade-off: decentralization widens interregional heterogeneity

[22] In terms of capital stock per capita for 2007, the District of Columbia is the richest state while Mississippi is the poorest state in the US. Their per capita capital stocks are 102,709 and 24,753 thousands of 2000 US dollars, respectively. See Yamarik (2013) and US Census.



(a) Utilitarian Congress ($\alpha = 1$). **(b)** Rawlsian Congress ($\alpha = 0$).

Figure 9: Numerical simulations of the frontier $\hat{\pi}(\kappa_r, \alpha)$ for different density functions $h(c)$. κ_p is normalized to 1, $c_0 = 0.01\kappa_p$, and $b = 4c_0$.



(a) Utilitarian Congress ($\alpha = 1$). **(b)** Rawlsian Congress ($\alpha = 0$).

Figure 10: Numerical simulations of the frontier $\hat{\pi}(\kappa_r, \alpha)$ for different values of b. κ_p is normalized to 1, $c_0 = 0.01\kappa_p$, and $h(c)$ is uniform.

and produces underinvestment inefficiencies (among other distortions), while centralization dampens regional disparities and can lead to an inefficiently high level of provision of local projects.

We find that: (i) small disparities can favor decentralization, (ii) large disparities do not necessarily eliminate decentralization optimality, and (iii) while decentralization exacerbates regional disparities, it can still be optimal under a Rawlsian constitution. The title of the paper condenses these key findings.

A number of extensions are left for further work. In particular, it would be interesting to evaluate tax regimes from a long run perspective in an infinite horizon version of the model, or to analyze the interaction of regional disparities with other forms of tax competition (such as commodity taxation). One could also formalize the influence of larger regions on the decisions of the central government within a political economy framework.

References

Arzaghi, M. and J. V. Henderson (2005). Why Countries are Fiscally Decentralizing. *Journal of Public Economics 89*(7), 1157–1189.

Aumann, R. J. (1959). Acceptable Points in General Cooperative n-Person Games. In R. Luce and A. Tucker (Eds.), *Contributions to the Theory of Games*, pp. 287–324. Princeton University Press.

Bellofatto, A. A. and M. Besfamille (2018). Regional State Capacity and the Optimal Degree of Fiscal Decentralization. *Journal of Public Economics 159*, 225–243.

Besfamille, M. and B. Lockwood (2008). Bailouts in Federations: Is a Hard Budget Constraint Always Best? *International Economic Review 49*(2), 577–593.

Besley, T. and S. Coate (2003). Centralized versus Decentralized Provision of Local Public Goods: A Political Economy Analysis. *Journal of Public Economics 87*(12), 2611–2637.

Brueckner, J. K. (2009). Partial Fiscal Decentralization. *Regional Science and Urban Economics 39*(1), 23–32.

Bucovetsky, S. (1991). Asymmetric Tax Competition. *Journal of Urban Economics 30*(2), 167–181.

Cai, H. and D. Treisman (2005). Does Competition for Capital Discipline Governments? Decentralization, Globalization, and Public Policy. *American Economic Review 95*(3), 817–830.

DePater, J. A. and G. M. Myers (1994). Strategic Capital Tax Competition: A Pecuniary Externality and a Corrective Device. *Journal of Urban Economics 36*(1), 66–78.

Goodspeed, T. J. (2002). Bailouts in a Federation. *International Tax and Public Finance 9*(4), 409–421.

Hatfield, J. W. and G. Padró i Miquel (2012). A Political Economy Theory of Partial Decentralization. *Journal of the European Economic Association 10*(3), 605–633.

Itaya, J., M. Okamura, and C. Yamaguchi (2008). Are Regional Asymmetries Detrimental to Tax Coordination in a Repeated Game Setting? *Journal of Public Economics 92*(12), 2403–2411.

Janeba, E. and M. Todtenhaupt (2018). Fiscal Competition and Public Debt. *Journal of Public Economics 168*, 47–61.

Janeba, E. and J. D. Wilson (2011). Optimal Fiscal Federalism in the Presence of Tax Competition. *Journal of Public Economics 95*(11), 1032–1311.

Köthenbürger, M. (2004). Tax Competition in a Fiscal Union with Decentralized Leadership. *Journal of Urban Economics 55*(3), 498–513.

Kyriacou, A. P., L. Muinelo-Gallo, and O. Roca-Sagalés (2015). Fiscal Decentralization and Regional Disparities: The Importance of Good Governance. *Papers in Regional Science 94*(1), 89–107.

Lessmann, C. (2012). Regional Inequality and Decentralization: An Empirical Analysis. *Environment and Planning A 44*(6), 1363–1388.

Lockwood, B. (2002). Distributive Politics and the Costs of Centralization. *Review of Economic Studies 69*(2), 313–337.

Martinez-Vazquez, J., S. Lago-Peñas, and A. Sacchi (2017). The Impact of Fiscal Decentralization: A Survey. *Journal of Economic Surveys 31*(4), 1095–1129.

Mongrain, S. and J. D. Wilson (2018). Tax Competition with Heterogeneous Capital Mobility. *Journal of Public Economics 167*, 177–189.

Musgrave, R. A. (1959). *The Theory of Public Finance*. New York: McGraw Hill.

Oates, W. E. (1972). *Fiscal Federalism*. New York: Harcourt Brace Jovanovich.

Oates, W. E. (1999). An Essay on Fiscal Federalism. *Journal of Economic Literature 37*(3), 1120–1149.

OECD (2017). *Making Decentralization Work in Chile: Towards Stronger Municipalities*. OECD Publishing, Paris.

OECD/KIPF (2016). *Fiscal Federalism 2016: Making Decentralization Work*. OECD Publishing, Paris.

Parchet, R. (2018). Are Local Tax Rates Strategic Complements or Strategic Substitutes? *American Economic Journal: Economic Policy, forthcoming*.

Peralta, S. and T. van Ypersele (2005). Factor Endowments and Welfare Levels in an Asymmetric Tax Competition Game. *Journal of Urban Economics 57*(2), 258–274.

Persson, T. and G. Tabellini (1992). The Politics of 1992: Fiscal Policy and European Integration. *Review of Economic Studies 59*(4), 689–710.

Prud'homme, R. (1995). The Dangers of Decentralization. *World Bank Research Observer 10*(2), 201–220.

Qian, Y. and G. Roland (1998). Federalism and the Soft-Budget Constraint. *American Economic Review 88*(5), 1146–1162.

Rodríguez-Pose, A. and N. Gill (2004). Is there a Global Link between Regional Disparities and Devolution? *Environment and Planning A 36*(12), 2097–2117.

Sacchi, A. and S. Salotti (2014). How Regional Inequality Affects Fiscal Decentralisation: Accounting for the Autonomy of Subcentral Governments. *Environment and Planning C: Government and Policy 32*(1), 144–162.

Stegarescu, D. (2009). The Effects of Economic and Political Integration on Fiscal Decentralization: Evidence from OECD Countries. *Canadian Journal of Economics 42*(2), 694–718.

Wildasin, D. E. (1997). Externalities and Bailouts Hard and Soft Budget Constraints in Intergovernmental Fiscal Relations. Working Paper.

Wilson, J. D. (1991). Tax Competition with Interregional Differences in Factor Endowments. *Regional Science and Urban Economics 21*(3), 423–451.

Wilson, J. D. (1999). Theories of Tax Competition. *National Tax Journal 52*(2), 269–304.

Yamarik, S. (2013). State-Level Capital and Investment: Updates and Implications. *Contemporary Economic Policy 31*(1), 62–72.

Appendix

A Proofs

A.1 Proof of Proposition 2

We start by proving equation (6), which pins down the direction of capital flows as a function of regional taxes. Letting $\lambda_{\ell m}$ be the multiplier associated with the non-negativity constraint in (5), the first-order condition for $f_{\ell m}$ yields

$$\tau_\ell - \tau_m + \lambda_{\ell m} = f_{\ell m},$$

along with the complementary slackness condition $\lambda_{\ell m} f_{\ell m} = 0$, $\lambda_{\ell m} \geq 0$. If $\tau_\ell > \tau_m$, $f_{\ell m} > 0$ and thus $\lambda_{\ell m} = 0$. If $\tau_\ell = \tau_m$, $\lambda_{\ell m} = f_{\ell m}$. In this case, the unique combination that satisfies the complementary slackness condition is $\lambda_{\ell m} = f_{\ell m} = 0$. Finally, if $\tau_\ell < \tau_m$, $\lambda_{\ell m} > 0$ to ensure that $f_{\ell m} \geq 0$. Hence, by complementary slackness $f_{\ell m} = 0$. This shows (6).

We move on to characterizing the tax reaction functions. Welfare of a resident of region ℓ at $t = 3$ when a project is refinanced is

$$W_{\ell,3}^{TD}(\tau_\ell, \tau_m) = (\kappa_\ell - f_{\ell m})(1 - \tau_\ell) + f_{\ell m}(1 - \tau_m) - \frac{1}{2}(f_{\ell m})^2 + b - c_0.$$

By the Envelope Theorem, $\partial W_{\ell,3}^{TD}(\tau_\ell, \tau_m)/\partial \tau_\ell < 0$. So to raise funds for refinancing, the regional government of ℓ should set the lowest tax rate that satisfies its budget constraint

$$\tau_\ell(\kappa_\ell - f_{\ell m} + f_{m\ell}) = c,$$

which using (6) can be written as

$$\tau_\ell(\kappa_\ell + \tau_m - \tau_\ell) = c. \tag{A.1}$$

Hence, given τ_m, the local government of ℓ sets τ_ℓ equal to smallest root of (A.1), namely

$$\tau_\ell(\tau_m) = \frac{1}{2}\left[\kappa_\ell + \tau_m - \sqrt{(\kappa_\ell + \tau_m)^2 - 4c}\right]. \tag{A.2}$$

This is region ℓ's tax reaction function when refinancing a project.[23] Such function is continuous, strictly decreasing and convex.

We close by characterizing Nash equilibria in tax rates. Case 1 of Proposition 2 is obvious by inspection of (A.2). Now suppose that both regions seek refinancing, as per case 2 of the proposition. Define the function $\Gamma : [0,1]^2 \to [0,1]^2$, with

$$\Gamma(\tau_p, \tau_r) = \left(\tau_r(\tau_p), \tau_p(\tau_r)\right).$$

This function is continuous, and maps a compact set into itself. Hence, by Brower's Theorem, Γ has at least one fixed point $(\hat{\tau}_p^{II}, \hat{\tau}_r^{II})$, which is a Nash equilibrium of the tax competition game and that satisfies

$$\hat{\tau}_p^{II} = \frac{1}{2}\left[\kappa_p + \hat{\tau}_r^{II} - \sqrt{(\kappa_p + \hat{\tau}_r^{II})^2 - 4c}\right], \quad \text{and} \quad \hat{\tau}_r^{II} = \frac{1}{2}\left[\kappa_r + \hat{\tau}_p^{II} - \sqrt{\left(\kappa_r + \hat{\tau}_p^{II}\right)^2 - 4c}\right]. \tag{A.3}$$

[23]Throughout the paper, we assume that $\kappa_p > 3\sqrt{b/2}$ and that $b \leq 1$. These assumptions ensure that the square root on the right hand side of (A.2) always exists and that all tax rates are always below 1.

To prove uniqueness, we evaluate

$$\phi(\kappa_p, \kappa_r) \equiv \lim_{\tau_p \to 0} \left.\frac{\partial \tau_r}{\partial \tau_p}\right|_{\tau_r(\tau_p)} - \lim_{\tau_r \to 0} \left.\frac{\partial \tau_r}{\partial \tau_p}\right|_{\tau_p(\tau_r)} = \frac{1}{2} - \frac{\kappa_r}{2\sqrt{\kappa_r^2 - 4c}} - \frac{2\sqrt{\kappa_p^2 - 4c}}{\sqrt{\kappa_p^2 - 4c} - \kappa_p}.$$

As $\kappa_p > 3\sqrt{b/2}$,

$$\lim_{\kappa_r \to \kappa_p} \phi(\kappa_p, \kappa_r) = \frac{\left(\kappa_p - 3\sqrt{\kappa_p^2 - 4c}\right)\left(\kappa_p + \sqrt{\kappa_p^2 - 4c}\right)}{-2\sqrt{\kappa_p^2 - 4c}\left(\kappa_p - \sqrt{\kappa_p^2 - 4c}\right)} > 0,$$

and

$$\frac{\partial \phi(\kappa_p, \kappa_r)}{\partial \kappa_r} = \frac{2c}{(\kappa_r^2 - 4c)\sqrt{\kappa_r^2 - 4c}} > 0.$$

Hence, for any $\kappa_r \geq \kappa_p$, $\phi(\kappa_p, \kappa_r)$ is strictly positive. Moreover, by convexity of the reaction functions $\tau_p(\tau_r)$ and $\tau_r(\tau_p)$, at $(\hat{\tau}_p^{II}, \hat{\tau}_r^{II})$ we have

$$\left.\frac{\partial \tau_r(\hat{\tau}_p^{II}, \hat{\tau}_r^{II})}{\partial \tau_p}\right|_{\tau_r(\tau_p)} > \left.\frac{\partial \tau_r(\hat{\tau}_p^{II}, \hat{\tau}_r^{II})}{\partial \tau_p}\right|_{\tau_p(\tau_r)}.$$

Therefore, the reaction functions cross only once.

Finally, using a similar geometric argument, we can show that $\hat{\tau}_p^{II} > \hat{\tau}_r^{II}$. If this were not the case, by convexity of the reaction functions, the 45° line would intersect $\tau_r(\tau_p)$ to the northeast of the corresponding intersection with $\tau_p(\tau_r)$. But by ($A.3$), the intersections of the reactions functions with the 45° line occur at $\tau_r = c/\kappa_r < \tau_p = c/\kappa_p$, yielding a contradiction. □

A.2 Proof of Proposition 3

The proof of part 1 is immediate, so we focus on parts 2 and 3. We start by establishing an intermediate result:

Lemma 2. *There exists a threshold κ^{ref} such that $c_r^I \leq c_p^{II}$ when $\kappa_r \leq \kappa^{ref}$, and $c_r^I > c_p^{II}$ otherwise.*

Proof. Consider how the threshold c_r^I changes with κ_r. First, $\lim_{\kappa_r \to \kappa_p} c_r^I = c_p^I$, as $\lim_{\kappa_r \to \kappa_p} RC_r^I(c) = RC_p^I(c)$. Second, c_r^I increases with κ_r. This is because $\hat{\tau}_r^I$ decreases with κ_r, so $RC_r^I(c)$ decreases with κ_r as well. Finally, $\lim_{\kappa_r \to \infty} c_r^I = b$, as $\lim_{\kappa_r \to \infty} RC_r^I(c) = c$.

Next we study how c_p^{II} evolves with κ_r. First, $\lim_{\kappa_r \to \kappa_p} c_p^{II} = b$. This follows by

$$\lim_{\kappa_r \to \kappa_p} RC_p^{II}(c) = c,$$

because when regions are symmetric, the Nash equilibrium $(\hat{\tau}_p^{II}, \hat{\tau}_r^{II})$ is symmetric and thus no deadweight loss emerges. Second, c_p^{II} decreases with κ_r, since $\hat{\tau}_p^{II}$ ($\hat{\tau}_r^{II}$) increases (decreases) with κ_r, so $RC_p^{II}(c)$ increases with κ_r. Lastly, when $\kappa_r \to \infty$, the Nash equilibrium $(\hat{\tau}_p^{II}, \hat{\tau}_r^{II}) \to (\hat{\tau}_p^{I}, 0)$. Hence,

$$\lim_{\kappa_r \to \infty} RC_p^{II}(c) = RC_p^{I}(c)$$

and $\lim_{\kappa_r \to \infty} c_p^{II} = c_p^{I}$.

By Bolzano's theorem, the properties above imply that the continuous function $g(\kappa_r) \equiv c_r^{I}(\kappa_r) - c_p^{II}(\kappa_r)$ is increasing in κ_r, and has a unique root denoted by κ^{ref}. □

Suppose that both regions face incomplete project and that $\kappa_r \leq \kappa^{ref}$. If $c \leq c_p^{I}$, refinancing is a dominant strategy for both regions because $b - RC_\ell^{II}(c) > b - RC_\ell^{I}(c) \geq 0$. Now let $c_p^{II} < c \leq b$. In this case, not refinancing is a dominant strategy for region p by definition of c_p^{II}, and not refinancing is also a best response for region r since

$$W_{r,2}^{TD}(R, NR) = \kappa_r - c_0 + b - RC_r^{I}(c) \leq \kappa_r - c_0 = W_{r,2}^{TD}(NR, NR).$$

Hence, no region refinances at the Nash equilibrium. When $c_p^{I} < c \leq c_r^{I}$, refinancing is a dominant strategy for region r while, for region p,

$$W_{p,2}^{TD}(R, R) = \kappa_p - c_0 + b - RC_p^{II}(c) \geq \kappa_p - c_0 = W_{p,2}^{TD}(NR, R),$$

so that both regions refinance at the Nash equilibrium. Finally, assume that $c_r^{I} < c \leq c_p^{II}$. Notice that

$$W_{p,2}^{TD}(R, R) = \kappa_p - c_0 + b - RC_p^{II}(c) \geq \kappa_p - c_0 = W_{p,2}^{TD}(NR, R),$$

but

$$W_{p,2}^{TD}(R, NR) = \kappa_p - c_0 + b - RC_p^{I}(c) < \kappa_p - c_0 = W_{p,2}^{TD}(NR, NR),$$

and similar conditions hold for region r. These payoffs give rise to a coordination game between regions, with two Nash equilibria: either both regions refinance in equilibrium, or no region does. We choose the first equilibrium because it is the only which is strong (Aumann (1959)), i.e., taking as given the strategy of the other region, no coalition of players can jointly deviate and thus increase the payoffs of each of its members. More specifically, by definition of the Nash equilibrium, no region can do better by unilaterally changing its equilibrium strategy. Now consider the 2-regions coalition. If both regions refinance, they do not want to deviate since $b - RC_\ell^{II}(c) \geq 0$. But, when no region refinances, they all wish to deviate because both regions obtain a higher payoff in the first Nash equilibrium.

To conclude, assume that both regions face incomplete project and $\kappa_r > \kappa^{ref}$. If $0 \leq c \leq c_p^{II}$, both regions refinance at the equilibrium. On the other hand, when $c_r^{I} < c \leq b$, no region refinances at the Nash equilibrium. Finally, suppose that $c_p^{II} < c \leq c_r^I$. Now, not refinancing is a dominant strategy for region p, while refinancing is a dominant strategy for region r. □

A.3 Proof of Proposition 4

The equilibria of the initiation game is affected by the configuration of (c, κ_r, π). In what follows we stratify this parametric area to analyze all possible equilibria. Throughout this proof we assume that $\kappa_r \leq \kappa^{ref}$, which implies that the refinancing equilibrium if both regions face incomplete projects is always symmetric (see Proposition 3).[24] It will be convenient to divide the resulting parametric area into three regions:

1. $\pi > c_0/b$, for all c and $\kappa_r \leq \kappa^{ref}$.
2. $\pi \leq c_0/b$, $c < c_p^I$, for all $\kappa_r \leq \kappa^{ref}$.
3. $\pi \leq c_0/b$, $c \geq c_p^I$, for all $\kappa_r \leq \kappa^{ref}$.

In the interest of space, we only fully characterize the equilibrium of the initiation subgame for cases 1 and 2. In case 1, initiating is clearly a dominant strategy for either region. We next analyze case 2, in which refinancing is a dominant strategy for both regions as $c < c_p^I$.

Let $i_\ell \in \{I, NI\}$ denote the initiation decision of region ℓ, where I and NI denote "initiation" and "no initiation", respectively, and let $W_{\ell,1}^{TD}(i_\ell, i_m)$ denote expected welfare of region ℓ, given the profile of initiation choices (i_ℓ, i_m) with $m \neq \ell$. Suppose $i_m = NI$. Then $i_\ell = I$ is a best response if and only if

$$W_{\ell,1}^{TD}(I, NI) = \kappa_\ell - c_0 + b - (1-\pi)RC_\ell^I(c) \geq \kappa_\ell.$$

Define the threshold $\tilde{c}_\ell^I$ satisfying

$$(1-\pi)RC_\ell^I(\tilde{c}_\ell^I) = b - c_0.$$

By definition, initiating is a best response of ℓ when region m does not initiate if and only if (c, κ_r, π) satisfies $c \leq \tilde{c}_\ell^I$.[25] Similarly, initiating is a best response if the other region initiates if and only if

$$W_{\ell,1}^{TD}(I, I) = \kappa_\ell - c_0 + b - (1-\pi)\left[\pi RC_\ell^I(c) + (1-\pi)RC_\ell^{II}(c)\right] \geq \kappa_r.$$

This condition boils down to $c \leq \tilde{c}_\ell^{II}$, where $\tilde{c}_\ell^{II}$ is defined by

$$(1-\pi)\left[\pi RC_\ell^I(\tilde{c}_\ell^{II}) + (1-\pi)RC_\ell^{II}(\tilde{c}_\ell^{II})\right] = b - c_0.$$

[24] The proof for $\kappa_r > \kappa^{ref}$ is analogous.

[25] The dependency of $\tilde{c}_\ell^I$ on (κ_r, π) is left implicit to simplify notation.

Lemma 3. *Given (π, κ_r), the thresholds $\tilde{c}^j_\ell$ satisfy:*

a) $\tilde{c}^j_p < \tilde{c}^j_r$ *for all* $j \in \{I, II\}$.

b) $\tilde{c}^I_\ell < \tilde{c}^{II}_\ell$ *for all* $\ell \in \{p, r\}$.

c) There exists a threshold κ^{init} *such that* $\tilde{c}^I_r \leq \tilde{c}^{II}_p$ *for* $\kappa_r \leq \kappa^{init}$, *and* $\tilde{c}^I_r > \tilde{c}^{II}_p$ *otherwise.*

Proof. Part a) follows from the fact that $RC^i_r(c) < RC^i_p(c)$ for all (c, κ_r, π). Part b) holds because $RC^{II}_\ell(c) < RC^I_\ell(c)$ for all (c, κ_r, π). We now turn to part c). In Appendix A.2 we've shown that $RC^I_r(c)$ decreases with κ_r, and $RC^{II}_p(c)$ increases with κ_r. In addition, $RC^I_p(c)$ is independent of κ_r. These properties imply that $\tilde{c}^I_r$ increases with κ_r, and $\tilde{c}^{II}_p$ decreases with κ_r. Moreover, using the definition of these cost thresholds we can show that $\lim_{\kappa_r \to \kappa_p} \left(\tilde{c}^{II}_p - \tilde{c}^I_r\right) > 0$. Part c) then follows by continuity of the cost thresholds in κ_r. □

By Lemma 3, given (c, π) we should analyze the equilibrium of the initiation game within two subcases, according on the value of κ_r. Suppose initially that $\kappa_r \leq \kappa^{init}$.[26] According to the lemma, the thresholds $\tilde{c}^j_\ell$ satisfy:

$$\tilde{c}^I_p < \tilde{c}^I_r \leq \tilde{c}^{II}_p.$$

Depending on where c falls in this inequality, four possibilities emerge:

(i) If $c \leq \tilde{c}^I_p$, initiating is a dominant strategy for both regions.

(ii) If $c \in (\tilde{c}^I_p, \tilde{c}^I_r]$, initiating is a dominant strategy for the rich. The best response for the poor is to initiate as well. Hence (I, I) is the unique Nash equilibrium.

(iii) If $c \in (\tilde{c}^I_r, \tilde{c}^{II}_p]$, two Nash equilibria emerge: either both regions initiate, or no region does. We select the first equilibrium, as it is the only one which is strong.

(iv) If $c > \tilde{c}^{II}_p$, the unique Nash equilibria is (NI, NI).

Now suppose that $\kappa_r > \kappa^{init}$, so that initiation thresholds satisfy

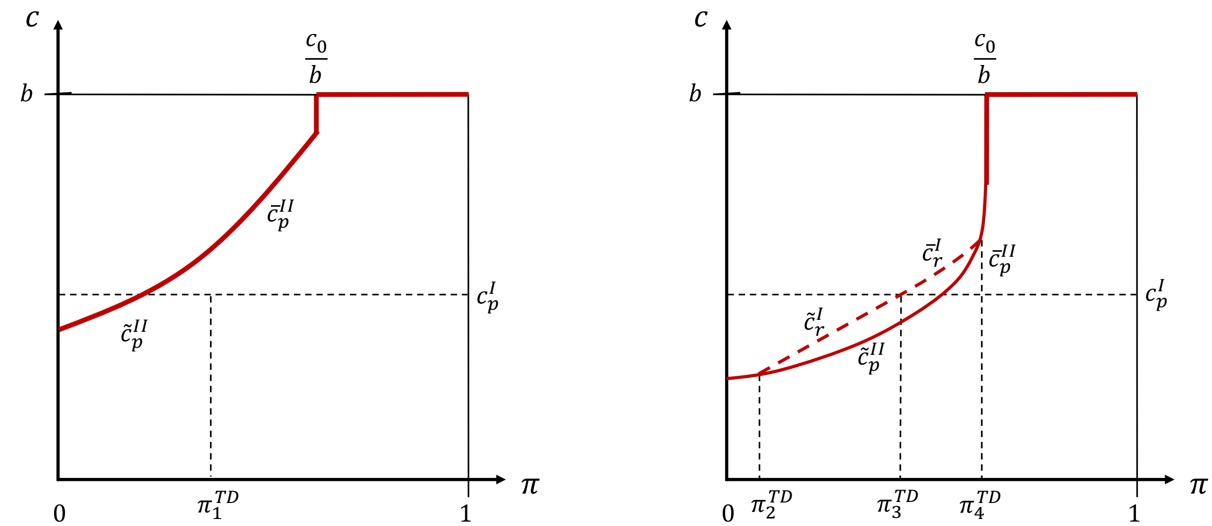
$$\tilde{c}^I_p < \tilde{c}^{II}_p < \tilde{c}^I_r.$$

Under this scenario we have:

(i) If $c \leq \tilde{c}^{II}_p$, the unique Nash equilibrium is (I, I).

(ii) If $c \in (\tilde{c}^{II}_p, \tilde{c}^I_r]$, not initiating is dominant for the poor, but initiating is dominant for the rich. Then the unique Nash equilibrium is asymmetric.

[26] It is straightforward to verify that $\kappa^{init} < \kappa^{ref}$.



(a) $\kappa_r \leq \kappa^{init}$ **(b)** $\kappa_r > \kappa^{init}$

Figure A.1: Project initiation thresholds under TD when $\kappa_r \leq \kappa^{ref}$.

(iii) If $c > \tilde{c}_r^I$, the unique Nash equilibria is (NI, NI).

This concludes our analysis of case 2 above, i.e., when $\pi \leq c_0/b$ and $c < c_p^I$. To summarize, both regions initiate when (c, π) is such that $c < \tilde{c}_p^{II}$; neither region initiates when (c, π) satisfies $c > \tilde{c}_r^I$; the rich initiates and the poor does not when (c, π) is such that $c \in [\tilde{c}_p^{II}, \tilde{c}_r^I]$, which only occurs whenever $\kappa > \kappa^{init}$.

The analysis of case 3, namely $\pi \leq c_0/b$, $c \geq c_p^I$, follows similar steps. Under that scenario, the relevant initiation thresholds are given by $(\bar{c}_r^I, \bar{c}_p^{II})$, which are defined by

$$(1-\pi)RC_r^I(\bar{c}_r^I) = b - c_0, \quad \text{and} \quad (1-\pi)\left[\pi b + (1-\pi)RC_p^{II}(\bar{c}_p^{II})\right] = b - c_0.$$

Then it can be shown that both regions initiate if $c < \bar{c}_p^{II}$; neither region initiates when if $c > \bar{c}_r^I$; the rich initiates and the poor does not if $c \in [\bar{c}_p^{II}, \bar{c}_r^I]$.

Figure A.1 summarizes the analysis of cases 1-3. The π-thresholds defined in that figure allow us to define

$$c_p^{TD} = \begin{cases} \tilde{c}_p^{II} & \text{if} \quad \pi \in [0, \pi_1^{TD}], \\ \bar{c}_p^{II} & \text{if} \quad \pi \in (\pi_1^{TD}, c_0/b], \\ b & \text{if} \quad \pi \in (c_0/b, 1], \end{cases}$$

for all κ_r, $c_r^{TD} = c_p^{TD}$ for $\kappa_r \leq \kappa^{init}$, and

$$c_r^{TD} = \begin{cases} \tilde{c}_p^{II} & \text{if} \quad \pi \in [0, \pi_2^{TD}], \\ \tilde{c}_r^{I} & \text{if} \quad \pi \in (\pi_2^{TD}, \pi_3^{TD}], \\ \bar{c}_r^{I} & \text{if} \quad \pi \in (\pi_3^{TD}, \pi_4^{TD}], \\ \bar{c}_p^{II} & \text{if} \quad \pi \in (\pi_4^{TD}, c_0/b], \\ b & \text{if} \quad \pi \in (c_0/b, 1], \end{cases}$$

for $\kappa_r > \kappa^{init}$. This completes the proof. □

A.4 Proof of Corollary 2

Parts 2 and 3 are immediate, so we focus on part 1. To show that regions may underinvest under TD it suffices to prove that $c_\ell^{TD} < c^*$ for $\ell \in \{p, r\}$. This follows by applying the definitions of c_ℓ^{TD} and c^*, and using that RC_ℓ^I is a strictly increasing and convex function of c, and that RC_p^{II} is a strictly increasing function of c.

A.5 Proof of Proposition 5

We break down the proof into two cases: finite κ_r and $\kappa_r \to \infty$. Throughout the proof we use the fact that $U_0^{\mathcal{I}}$ are continuous and (almost everywhere) differentiable functions of π for $\mathcal{I} \in \{TC, TD\}$, and we explicitize the dependency of such functions on (κ_r, π, α).

A.5.1 Finite κ_r

We proceed by characterizing the optimal regime for different values of π. First, it is clear that if $\pi = 1$ both regimes are equivalent. Second, suppose $\pi \in [c_0/b, 1)$. For this range of π, it is straightforward to show that

$$U_0^{TC}(\kappa_r, \pi, \alpha) = \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] + b - c_0 - (1-\pi)\left[\alpha\frac{\kappa_r}{\kappa} + (2-\alpha)\frac{\kappa_p}{\kappa}\right]\bar{c}. \tag{A.4}$$

Also:

$$U_0^{TD}(\kappa_r,\pi,\alpha) = \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] + b - c_0 - \frac{\alpha}{2}\Big[\int_0^{c_r^I} \Delta_r(c,\kappa_r,\pi)h(c)dc$$
$$+ (1-\pi)\int_{c_r^I}^{c_p^{II}} \left((1-\pi)RC_r^2(c) + \pi b\right) h(c)dc + (1-\pi)b\int_{c_p^{II}}^{b} h(c)dc\Big]$$
$$- \frac{2-\alpha}{2}\Big[\int_0^{c_p^I} \Delta_p(c,\kappa_r,\pi)h(c)dc + (1-\pi)\int_{c_p^I}^{c_p^{II}} \Big((1-\pi)RC_p^{II}(c) + \pi b\Big) h(c)dc$$
$$+ (1-\pi)b\int_{c_p^{II}}^{b} h(c)dc\Big] \tag{A.5}$$

if $\kappa_r \leq \kappa^{ref}$, and

$$U_0^{TD}(\kappa_r,\pi,\alpha) = \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] + b - c_0 - \frac{\alpha}{2}\Big[\int_0^{c_p^{II}} \Delta_r(c,\kappa_r,\pi)h(c)dc$$
$$+ (1-\pi)\int_{c_p^{II}}^{c_r^I} \left((1-\pi)RC_r^2(c) + \pi b\right) h(c)dc + (1-\pi)b\int_{c_r^I}^{b} h(c)dc\Big]$$
$$- \frac{2-\alpha}{2}\Big[\int_0^{c_p^I} \Delta_p(c,\kappa_r,\pi)h(c)dc + (1-\pi)\int_{c_p^I}^{c_p^{II}} \Big((1-\pi)RC_p^{II}(c) + \pi b\Big) h(c)dc$$
$$+ (1-\pi)b\int_{c_p^{II}}^{b} h(c)dc\Big] \tag{A.6}$$

if $\kappa_r > \kappa^{ref}$, where

$$\Delta_r(c,\kappa_r,\pi) \equiv (1-\pi)\left[\pi RC_r^I(c) + (1-\pi)RC_r^{II}(c)\right],$$

and

$$\Delta_p(c,\kappa_r,\pi) \equiv (1-\pi)\left[\pi RC_p^I(c) + (1-\pi)RC_r^2(c)\right].$$

By (A.4)-(A.6), we have $U_0^{TC}(\kappa_r,\pi,1) > U_0^{TD}(\kappa_r,\pi,1)$ (essentially, TC is fully efficient while TD generates refinancing distortions). Moreover, it follows that

$$\frac{\partial U_0^{TC}(\kappa_r,\pi,\alpha)}{\partial\alpha} < \frac{\partial U_0^{TD}(\kappa_r,\pi,\alpha)}{\partial\alpha},$$

which implies that

$$U_0^{TC}(\kappa_r,\pi,\alpha) > U_0^{TD}(\kappa_r,\pi,\alpha) \quad \text{for all} \quad \alpha\in[0,1] \quad \text{if} \quad \pi \geq c_0/b. \tag{A.7}$$

For the rest of the proof, we compare equilibrium welfare under each regime when $\pi\in[0,c_0/b)$. It will be convenient to isolate different cases, depending on which regime dominates at $\pi = 0$. In fact, based on the configuration of parameters, we may have[27]

$$U_0^{TD}(\kappa_r, 0, \alpha) > U_0^{TC}(\kappa_r, 0, \alpha), \quad \text{or} \quad U_0^{TD}(\kappa_r, 0, \alpha) \leq U_0^{TC}(\kappa_r, 0, \alpha).$$

We next consider each subcase separately.

Subcase 1: $U_0^{TD}(\kappa_r, 0, \alpha) > U_0^{TC}(\kappa_r, 0, \alpha)$. In this case, continuity and (A.7) imply that there exist a threshold $\hat{\pi}(\kappa_r, \alpha) \in [0, c_0/b)$ such that

$$U_0^{TD}(\kappa_r, \hat{\pi}(\kappa_r, \alpha), \alpha) = U_0^{TC}(\kappa_r, \hat{\pi}(\kappa_r, \alpha), \alpha). \tag{A.8}$$

To prove uniqueness, we need the following lemma:

Lemma 4. *Suppose there exits a $\hat{\pi}(\kappa_r, \alpha) \in [0, c_0/b)$ such that (A.8) holds, given (κ_r, α). Then*

$$\frac{\partial U_0^{TC}(\kappa_r, \hat{\pi}(\kappa_r, \alpha), \alpha)}{\partial \pi} \geq \frac{\partial U_0^{TD}(\kappa_r, \hat{\pi}(\kappa_r, \alpha), \alpha)}{\partial \pi}. \tag{A.9}$$

In words, Lemma 4 shows that U_0^{TC} is steeper than U_0^{TD} if these functions cross at $\hat{\pi}(\kappa_r, \alpha) \in [0, c_0/b)$. Uniqueness then follows immediately from the fact that social welfare functions are continuous in π. And, since $U_0^{TD}(\kappa_r, 0, \alpha) > U_0^{TC}(\kappa_r, 0, \alpha)$, we get that TD dominates if and only if (κ_r, π, α) satisfy $\pi \leq \hat{\pi}(\kappa_r, \alpha)$.

It is not possible to show where does $\hat{\pi}(\kappa_r, \alpha)$ lie within the interval $[0, c_0/b)$. Hence, the full proof to Lemma 4 is algebraically intensive as it requires to show (A.9) for all possible subintervals of $[0, c_0/b)$ and for the whole range of (κ_r, α). For reasons of space, we only provide a sketch of proof for the lemma by showing (A.9) for a particular case.

Proof of Lemma 4 (Sketch): Suppose that

$$\kappa_r \leq \min\left\{\left(\frac{b}{c_0} - 1\right)\kappa_p, \kappa^{init}\right\}, \tag{A.10}$$

and that

$$\hat{\pi}(\kappa_r, \alpha) \in [0, \pi_1^{TD}(\kappa_r)], \tag{A.11}$$

where π_1^{TD} was defined in Appendix A.3. Under TC, the region p initiates all projects because by Assumption 2 we have $c_p^{TC}(\kappa_r, 0) > b$ (see equation (4)). Similarly, region r also initiates all

[27]For example, when $\alpha = 1$ and $\kappa_r = \kappa_p$, $U_0^{TD}(\kappa_r, 0, \alpha) > U_0^{TC}(\kappa_r, 0, \alpha)$ because TD replicates the first best. Applying a continuity argument, we know that this inequality should hold in a neighborhood of $\alpha = 1$ and $\kappa_r = \kappa_p$.

projects given that $c_r^{TC}(\kappa_r, 0) > b$, by (A.10). As a consequence, we have

$$U_0^{TC}(\kappa_r, \pi, \alpha) = \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] + b - c_0 - (1-\pi)\left[\alpha\frac{\kappa_r}{\kappa} + (2-\alpha)\frac{\kappa_p}{\kappa}\right]\bar{c}$$

and

$$\frac{\partial U_0^{TC}(\kappa_r, \pi, \alpha)}{\partial \pi} = \left[\alpha\frac{\kappa_r}{\kappa} + (2-\alpha)\frac{\kappa_p}{\kappa}\right]\bar{c} > 0, \tag{A.12}$$

where $\bar{c}$ is the expected value of c.

Now we compute the derivative of U_0^{TD} with respect to π. Given (A.10) and (A.11):

$$\begin{aligned} U_0^{TD}(\kappa_r, \pi, \alpha) =& \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] + \frac{\alpha}{2}\int_0^{c_p^{TD}(\kappa_r,\pi)} \left[b - c_0 - \Delta_r(c, \kappa_r, \pi)\right] h(c)dc \\ &+ \frac{2-\alpha}{2}\int_0^{c_p^{TD}(\kappa_r,\pi)} \left[b - c_0 - \Delta_p(c, \kappa_r, \pi)\right] h(c)dc, \end{aligned} \tag{A.13}$$

This implies:

$$\begin{aligned} \frac{\partial U_0^{TD}(\kappa_r, \pi, \alpha)}{\partial \pi} =& -\frac{\alpha}{2}\int_0^{c_p^{TD}(\kappa_r,\pi)} \frac{\partial \Delta_r(c, \kappa_r, \pi)}{\partial \pi} h(c)dc \\ &- \frac{2-\alpha}{2}\int_0^{c_p^{TD}(\kappa_r,\pi)} \frac{\partial \Delta_p(c, \kappa_r, \pi)}{\partial \pi} h(c)dc \\ &+ \frac{\alpha}{2}\left[b - c_0 - \Delta_r(c_p^{TD}(\kappa_r, \pi), \kappa_r, \pi)\right] h(c_p^{TD}(\kappa_r, \pi))\frac{\partial c_p^{TD}(\kappa_r, \pi)}{\partial \pi}, \end{aligned} \tag{A.14}$$

where we used that $\Delta_p(c_p^{TD}(\kappa_r, \pi), \kappa_r, \pi) = b - c_0$ by definition of c_p^{TD} (see Appendix A.3). Applying the definitions of $\Delta_\ell(c, \kappa_r, \pi)$ and (A.12), and evaluating (A.14) at $\hat{\pi}(\kappa_r, \alpha)$ we obtain

$$\begin{aligned} \frac{\partial U_0^{TD}(\kappa_r, \hat{\pi}, \alpha)}{\partial \pi} =& \frac{\partial U_0^{TC}(\kappa_r, \hat{\pi}, \alpha)}{\partial \pi} - (1-\alpha)\frac{\kappa_r - \kappa_p}{\kappa}\bar{c} - \int_0^{c_p^{TD}(\kappa_r,\hat{\pi})} \left[\frac{\alpha}{2}\frac{\left(\hat{\tau}_r^I\right)^2}{2} + \frac{2-\alpha}{2}\frac{\left(\hat{\tau}_p^I\right)^2}{2}\right] h(c)dc \\ &- \frac{1}{1-\hat{\pi}}\int_{c_p^{TD}(\kappa_r,\hat{\pi})}^{b} \left[2(b - c_0) - (1-\hat{\pi})c\right] h(c)dc \\ &+ \frac{\alpha}{2}\left[b - c_0 - \Delta_r(c_p^{TD}(\kappa_r, \hat{\pi}), \kappa_r, \hat{\pi})\right] h(c_p^{TD}(\kappa_r, \hat{\pi}))\frac{\partial c_p^{TD}(\kappa_r, \hat{\pi})}{\partial \pi}. \end{aligned} \tag{A.15}$$

By the Implicit Function Theorem,

$$\frac{\partial c_p^{TD}(\kappa_r, \pi)}{\partial \pi} = -\frac{\partial \Delta_p(c, \kappa_r, \pi)/\partial \pi}{\partial \Delta_p(c, \kappa_r, \pi)/\partial c} < \frac{2c^*(\pi) - RC_p^I(c)}{1-\pi},$$

where we used that $\partial \Delta_p(c, \kappa_r, \pi)/\partial \pi = RC_p^I(c) - 2c^*(\pi)$, and that $\partial \Delta_p(c, \kappa_r, \pi)/\partial c > 1 - \pi$. Using this fact into (A.15) we get (after rearranging):

$$
\begin{aligned}
\frac{\partial U_0^{TD}(\kappa_r,\hat{\pi},\alpha)}{\partial \pi} \leq & \frac{\partial U_0^{TC}(\kappa_r,\hat{\pi},\alpha)}{\partial \pi} - (1-\alpha)\frac{\kappa_r-\kappa_p}{\kappa}\bar{c} - \int_0^{c_p^{TD}(\kappa_r,\hat{\pi})}\left[\frac{\alpha}{2}\frac{\left(\hat{\tau}_r^I\right)^2}{2} + \frac{2-\alpha}{2}\frac{\left(\hat{\tau}_p^I\right)^2}{2}\right]h(c)dc \\
& - \frac{1}{1-\hat{\pi}}\Bigg\{\int_{c_p^{TD}(\kappa_r,\hat{\pi})}^{b}\left[2(b-c_0)-(1-\hat{\pi})c\right]h(c)dc \\
& - \alpha\left[b-c_0-\Delta_r(c_p^{TD}(\kappa_r,\hat{\pi}),\kappa_r,\hat{\pi})\right]h(c_p^{TD}(\kappa_r,\hat{\pi}))\left(c^*(\hat{\pi})-\frac{RC_p^I(c_p^{TD}(\kappa_r,\hat{\pi}))}{2}\right)\Bigg\}.
\end{aligned}
$$

With some algebra we can show that, if Assumption 1 is satisfied, the term in curly brackets is strictly positive. This implies that (A.9) holds under (A.10) and (A.11). We can similarly prove that (A.9) is verified for all $\kappa_r \in [0,\infty)$, $\alpha \in [0,1]$, and $\hat{\pi}(\kappa_r,\alpha) \in [0, c_0/b)$. □

Subcase 2: $U_0^{TD}(\kappa_r,0,\alpha) \leq U_0^{TC}(\kappa_r,0,\alpha)$. Here U_0^{TD} and U_0^{TC} cannot cross at any $\pi \in [0, c_0/b)$. If this were the case, U_0^{TD} would intersect U_0^{TC} from below along the π dimension, thus contradicting Lemma 4. In this case, we set $\hat{\pi}(\kappa_r,\alpha) = 0$.

A.5.2 $\kappa_r \to \infty$

As in the previous section, we only focus on $\pi \leq c_0/b$, since TC dominates otherwise, and both regimes are equivalent for $\pi = 1$. Let $U_0^{\mathcal{I}}(\infty,\pi,\alpha) \equiv \lim_{\kappa_r\to\infty} U_0^{\mathcal{I}}(\kappa_r,\pi,\alpha)$ for $\mathcal{I} \in \{TC, TD\}$. Using the results on the initiation and refinancing equilibria in each regime, we can show that:

$$
\begin{aligned}
U_0^{TC}(\infty,\pi,\alpha) = & \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] \\
& + \frac{\alpha}{2}\left[\int_0^{c^*(\pi)}(b-c_0-(1-\pi)c)\,h(c)dc - (1-\pi)\bar{c}\right] + \frac{2-\alpha}{2}(b-c_0), \qquad \text{(A.16)}
\end{aligned}
$$

and

$$
\begin{aligned}
U_0^{TD}(\infty,\pi,\alpha) = & \frac{1}{2}\left[\alpha\kappa_r + (2-\alpha)\kappa_p\right] + \frac{\alpha}{2}\int_0^{c^*(\pi)}(b-c_0-(1-\pi)c)\,h(c)dc \\
& + \frac{2-\alpha}{2}\int_0^{c_p^{TD}(\pi,\infty)}\left(b-c_0-(1-\pi)RC_p^I(c)\right)h(c)dc, \qquad \text{(A.17)}
\end{aligned}
$$

where $c_p^{TD}(\infty, \pi) \equiv \lim_{\kappa_r \to \infty} c_p^{TD}(\kappa_r, \pi)$. Now let $\pi = 0$ and define:

$$\nabla(\alpha) \equiv U_0^{TD}(\infty, 0, \alpha) - U_0^{TC}(\infty, 0, \alpha) = \\ \frac{1}{2}\left\{\alpha\bar{c} + (2-\alpha)\left[\int_0^{c_p^{TD}(\infty,0)} \left[b - c_0 - RC_p^I(c)\right] h(c)dc - (b - c_0)\right]\right\}, \quad \text{(A.18)}$$

where $c_p^{TD}(\infty, 0) \equiv \lim_{\kappa_r \to \infty} c_p^{TD}(\kappa_r, 0)$.

Suppose that $\nabla(\alpha) > 0$. Since welfare functions are continuous in π, there exists a value $\hat{\pi}(\infty, \alpha) \in [0, c_0/b)$ such that

$$U_0^{TC}(\infty, \hat{\pi}(\infty, \alpha), \alpha) - U_0^{TD}(\infty, \hat{\pi}(\infty, \alpha), \alpha) = 0,$$

At $\hat{\pi}(\infty, \alpha)$, it follows from (A.16) and (A.17) that

$$\frac{\partial U_0^{TC}(\infty, \hat{\pi}(\infty, \alpha), \alpha)}{\partial \pi} - \frac{\partial U_0^{TD}(\infty, \hat{\pi}(\infty, \alpha), \alpha)}{\partial \pi} = \\ \frac{1}{2}\left[\alpha\bar{c} - (2-\alpha)\int_0^{c_p^{TD}(\infty,(\hat{\pi}(\infty,\alpha))} RC_p^I(c)h(c)dc\right] > 0. \quad \text{(A.19)}$$

Hence, at $\hat{\pi}(\infty, \alpha)$, $U_0^{TC}(\infty, \pi, \alpha)$ is steeper than $U_0^{TD}(\infty, \pi, \alpha)$. This implies that $\hat{\pi}(\infty, \alpha)$ is unique, by applying the same logic that we used in Section A.5.1.

Now suppose that $\nabla(\alpha) \leq 0$. It is straightforward to show that $U_0^{TC}(\infty, \pi, \alpha)$ and $U_0^{TD}(\infty, \pi, \alpha)$ cannot intersect (or, equivalently, that $\hat{\pi}(\infty, \alpha) = 0$). If they did, (A.19) would be violated. □

A.6 Proof of Proposition 6

We show a more general result for an arbitrary $\alpha \in [0, 1]$. By the Implicit Function Theorem:

$$\frac{\partial \hat{\pi}(\kappa_r, \alpha)}{\partial \kappa_r} = -\frac{\partial U_0^{TD}(\kappa_r, \hat{\pi}, \alpha)/\partial \kappa_r - \partial U_0^{TC}(\kappa_r, \hat{\pi}, \alpha)/\partial \kappa_r}{\partial U_0^{TD}(\kappa_r, \hat{\pi}, \alpha)/\partial \pi - \partial U_0^{TC}(\kappa_r, \hat{\pi}, \alpha)/\partial \pi}. \quad \text{(A.20)}$$

The denominator is negative by Lemma 4. To sign the numerator, we need to consider all possible expressions for $U_0^{TD}(\kappa_r, \pi, \alpha)$ across $\pi \in [0, c_0/b)$ as it cannot be shown where $\hat{\pi}(\kappa_r, \alpha)$ lies within that interval. While we have analyzed all possibilities, here we sign the numerator of (A.20) for a particular case (the proof of the other cases is analogous and available upon request). So assume that $\pi \in [0, \pi_1^{TD}(\kappa_r)]$. Then

$$\lim_{\kappa_r \to \kappa_p} \left[\partial U_0^{TD}(\kappa_r, \hat{\pi}, \alpha)/\partial \kappa_r - \partial U_0^{TC}(\kappa_r, \hat{\pi}, \alpha)/\partial \kappa_r \right] =$$

$$- (1-\pi) \int_0^{c_p^{TD}(\kappa_p,\pi)} \left[(1-\alpha)(1-\pi)\hat{\tau}^{II} \left(\frac{\partial \hat{\tau}_p^{II}}{\partial \kappa_r} - \frac{\partial \hat{\tau}_r^{II}}{\partial \kappa_r} \right) + \frac{\alpha}{2} \pi \, \hat{\tau}_p^I \frac{\partial \hat{\tau}_r^I}{\partial \kappa_r} \right] h(c)dc$$
$$- (1-\pi)(1-\alpha)\frac{\bar{c}}{2\kappa_p} \quad \text{(A.21)}$$

where $\hat{\tau}^{II} = \lim_{\kappa_r \to \kappa_p} \hat{\tau}_p^{II} = \lim_{\kappa_r \to \kappa_p} \hat{\tau}_r^{II}$. Since $\frac{\partial \hat{\tau}_r^{II}}{\partial \kappa_r} < 0 < \frac{\partial \hat{\tau}_p^{II}}{\partial \kappa_r}$ and $\frac{\partial \hat{\tau}_r^{I}}{\partial \kappa_r} < 0$, it follows that (A.21) is strictly positive when $\alpha = 1$ and strictly negative if $\alpha = 0$. Moreover, as (A.21) monotonically increases with α, Bolzano's Theorem implies that there exists $\underline{\alpha}$ such that, when $\alpha \geq \underline{\alpha}$, $\hat{\pi}(\kappa_r, \alpha)$ increases with κ_r in a neighborhood of $\kappa_r = \kappa_p$. □

A.7 Proof of Proposition 7

To prove the result we make use of the function $\nabla(\alpha)$ defined in (A.18). Using $c_p^{TD}(\infty, 0) < b$ it follows that $\frac{\partial}{\partial \alpha}\nabla(\alpha) > 0$. Moreover,

$$\nabla(0) = \int_0^{c_p^{TD}(\infty,0)} \left[b - c_0 - RC_p^I(c) \right] h(c)dc - (b - c_0) < 0,$$

while

$$\nabla(1) = \frac{1}{2} \left\{ \int_0^{c_p^{TD}(\infty,0)} \left[b - c_0 - RC_p^I(c) \right] h(c)dc - (b - c_0 - \bar{c}) \right\},$$

which is positive if and only if (8) holds. Since welfare functions are continuous in α, the above implies that, under condition (8), there exists a threshold $\bar{\alpha}$ such that $\nabla(\alpha) > 0$ if and only if $\alpha > \bar{\alpha}$. If (8) is violated, $\nabla(\alpha) \leq 0$ for all $\alpha \in [0, 1]$. The statement of the proposition is obviously nested by setting $\alpha = 1$. □

A.8 Proof of Lemma 1

We start by deriving D_0^{TC}. Let π_r^{TC} and $\pi_p^{TC} < \pi_r^{TC}$ be defined by $c_r^{TC}(\kappa_r, \pi_r^{TC}) = b$ and $c_p^{TC}(\pi_p^{TC}) = b$. Using these definitions, it follows that:

$$D_0^{TC}(\kappa_r, \pi) = \begin{cases} \Delta\kappa - 2(1-\pi)\frac{\kappa_r - \kappa_p}{\kappa} \int_0^{c_r^{TC}} ch(c)dc \\ \qquad - \int_{c_r^{TC}}^{c_p^{TC}} \left[b - c_0 + (1-\pi)\frac{\kappa_r-\kappa_p}{\kappa}c\right] h(c)dc & \text{if} \quad \pi \in [0, \pi_p^{TC}], \\ \\ \Delta\kappa - (1-\pi)\frac{\kappa_r-\kappa_p}{\kappa}\bar{c} - \int_0^{c_r^{TC}} \left[b - c_0 + (1-\pi)\frac{\kappa_r-\kappa_p}{\kappa}c\right] h(c)dc & \text{if} \quad \pi \in (\pi_p^{TC}, \pi_r^{TC}], \\ \\ \Delta\kappa - 2(1-\pi)\frac{\kappa_r-\kappa_p}{\kappa}\bar{c} & \text{if} \quad \pi \in (\pi_r^{TC}, 1], \end{cases}$$

where $\Delta\kappa \equiv \kappa_r - \kappa_p$. Clearly, we have $D_0^{TC}(\kappa_r, \pi) < \Delta\kappa$ for all (κ_r, π).

We can similarly show that $D_0^{TD}(\kappa_r, \pi) > \Delta\kappa$ for all (κ_r, π). This derivation is available upon request, as there are many subcases of (κ_r, π) to consider. □

A.9 Proof of Proposition 8

Notably, $\partial U_0^{\mathcal{I}} / \partial\alpha = D_0^{\mathcal{I}}$, so using the Implicit Function Theorem we get:

$$\frac{\partial\hat{\pi}(\kappa_r, \alpha)}{\partial\alpha} = \frac{D_0^{TD}(\kappa_r, \hat{\pi}) - D_0^{TC}(\kappa_r, \hat{\pi})}{\partial U_0^{TC}(\kappa_r, \hat{\pi}, \alpha)/\partial\pi - \partial U_0^{TD}(\kappa_r, \hat{\pi}, \alpha)/\partial\pi}, \tag{A.22}$$

which, given Lemmas 1 and 4 is positive. This shows part 1. Parts 2 and 3 have been shown in Appendices A.6 and A.7, respectively.

A.10 Proof of Proposition 9

If $\alpha = 0$, $U_0^{\mathcal{I}}(\kappa_r, \pi, 0) = W_{p,0}^{\mathcal{I}}(\kappa_r, \pi)$ for $\mathcal{I} \in \{TC, TD\}$. Suppose that $\pi = 0$ and $\kappa_r = \kappa_p$. Under Assumption 2 we get that

$$W_{p,0}^{TD}(\kappa_p, 0) = \kappa_p + \int_0^{b-c_0} [b - c_0 - c]\, h(c)dc > \kappa_p + b - c_0 - \bar{c} = W_{p,0}^{TC}(\kappa_p, 0),$$

because under TD, only projects with positive benefit are initiated by region p, whereas all projects (even those with negative net benefit) are initiated under TC by region p. On the other hand, if

$\kappa_r \to \infty$, then

$$\lim_{\kappa_r \to \infty} W_{p,0}^{TD}(\kappa_r, 0) = \kappa_p + \int_0^{c_p^{TD}(\infty,0)} \left[b - c_0 - RC_p^I(c) \right] h(c) dc < \kappa_p + b - c_0 = \lim_{\kappa_r \to \infty} W_{p,0}^{TC}(\kappa_r, 0),$$

where the last equality follows from (A.16) evaluated at $\alpha = 0$. Then, by continuity, there exists a threshold $\underline{\kappa}_r > \kappa_p$ satisfying $W_{p,0}^{TD}(\underline{\kappa}_r, 0) = W_{p,0}^{TC}(\underline{\kappa}_r, 0)$, such that TD dominates whenever $\kappa_p \leq \kappa_r \leq \underline{\kappa}_r$.

Put differently, $\hat{\pi}(\kappa_r, 0)$ crosses the κ_r-axis at $\underline{\kappa}_r$. In addition, the frontier $\hat{\pi}(\kappa_r, \alpha)$ also intersects the π-axis at a strictly positive value of π which is independent of α. We conclude that there exists a non-empty parametric area in the (κ_r, π) plane such that TD dominates when $\alpha = 0$. $\square$