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Public Capital and Fiscal Constraint in Sovereign Debt Crises*

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Abstract

Sovereigns' public capital and fiscal constraint influence sovereign debt crises and resolution. We compile a dataset on public expenditure composition around restructurings with private external creditors. We show that during restructurings, public investment (i) experiences severe decline and slow recovery, (ii) differs from public consumption and transfers, and (iii) relates with restructuring delays. We develop a theoretical model of defaultable debt that embeds endogenous public capital accumulation, expenditure composition, production and multi-round debt renegotiations. The model quantitatively shows public investment dynamics and tight fiscal constraint delay debt settlement—"capital accumulation delays" and "fiscal delays". Data support these theoretical predictions.

JEL Classification Codes: F34, F41, H63

Key words: Sovereign Debt; Sovereign Default; Debt Restructuring; Public Investment; Public Capital; Fiscal Constraint.

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1 Introduction

Sovereigns' public capital and fiscal constraint influence sovereign debt crises and resolution. We compile a new dataset on public expenditure composition around debt restructurings with private external creditors. We show that during restructurings, public investment (i) experiences a severe decline and a slow recovery, (ii) differs from public consumption and transfers, and (iii) relates with restructuring delays. To explain these stylized facts, we develop a theoretical model of defaultable debt that explicitly embeds endogenous public capital accumulation, expenditure composition, production and multi-round debt renegotiations. Our model quantitatively shows that public investment dynamics and tight fiscal constraint delay debt settlement—"capital accumulation delays" and "fiscal delays". Data support these theoretical predictions.

We start by presenting a comprehensive new dataset on public expenditure composition at 179 privately-held external debt restructurings over 1978–2010. Following a detailed classification by the United States (US) Bureau of Economic Analysis (BEA 2005), we newly compile public consumption, investment, transfers and capital. Our dataset provides much a wider coverage of restructuring episodes, time-series and categories, and is thus superior to existing databases (e.g., the IMF World Economic Outlook). We then merge our newly-constructed data with an existing dataset on the duration and strategies of restructurings from Asonuma and Trebesch (2016).

The consolidated datasets provide five new stylized facts on 111 post-default restructurings—sovereigns default first and renegotiate their defaulted debt later. First, public investment experiences a severe decline and a slow recovery during restructurings. Second, the dynamics differ from those around non-debt crisis recessions. Third, in contrast to public investment, public consumption and transfers experience a short-lived decline and a quick recovery. Fourth, public expenditure skews towards consumption and transfers during restructurings. Fifth, the severe declines and slow recoveries in public investment are associated with lengthy restructuring delays. We confirm these findings through both panel and cross-sectional regressions.

Our empirical findings unveil a new dimension of sovereign debt and default, which the literature has not fully explored yet. In particular, one question emerges from the facts: Why does public investment experience a severe decline and a slow recovery in debt crises, but public consumption and transfers do not? By answering this question, we raise a more fundamental question in the literature: What is the role of public capital and tight fiscal constraint on sovereign debt crises and resolution? In this context, tight fiscal constraint is defined as the limited ability of the government to extract resources from the private sector. This is because both public capital and tight fiscal constraint directly interact with the sovereign's default, debt settlement and borrowing choice.[1] These questions challenge the current understanding in the literature that neither public capital nor fiscal constraint plays the role in sovereign debt

[1]In reality, the government often finds it difficult to extract resources from the private sector through both lump-sum taxation (without distortions) and an increase in the level of current distortionary taxation. These severely constrain its resource allocation choice, i.e., tight fiscal constraint. Ongoing work by Asonuma, Joo and Zhang (2021), with an empirical analysis on tax revenues, provides empirical evidence on few cases on lump-sum taxation (without distortions) during debt restructurings.

restructurings.

To our knowledge, we are the first to shed light on the role of public capital and tight fiscal constraint jointly on the sovereign debt crises and resolution. To address these questions, we construct a theoretical sovereign debt model that explicitly embeds endogenous public capital accumulation, expenditure composition, production and post-default multi-round renegotiations with a risk averse sovereign and its risk-neutral foreign creditors. The model is built on the classical setup of Eaton and Gersovitz (1981) as in the recent quantitative analysis of sovereign debt.[2] In particular, our model of defaultable debt follows two conventional frameworks in the literature: (i) one with a meaningful role for fiscal policy i.e., when private and public sectors are separated due to both distortionary tax and two types of consumption (Cuadra et al. 2010; Arellano and Bai 2017) and (ii) one with multi-round debt renegotiations after default (Benjamin and Wright 2013; Bi 2008).

The important theoretical innovation is incorporating endogenous public capital accumulation, expenditure composition, and production with public capital and labor in the model with endogenous defaults and renegotiations. We explicitly depart from two standard modeling approaches: an exogenous income process (e.g., Arellano 2008; Aguiar and Gopinath 2006) and endogenous production with labor (e.g., Mendoza and Yue 2012; Cuadra et al. 2010). At each period, the sovereign chooses its expenditure composition (public consumption, investment and transfers) together with its choice of repayment and default (settlement and delay), and of external borrowing. Public capital is accumulated through public investment—net of both depreciation and adjustment costs.

We emphasize two novel predictions in our theoretical model. First, the model makes predictions about the role of public capital and (full) tight fiscal constraint on the sovereign's choice of default, debt settlement and restructuring delays. *After default*, the sovereign is willing to delay renegotiations, ceteris paribus, when public capital is low and/or when it has (full) tight fiscal constraint. It opts to invest limited resources—owing to both (full) tight fiscal constraint and financial exclusion—in public capital rather than use its resources for recovered debt payments given the high marginal product of public capital. As a result, debt settlement and delays are driven by the marginal product of public capital and the fiscal constraint further tightened by financial exclusion in addition to a conventional recovery of repayment capacity (Benjamin and Wright 2013; Bi 2008). Longer delays due to these two new drivers "capital accumulation delays" and "fiscal delays" differentiate our paper from previous studies.

Before default, shown only quantitatively, the sovereign's willingness to repay remains unchanged or decreases when public capital increases.[3] On the one hand, ex ante, higher public capital improves the sovereign's repayment capacity ("smoothing channel"). On the other hand, ex post (after default), higher public capital smooths household consumption in financial autarky ("autarky channel") and achieves quick debt settlement ("renegotiation channel"). Effects

[2] See Arellano (2008) and other studies covered in Aguiar and Amador (2014) and Aguiar et al. (2016).

[3] Gordon and Guerron-Quintana (2018) and Park (2017) focus on the role of total (private) capital on sovereign default. As there is no "fiscal constraint" explicitly separating public and private sectors in their models, resources can be transferred freely between two sectors.

from the latter two channels weakly dominate those from the former channel. The renegotiation channel, newly introduced in our paper, differentiates our paper from Gordon and Guerron-Quintana (2018) in which the sovereign's willingness to repay increases as total (private) capital increases.[4] As in Arellano and Bai (2017), the sovereign is willing to default, ceteris paribus, when it has (full) tight fiscal constraint.

Second, the model provides predictions on a mechanism of public investment dynamics and how (full) tight fiscal constraint plays a role. *At the onset of default*, both a severe productivity shock and (full) tight fiscal constraint interact with the sovereign's consumption-smoothing motive and impatience. The interaction of these factors results in a sharp decline in public investment and default. This is because the impatient government, with a consumption-smoothing motive, is willing to smooth household consumption by stabilizing public consumption and transfers. Due to (full) tight fiscal constraint, the sovereign cannot allocate enough resources to public investment and external debt payments i.e. a sharp reduction in public investment and default.

During restructuring, a combination of slow recovery of productivity, prohibition on external borrowing, (full) tight fiscal constraint and the sovereign's consumption-smoothing motive and impatience generates both slow public capital accumulation and lengthy renegotiations. Public capital accumulation is slow both because external borrowing is unfeasible until the government reaches a settlement with its creditors, and because due to (full) tight fiscal constraint, the impatient government with a consumption-smoothing motive is willing to smooth household consumption limiting resources for investment. This cycle continues until the sovereign accumulates public capital to a high level and reaches settlement. When fiscal constraint is relaxed or removed (i.e., "partial" or "no fiscal constraint"), the sovereign is more willing to settle and experiences a milder decline and a quicker recovery in public investment, and shorter delays than our baseline with (full) tight fiscal constraint.

Our theoretical predictions are supported by data: both the severe decline and the slow recovery in public investment delay debt settlement. First, a panel analysis on debt settlement using 111 post-default episodes at an annual frequency confirms these predictions. Second, the quantitative analysis calibrated to the Argentine default and restructuring in 2001–05 replicates the five stylized facts: (i) a severe decline and a slow recovery of public investment, (ii) a difference in public debt dynamics between debt restructurings and non-debt crisis recessions, (iii) a short-lived decline and quick recovery of public consumption and transfers, (iv) public expenditure skewing towards consumption and transfers, (v) an association between public investment dynamics (e.g., declines and recoveries) and delays in restructurings.

Literature Review Our paper contributes to both theoretical and empirical literature on the role of public capital (investment) on business cycles.[5] In the theoretical strand of literature, Baxter and King (1993) find that public investment has significant effects on private output and investment, resulting in a large supply side fiscal multiplier. Azzimonti (2015) shows that

[4]Hamann et al. (2018) also find similar two opposing effects of oil reserves on the sovereigns' default.

[5]See also Leeper et al. (2010) and Ramey (forthcoming) for a role of public investment on business cycles.

political re-election uncertainty triggers a reduction in public investment which, in turn, results in an economic downturn. In the empirical strand of literature, Ashauer (1989) finds evidence that public and private capital stocks are complementary inputs to the private production technology in the US. Our paper contributes to both the empirical and theoretical strands of literature by showing new empirical findings on public investment around debt restructurings and theoretical findings on the role of public capital on debt crisis and crisis resolution.

The paper is also related to the theoretical literature exploring interactions between fiscal policy and a sovereign's default and external borrowing choice (e.g., Cuadra et al. 2010; Arellano and Bai 2017; D'Erasmo and Mendoza 2016, 2021; Pouzo and Presno 2016; Hatchondo et al. 2017; Bianchi et al. 2019; Roch and Uhlig 2018).[6,7] These studies explicitly embed different fiscal policy instruments on expenditure (e.g., public consumption or transfers) and on revenue (e.g., labor income tax or consumption tax) in the model with endogenous default and production with labor. Our paper differs from the existing literature in that with public investment newly introduced in the model, it explains the role of public capital and tight fiscal constraint on a sovereign's default, debt settlement and restructuring delays.

Lastly, the theoretical work on sovereign debt restructurings models the outcome of default and debt renegotiation as bargaining between a sovereign debtor and its creditors.[8] With multi-round renegotiations, both Benjamin and Wright (2013) and Bi (2008) explain that recovery of the debtor's repayment capacity generates delays, and Asonuma and Joo (2020) show that both the debtor's repayment capacity and its risk averse creditor's consumption-smoothing motive interact and drive longer delays. On the contrary, Bai and Zhang (2012) find that delays arise due to information asymmetry between the debtor and its creditors. We fill a gap in the literature by explaining two new mechanisms of delays: capital accumulation delays and fiscal delays.

[6]Mendoza et al. (2014) explore interactions between fiscal policy, i.e., different taxation methods and external borrowing choice in highly-integrated two-country set-up without the sovereigns' default choice.

[7]See also Gonçalves and Guimaraes (2015), Fink and Scholl (2016), and Karantounias (2018). For empirical work on sovereign debt and fiscal policy, see Kaminsky et al. (2005), Ilzetzki et al. (2013), Frankel et al. (2013), and Ilzetzki (2011).

[8]See also Bulow and Rogoff (1989), Kovrijnykh and Szentes (2007), Yue (2010), Arellano et al. (2018, 2019), D'Erasmo (2011), Hatchondo et al. (2014), Asonuma and Trebesch (2016), Pitchford and Wright (2012), Fernandez and Martin (2014), Dvorkin et al. (2021), and Asonuma (2016).

2 Dataset and Stylized Facts

2.1 New Dataset on Public Expenditure Composition

Confronted with debt crises and restructurings, sovereigns often implement fiscal expenditure reduction programs associated with financing by multilateral sources, e.g., an IMF-supported program. The fiscal adjustment programs feature substantially different treatment in public expenditure composition, particularly large cuts in public investment in contrast with small cuts in public consumption. Representative episodes are Latin American debt crises in the early 1980s. Argentina, Brazil, and Peru implemented expenditure reduction programs which resulted in severe reductions in public investment: 1.1–2.8 percent of GDP on average in 1983–87 (Calderon et al. 2003).[9] The severe reductions in public investment, which were not completely offset by increases in private investment, resulted in a significant drop in GDP growth.

To explore explicitly the role of public capital and tight fiscal constraint on the sovereign debt crises and resolution, we first need to identify precisely each category of public expenditure and its dynamics during debt restructurings. For this, we code a new dataset on public expenditure composition—consumption, investment, transfers, and capital—at 179 privately-held external debt restructurings over 1978–2010.

One main challenge for this coding exercise was a lack of high quality data on public expenditure composition satisfying criterion for (i) cross-country (in particular defaulting countries), (ii) times series, and (iii) category coverage simultaneously. The IMF World Economic Outlook (WEO) database provides annual data on government spending components, but the database meets only the third criteria. Data are available only for limited years, i.e., since 2000 and for limited sample of countries, i.e., advanced countries. The World Bank (WB) Global Development Finance (GDF) database provides annual consumption data, i.e., general government final consumption. The database meets both the first and second criterion. This is because the indicator covers only one sub-category of public consumption and lacks compensation of general government employees (including employer contributions for government social insurance)—one of the large sub-categories of public consumption—underestimating total public consumption.

To have high quality data on categories of public expenditure, we therefore combine the limited yearly data on public expenditure from IMF (2015), WEO, and WB GDF with rich information from a new broad range of sources.[10] Important quantitative sources for us in particular are the IMF Staff Reports from the IMF archives (Article IV consultations, requests and reviews for IMF-supported programs, information annexes, etc.). For a detailed classification of public consumption, investment and transfers, we follow US BEA (2005)—explained in Table A2 in Appendix A.2. The coding outcome is documented in detail for each of the 179 restructuring episodes and backed by the exact sources used for coding. Table A3 in Appendix A.2 shows coding examples and the underlying sources for a few exemplary cases.

[9] Sach (1990) explains that in Latin American fiscal adjustment programs, the authorities prioritized cuts in public investment over cuts in public consumption, i.e., reductions in public sector real wage or employment.

[10] Appendix A.1 explains how IMF (2015) constructs both public capital and investment series.

Table 1 summarizes our public expenditure composition dataset demonstrating four main advantages compared to existing ones, e.g., IMF WEO or WB GDF. First of all and most importantly, it is the first comprehensive public expenditure composition dataset which covers a wide range of categories including transfers—little has been covered in existing datasets. Second, each expenditure category in our dataset covers at least 70 percent of all restructuring episodes (124 cases out of 179 episodes). Third, each expenditure category covers three distinct time periods around restructuring episodes: pre-restructuring, restructuring and post-restructuring periods. Fourth, each expenditure series is comprised of sub-categories; for instance, public consumption series include compensation of general government employees.

Table 1: Public Consumption, Investment, Transfers and Capital for Restructurings in 1978–2010[1/]

	Observation	Mean	Observation	Mean	Observation	Mean
Restructuring Episodes	179					
Restructuring Duration	3.8					
	Pre-restructuring period		**Restructuring period** *Percent of GDP*		**Post-restructuring period**	
Public Consumption, average[2/]	124	13.1	124	12.0	124	11.7
Public Investment, average[2/]	151	4.7	151	3.7	151	4.0
Public Transfers, average[2/]	124	5.3	124	3.9	124	4.6
Public Capital, average[2/]	151	75.0	151	74.2	151	74.9

[1/] For all components of public expenditure, our dataset has both series in real and level (constant 2011 US dollars), and in percent of GDP.
[2/] For each restructuring episode, we take an average of public expenditure series for corresponding periods: (i) pre-restructuring period, i.e., 3 years before the start of restructurings; (ii) restructuring period, i.e., from the start to the end of restructurings; (iii) post-restructuring period, i.e., 3 years after the end of restructurings. Then, we take an average of the obtained statistics across restructuring observations.

2.2 Empirical Findings: Five Stylized Facts

We merge our newly-constructed data with the existing dataset on the duration and strategies (preemptive or post-default) of restructurings from Asonuma and Trebesch (2016). Asonuma and Trebesch (2016) differentiate post-default episodes (111 cases covering 62 percent of all episodes)—the government defaults first and renegotiates its debt—from preemptive exchanges—renegotiations take place prior to a payment default. Our findings for post-default debt restructurings in 1978–2010 can be summarized in five main stylized facts.[11]

- ***Stylized fact 1: Public investment experiences a severe decline and a slow recovery around restructurings.***

Figure 1: Public Investment

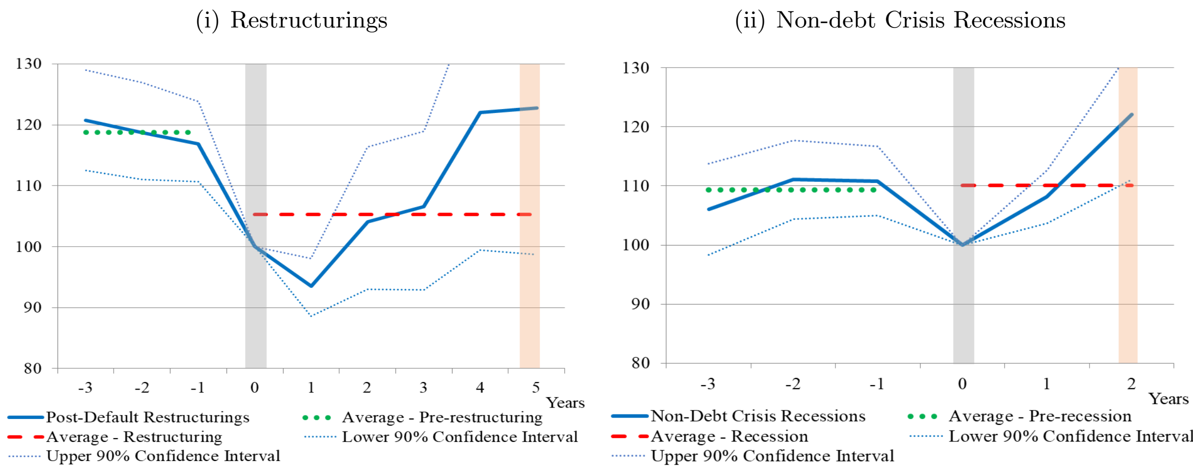


Figure 1 shows the dynamics of public investment around restructurings and non-debt crisis recessions.[12] In panels (i) and (ii), the start and end of the debt restructurings and non-debt crisis recessions—the default or restructuring announcement for the start and the debt exchange for the end defined in Asonuma and Trebesch (2016)—are marked by gray and orange vertical bars, respectively. Public investment is in real and level terms and is normalized at levels at the start of debt restructurings and non-debt crisis recessions (=100). The blue solid lines show an average for all post-default restructuring episodes and non-debt crisis recessions for which public investment is available in our dataset. The green dotted and red dashed lines show average public investment during the pre-restructuring (pre-recession) and restructuring (recession) periods.

[11] Our findings relate to empirical literature on sovereign debt restructurings. See Benjamin and Wright (2013), Sturzenegger and Zettelmeyer (2006, 2008), Reinhart and Rogoff (2009), Cruces and Trebesch (2013), Kaminsky and Vega-Garcia (2016), Reinhart and Trebesch (2016), Asonuma and Trebesch (2016), and Asonuma and Joo (2020).

[12] Izquierdo et al. (2019) find empirically that some European EMs with low initial stock of public capital have significantly higher public investment multipliers than those with high initial stock of public capital over 1987–2014.

Panel (i) shows that public investment declines markedly at the onset of debt crises (year 0) and stays below the pre-crisis level in the subsequent years. Public investment only recovers to the pre-crisis level in year 4, leading to the debt settlement in year 5. Average investment in the restructuring period (red dashed line) is significantly lower than that in the pre-restructuring period (green dotted line).

- ***Stylized fact 2: Public investment dynamics around restructurings differ from those around non-debt crisis recessions.***

A non-debt crisis recession is defined as an event over periods (at least two years) from the first year when GDP deviation from the Hodrick-Prescott (hereafter HP) filtered trend turns negative to the year before it recovers to positive. Duration of recessions is 2.2 years on average, shorter than that of post-default restructurings (5.0 years). Panel (ii) shows that public investment declines temporarily at the onset of recessions (year 0). Immediately after, public investment recovers quickly and reaches the pre-recession level in year 1 (Baxter and King 1993). Average public investment in the recession period (red dashed line) is at the same level with that in the pre-recession period (green dotted line). A contrast between panels (i) and (ii) shows a difference in public investment dynamics between restructurings and non-debt crisis recessions: a severe decline and a slow recovery versus a short-lived decline and a quick recovery. When we measure public investment as percent of GDP, we observe the same dynamics of public investment-to-GDP ratio for both restructurings and non-debt crisis recessions (Figure B1 in Appendix B.1).

- ***Stylized fact 3: Public consumption and transfers experience a short-lived decline and a quick recovery around restructurings.***

Figure 2: Public Consumption and Transfers

(i) Restructurings

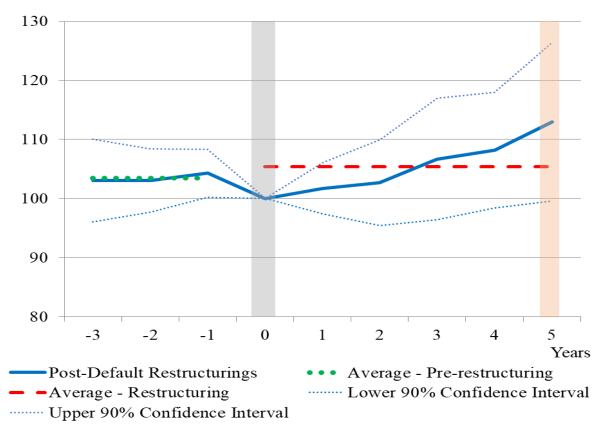


Figure 2 shows the dynamics of public consumption and transfers around restructurings.[13] We follow the same presentation approach as in Figure 1 in terms of time horizon, timing of events (both start and end of debt restructurings), scale (real and level), normalization of the series at level of the start of restructurings (=100), and average in the two periods. Panel (i) shows that public consumption and transfers fall temporarily at the onset of debt crises (year 0). Instantly after, public consumption and transfers recover quickly and reach the pre-crisis level in year 2. Average public consumption and transfers in the restructuring period (red dashed line) are slightly higher than that in the pre-restructuring period (green dotted line). A contrast between panel (i) in Figures 1 and 2 shows a difference in the dynamics between public consumption and transfers, and investment. Public investment experiences a severe decline and a slow recovery, while public consumption and transfers experience a short-lived decline and a quick recovery. When we measure public consumption and transfers as percent of GDP, we also observe the same dynamics of public consumption and transfers-to-GDP ratio (Figure B2 in Appendix B.1).

To obtain more systemic and robust evidence—not contaminated by the effects of business cycles—we apply a standard panel fixed effects regression of public investment, consumption, and transfers (all measured as a deviation from the HP-filtered trend) for post-default restructurings reported in Table 2. We use two measures of public investment: (i) public investment deviation from the trend, and (ii) growth rate of public capital. Main explanatory variables are dummy variables for the restructuring and post-restructuring periods. Both GDP deviation from the HP-filtered trend and lagged public and publicly-guaranteed (PPG) external debt (in percent of GDP) from the WB World Development Indicators (WDI) database are included to control the effects of business cycles and debt level.

The main result reported in Table 2 is that public investment—measured both as a deviation from the trend and as a percentage change in public capital—is significantly lower in the restructuring period than that in the pre-restructuring period (columns 1 and 2). Quantitatively, on average, public capital growth rate is lower by 1.3 percent in the restructuring period than that in the pre-restructuring period. On the contrary, neither public consumption nor transfers in the restructuring period differs significantly from that in the pre-restructuring period (columns 3 and 4).

Moreover, Table 2 also contrasts results on public investment between debt restructurings and non-debt crisis recessions. Public investment is not significantly lower in the recession period than that in the pre-recession period (columns 5 and 6).

[13] Michaud and Rothert (2018) find empirically that social transfers are procyclical and significantly contribute to procyclical government expenditure in EMs.

Table 2: Public Investment, Capital, Consumption and Transfers around Restructurings

	Debt restructuring				Non-debt crisis recession	
	Investment	Capital	Consumption	Transfers	Investment	Capital
	deviation from trend, current[3/]	percentage change, current[4/]	deviation from trend, current[3/]	deviation from trend, current[3/]	deviation from trend, current[3/]	percentage change, current[4/]
	(1)	(2)	(3)	(4)	(5)	(6)
	coef/se	coef/se	coef/se	coef/se	coef/se	coef/se
Restructuring period	-0.14***	-1.26***	0.007	-0.02	-	-
(current, dummy)[1/]	(0.03)	(0.23)	(0.011)	(0.03)		
Post-restructuring period	-0.07**	-0.87***	0.003	-0.04	-	-
(current, dummy)[2/]	(0.03)	(0.24)	(0.012)	(0.03)		
Non-debt crisis recession period	-	-	-	-	0.02	0.10
(current, dummy)[1/]					(0.03)	(0.24)
Post-non debt crisis recession period	-	-	-	-	-0.01	0.28
(current, dummy)[2/]					(0.03)	(0.24)
GDP deviation from trend	0.03***	0.07***	0.01***	0.01***	0.03***	0.05**
(current, percent)[3/]	(0.003)	(0.03)	(0.001)	(0.003)	(0.004)	(0.03)
PPG external debt	-0.0007***	-0.01***	0.00003	0.000005	-0.001***	-0.01***
(lagged, percent of GDP)	(0.003)	(0.002)	(0.0001)	(0.0002)	(0.0004)	(0.003)
Constant	0.10***	4.18***	-0.008	0.01	0.06*	4.74***
	(0.03)	(0.21)	(0.01)	(0.03)	(0.03)	(0.25)
Episode-specific fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of restructuring episodes	97	96	92	81	171	169
Number of observations	1,043	996	949	747	1488	1469
F-statistics	37.94	21.39	19.59	4.02	19.32	6.07
R^2	0.139	0.087	0.084	0.024	0.058	0.013

Notes: The table shows results from fixed effects OLS regressions. The dependent variables are public investment deviation from the trend in columns (1) and (5), public capital percentage change in columns (2) and (6), public consumption deviation from the trend in column (3), and public transfers deviation from the trend in column (4). The main explanatory variables are dummy variables for the restructuring and post-restructuring periods. Columns (1)–(4) report regressions results for debt restructurings, while columns (5)–(6) for non-debt crisis recessions. All regressions include episode-specific fixed effects. Significance levels are denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, respectively. Robust standard errors clustered on the episode level are in parentheses.
[1/] A dummy variable for the restructuring (recession) period is set 1 in the restructuring (recession) period and 0 in both the pre- and post-restructuring (pre-recession and post-recession) periods.
[2/] A dummy variable for the post-restructuring (post-recession) period is set 1 in the post-restructuring (post-recession) period and 0 in both the pre-restructuring and restructuring (pre-recession and recession) periods.
[3/] A deviation from the trend is a percentage deviation from the trend obtained by applying a Hodrick-Prescott (HP) filter to annual series with filter of 6.25.
[4/] Percentage change of public capital from its level in the previous year.

- ***Stylized fact 4 : Public expenditure skews towards consumption and transfers during restructurings.***

Panels (i) and (ii) in Figure 3 show average changes in public consumption and transfers, and investment, respectively—measured as percent of GDP—between the pre-restructuring and restructuring periods for all post-default restructuring episodes. To be comparable with average in the pre-restructuring period, we take the average over the first 3 years during debt restructurings. Public consumption and transfers-to-GDP ratio differs only marginally, i.e., 0.7 percent

Figure 3: Public Expenditure Composition around Restructurings

(i) Public Consumption and Transfers (percent of GDP) | (ii) Public Investment (percent of GDP) | (iii) Public Investment (percent of public expenditure)

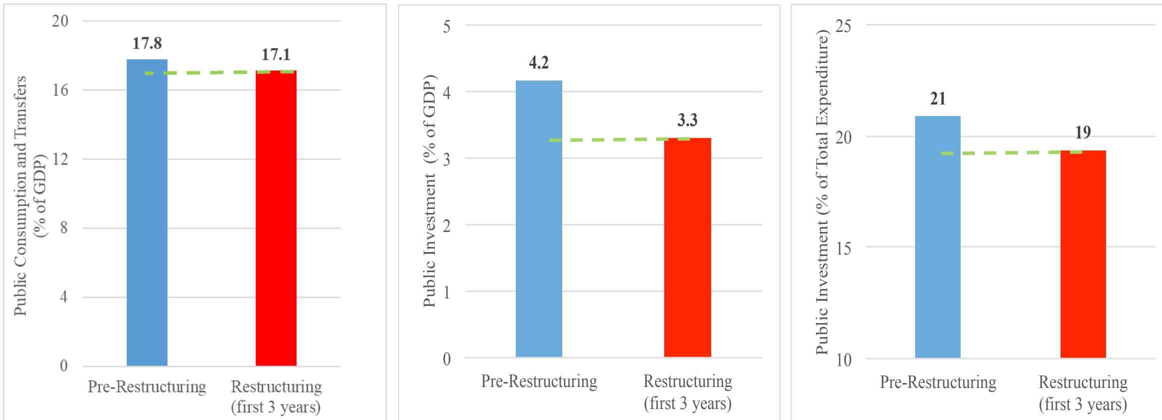


Table 3: Public Expenditure Composition around Restructurings

	Investment	Consumption	Transfers	Investment
	percent of GDP, current	percent of GDP, current	percent of GDP, current	percent of expenditure, current
	(1)	(2)	(3)	(4)
	coef/se	coef/se	coef/se	coef/se
Restructuring period (current, dummy)[1/]	-0.93***	-1.01***	0.28*	-2.31***
	(0.15)	(0.35)	(0.14)	(0.65)
Post-restructuring period (current, dummy)[1/]	-0.78***	-0.89	0.21	-0.32
	(0.16)	(0.61)	(0.25)	(1.14)
GDP deviation from trend (current, percent)[2/]	0.03**	0.02	0.03*	0.10
	(0.02)	(0.04)	(0.016)	(0.07)
Constant	4.48***	12.77***	3.04***	22.31***
	(0.13)	(0.29)	(0.12)	(0.54)
Episode-specific fixed effects	Yes	Yes	Yes	Yes
Number of restructuring episodes	96	93	93	91
Number of observations	1,036	906	906	887
F-statistics	17.87	8.02	1.83	4.50
R^2	0.071	0.038	0.009	0.022

Notes: The table shows results from fixed effects OLS regressions. The dependent variables are public investment (percent of GDP) in column (1), public consumption (percent of GDP) in column (2), public transfers (percent of GDP) in column (3), and public investment (percent of public expenditure) in column (4). The main explanatory variables are dummy variables for the restructuring and post-restructuring periods. All regressions include episode-specific fixed effects. Significance levels denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, respectively. Robust standard errors clustered on the episode level in parentheses.
[1/] A dummy variable for the restructuring (post-restructuring) period is set 1 in the restructuring period and 0 in both the pre- and post-restructuring (pre- and restructuring) periods.
[2/] A deviation from the trend is a percentage deviation from the trend obtained by applying a Hodrick-Prescott (HP) filter to annual series with filter of 6.25.

of GDP on average between the pre-restructuring and restructuring periods—equivalent to 4 percent of pre-restructuring consumption and transfers-to-GDP ratio. On the contrary, public investment-to-GDP ratio differs substantially, i.e., 0.9 percent of GDP on average between the pre-restructuring and restructuring periods—equivalent to 21 percent of pre-restructuring investment-to-GDP ratio.

Panel (iii) in Figure 3 shows that the share of public investment in public expenditure is reduced to 19 percent in the restructuring period—the decline is equivalent to 7 percent of pre-restructuring share of public investment. Public expenditure skews heavily towards consumption and transfers during debt restructurings.

Table 3 provides econometric support for this stylized fact. It reports results of panel fixed effects regression of public expenditure components (both in percent of GDP and percent of public expenditure) for post-default restructurings. We also use GDP deviation from the trend and lagged PPG external debt to control the effects of business cycles and debt level.

Public investment, on average, is significantly reduced in the restructuring period (column 1): by 0.9 percent of GDP equivalent to 21 percent of estimated average public investment. Public consumption, on average, is less remarkably reduced in the restructuring period (column 2): by 1.0 percent of GDP equivalent to 8 percent of estimated average public consumption. In contrast, public transfers, on average, are significantly increased in the restructuring period: by 0.3 percent of GDP equivalent to 9 percent of estimated average public transfers.

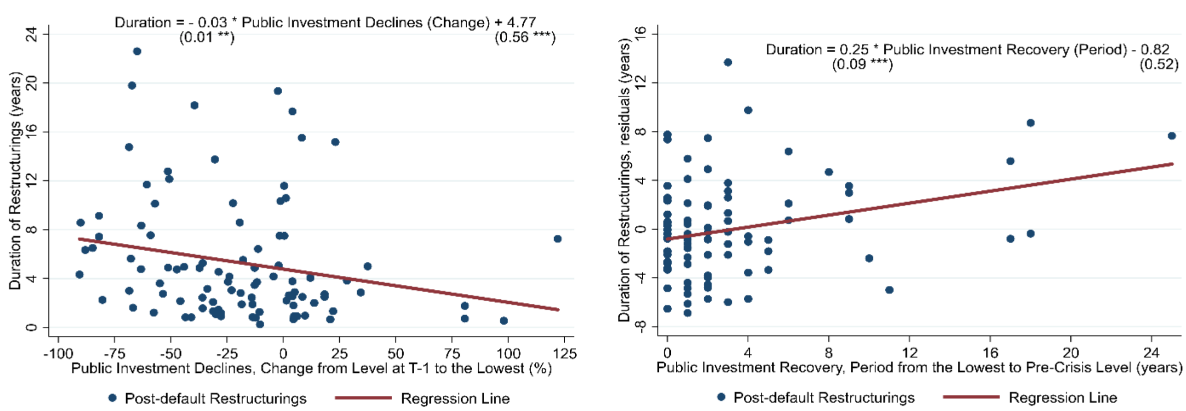
Most importantly, as a result of these changes in public expenditure components, column 4 shows that the share of public investment in public expenditure is significantly lower (by 2.3 percent of public expenditure) in the restructuring period than that in the pre-restructuring period.

- ***Stylized fact 5 : Both sharp declines and slow recoveries in public investment are associated with longer delays in restructurings.***

Figure 4: Declines and Recoveries in Public Investment and Duration of Restructurings

(i) Declines in Public Investment

(ii) Recoveries in Public Investment



Panels (i) and (ii) in Figure 4 show scatter plots of the duration of restructurings and the declines and recoveries in public investment level during debt crises. The declines in public investment are measured as a percentage change of public investment from the level in year t-1 to the lowest level, i.e., the level at end of declining trend. The recoveries in public investment are measured in periods (years) from the time at which public investment is at the lowest level to the time at which it recovers to the pre-crisis average. In panel (ii), duration of restructurings is reported as residuals from a partial regression excluding recoveries in public investment. Restructurings are protracted when sovereign debtors experience both severe declines and slow recoveries in public investment (the fitted lines in panels i and ii). When we measure both declines and recoveries with public investment-to-GDP ratio, we observe the same relationships between declines and recoveries in public investment-to-GDP ratio and duration of restructurings (Figure B3 in Appendix B.2).

These relationships are also supported by Table B1 in Appendix B.3 which reports cross-sectional regression results of restructuring duration for all post-default restructuring episodes. We use two sets of measures: declines and recoveries in public investment (level) and in public investment-to-GDP ratio. We add a conventional set of controls for duration of restructurings used in the empirical literature on sovereign debt (Trebesch 2019; Bai and Zhang 2012; Asonuma and Joo 2020). The set includes (i) the debtors' macroeconomic variables—GDP deviation from the trend obtained by applying a HP filter, external debt-to-GDP ratio, export-to-debt service ratio (all at the end of restructurings), and a dummy variable for an IMF-supported program; (ii) the pre-restructuring level of public capital, (iii) a global variable, e.g., London Interbank Offered Rate (LIBOR), and (iv) a restructuring method variable such as a dummy variable for bond exchanges. Regression results confirm these two relationships are significant for both two measures. We also confirm the robustness of these results when we deal with outliers in the sample of duration, and declines and recoveries in public investment (Tables B2 in Appendix B.3).

3 Theoretical Model

3.1 Summary of Theoretical Findings

Our theoretical model is built to shed light on the role of public capital and fiscal constraint on sovereign debt crises and resolution. In particular, our model of sovereign debt embeds explicitly endogenous public capital accumulation, expenditure composition and production, and post-default multi-round renegotiations. To account for different economic situations for sovereign debtors, we take a two-step approach. At the first stage, we use a conventional sovereign debt model with fiscal policy—private and public sectors are separated by distortionary consumption tax and two different consumption goods (Cuadra et al. 2010; Arellano and Bai 2017)—as benchmark and derive main results in Sections 3–5. At the second stage, we incorporate additional assumptions used in the previous studies (e.g., Aguiar and Gopinath 2006; Benjamin and Wright 2013) in our framework and show robustness of our model in Appendix C.

First, the model makes predictions about the role of public capital and (full) tight fiscal constraint on the sovereign's choice of default, debt settlement, and restructuring delays. *After default*, the sovereign is willing to delay renegotiations, ceteris paribus, when public capital is low and/or it has (full) tight fiscal constraint. It opts to invest its limited resources—owing to both (full) tight fiscal constraint and financial exclusion—in public capital rather than pay recovered debt payments given the high marginal product of public capital. Both public capital and the (full) tight fiscal constraint, further tightened by financial exclusion, determine debt settlement and delays.[14] *Before default*, shown only quantitatively, the sovereign's willingness to repay remains unchanged or decreases when public capital increases. On the one hand, ex ante, higher public capital improves its repayment capacity (smoothing channel). On the other hand, ex post (after default), higher public capital smooths household consumption in financial autarky (autarky channel) and achieves quick debt settlement (renegotiation channel). Benefits from the latter two channels weakly dominate those from the former channel due to introduction of the renegotiation channel. The sovereign is willing to default, ceteris paribus, when it has (full) tight fiscal constraint (Arellano and Bai 2017).

Second, the model also provides predictions on a mechanism on public investment dynamics and the role of (full) tight fiscal constraint. *At the onset of default*, both a severe productivity shock and (full) tight fiscal constraint interact with the sovereign's consumption-smoothing motive and impatience. Given (full) tight fiscal constraint, the impatient government priorities public consumption and transfers for household consumption smoothing over public investment and external debt payments i.e. a decline in public investment and default. *During the restructuring*, a combination of slow recovery of productivity, prohibition on external borrowing, (full) tight fiscal constraint and the sovereign's consumption-smoothing motive and impatience generates both slow public capital accumulation and lengthy renegotiations. Public capital accu-

[14] There is no immediate settlement with new lending due to limited commitment (Benjamin and Wright 2013). This is because when the sovereign's repayment capacity has not fully recovered due to low productivity, the creditors anticipate that the sovereign is more likely to default on newly issued debt immediately after settlement, and opt to delay the settlement during next debt renegotiations.

mulation is slow both because external borrowing is unfeasible until debt settlement and because the sovereign is willing to smooth household consumption limiting resources for investment.

3.2 Assumptions in the Model

There are four agents in the model: a household, a firm, a sovereign (government), and foreign creditors.[15] The sovereign is risk averse and cannot affect the global risk-free interest rate (r^*). Foreign creditors are risk-neutral. They can borrow or lend as much as needed at the constant risk-free interest rate in the international capital market.

In each period, a stochastic productivity shock a_t materializes. It is stochastic, drawn from a compact set $A = [a_{min}, a_{max}] \subset R$. $\mu(a_{t+1}|a_t)$ is a probability distribution of a shock a_{t+1} conditional on its previous realization a_t. In addition, the sovereign has a credit record $h_t \in [0, 1]$, which indicates whether it has maintained access to the market ($h_t = 0$) or whether it has lost market access due to default ($h_t = 1$).

After observing the productivity shock, the sovereign receives consumption tax revenues (no lump-sum taxation allowed) and decides expenditure composition—public consumption, investment and transfers—and choice of repayment and default (settlement and delay) and of external borrowing. Consumption tax revenues are determined by the household's optimal choice of private consumption given a constant consumption tax rate. Public consumption and transfers are provided to the household to improve his utility directly or indirectly by smoothing private consumption. Public capital rented to the firm is accumulated through net investment and is subject to both depreciation and adjustment costs.

The household receives profits from the firm, and public consumption and transfers from the government, respectively. He chooses private consumption and labor supply, and pays consumption taxes to the government. The firm receives public capital from the government, chooses labor demand, and pays profits to the household.

The sovereign bond market is incomplete. Only the sovereign can borrow and lend only via one-period, zero-coupon sovereign bonds at the market, while neither the household nor firm can.[16] b_{t+1} denotes the amount of bonds to be repaid in the next period whose set is shown by $B = [b_{min}, b_{max}] \subset R$ where $b_{min} \leq 0 \leq b_{max}$. We set the lower bound for the sovereign's bond holding at $b_{min} > -y_{max}/r^*$, which is the largest debt that the sovereign can repay. The upper bound b_{max} is the high level of assets that the sovereign may accumulate.[17] We assume $q(b_{t+1}, k^g_{t+1}, 0, a_t)$ to be price of sovereign bonds with the sovereign's asset position b_{t+1}, public

[15] In this theoretical and quantitative analysis, the term sovereign corresponds to the government.

[16] Our model of debt renegotiations with one-period bonds follows Benjamin and Wright (2013), Bi (2008), and Yue (2010). Relaxing the model to include long-duration bonds does not provide additional insights but increases the technical difficulty to track the model. This is because old bonds are exchanged with new bonds with the same maturity and smaller outstanding (debt stock), i.e., no change in maturity structure of bonds due to an exchange (Hatchondo et al. 2014). See Hatchondo and Martinez (2009), Arellano and Ramanarayanan (2012), and Chatterjee and Eyigungor (2012) for long-duration bond models without debt renegotiations, and Sanchez et al. (2018) and Dvorkin et al., (2021) for endogenous maturity choice.

[17] b_{max} exists when the interest rate on the sovereign's savings is sufficiently low compared to the discount factor, which is satisfied as $(1 + r^*)\beta < 1$.

capital k^g_{t+1}, a good credit record ($h_t = 0$), and a productivity shock a_t. The bond price is determined in equilibrium.

We assume that the creditors always commit to repay their debt. However, the sovereign is free to decide whether to repay its debt or to default. If the sovereign chooses to repay its debt, it will preserve access to the international capital market in the next period. On the contrary, if it chooses to default, it is then subject to both exclusion from the international capital market and direct productivity loss.[18,19] When a default occurs, the sovereign and the creditors negotiate a reduction of unpaid debt via multi-round bargaining. At the renegotiation, one party, who is randomly selected with exogenous and constant probability, chooses whether to propose an offer with haircuts (recovery rates) or to pass its option. The other party decides whether to accept or reject the offer. If the offer with haircuts is proposed and accepted, then the sovereign regains access to the international capital market in the next period ($h_{t+1} = 0$), and the creditors receive recovered debt payments. Otherwise, both parties continue the negotiation over debt in arrears in the next period.

In order to avoid permanent exclusion from the international capital market and direct productivity loss, the sovereign has an incentive to renegotiate over haircuts. Similarly, the creditors are also willing to renegotiate over the reduction of unpaid debt because they expect nonzero recovered debt payments.

3.3 Timing of the Model

Figure 5 summarizes the timing of decisions within each period.

1. The sovereign starts the current period with initial assets/debt and public capital. We are in node (A).

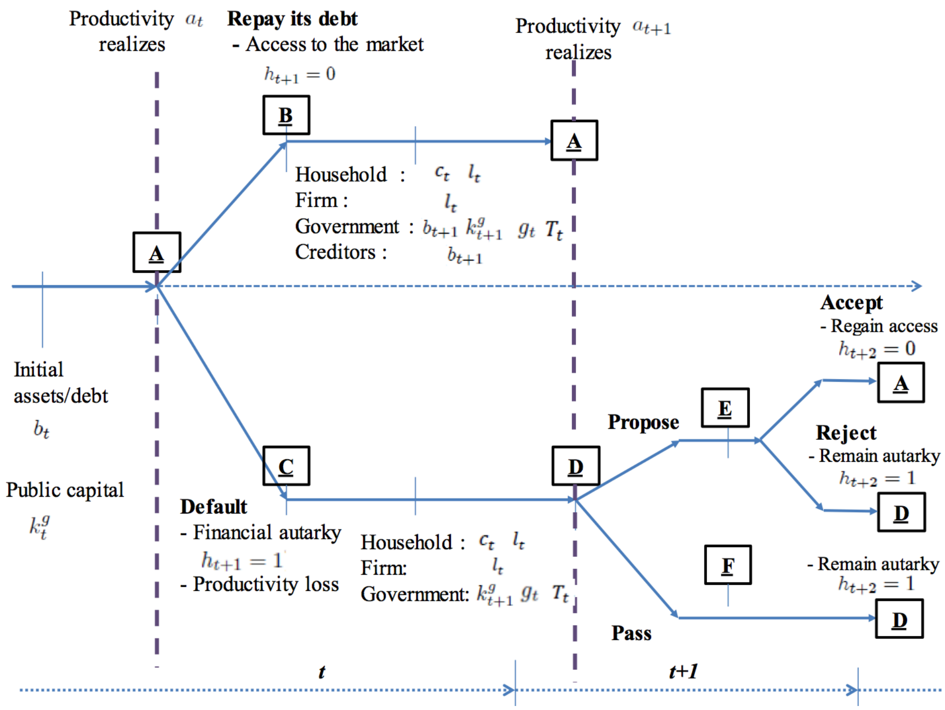
2. A productivity shock (a_t) realizes. The sovereign decides whether to repay its debt or to default.

3. (a) In node (B) (repayment node), if repayment is chosen, we move to the upper branch of a tree. The sovereign maintains market access ($h_{t+1} = 0$) and chooses assets/debt, public consumption, capital and transfers. Default risk is determined and foreign creditors choose the level of sovereign bonds in the next period. The sovereign bond price is determined in the market. The household chooses his private consumption

[18]The direct productivity loss assumption in our production model is conceptually equivalent to "output costs" assumption in conventional (exogenous) endowment models (e.g., Arellano 2008; Aguiar and Gopinath 2006; Yue 2010). In this regard, the direct production loss is widely accepted in the sovereign debt literature with endogenous production (Cuadra et al. 2010; Arellano and Bai 2017; Gordon and Guerron-Quintana 2018). Both assumptions are broadly in line with empirical estimates of output loss at default in general (Sturzenegger 2004; Tomz and Wright 2007; Levy-Yeyati and Panizza 2011) and those at a post-default restructuring (Asonuma and Trebesch 2016; Asonuma et al. 2021).

[19]Mendoza and Yue (2012) theoretically explain that exclusion from the international capital market leads to declines in production efficiency due to a lack of imported inputs and labor reallocation away from final goods production.

Figure 5: Timing of Model



and labor supply, and the firm chooses labor demand. We proceed to node (A) in the next period.

(b) In node (C) (default node), if default is chosen, we move to the lower branch of a tree. The sovereign loses access to the international capital market ($h_{t+1} = 1$), suffers the direct productivity loss, and chooses public consumption, capital and transfers. The household chooses his private consumption and labor supply, and the firm chooses labor demand.

4. A productivity shock (a_{t+1}) realizes.

5. In node (D) (default node), with constant probability, the sovereign has an opportunity to propose an offer to its creditors. Otherwise, the creditors have an opportunity to propose an offer to the sovereign. The proposer decides whether to propose an offer or to pass.

6. (a) In node (E) (propose node), if the proposer chooses to propose an offer, the counterpart decides whether to accept or reject the offer. If the counterpart accepts the offer, the sovereign regains market access in the next period ($h_{t+2} = 0$). We move to node (A) in the next period. On the contrary, if the counterpart rejects the offer, the sovereign remains in autarky ($h_{t+2} = 1$). We move back to node (D).

   (b) In node (F) (pass node) if the proposer chooses to pass, the sovereign remains in autarky ($h_{t+2} = 1$). We move back to node (D).

4 Recursive Equilibrium

4.1 Household's Problem

This section defines the stationary recursive equilibrium of our model. A representative household's utility function is defined as:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t [(1-\lambda)u(c_t, l_t) + \lambda v(g_t)]$$

where $0 < \beta < 1$ is a discount factor and c_t, l_t, g_t denote private consumption, labor supply and public consumption in period t, respectively. His period utility function is separable between a multiple of private consumption and labor supply, and public consumption. Both $u(\cdot)$ and $v(\cdot)$ are continuous, strictly increasing, strictly concave, and satisfy the Inada conditions. λ denotes the weight on public consumption in the household's utility function.

The household takes as given the wage rate w_t, profits paid by a firm π_t^F, public transfers T_t, public consumption g_t and a consumption tax rate τ, and chooses private consumption and labor supply.[20] He does not borrow directly from abroad, but the government borrows, provides public consumption and transfers, and makes default decisions internalizing the household's utility.[21] The household's optimization problem is written as:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t [(1-\lambda)u(c_t, l_t) + \lambda v(g_t)] \tag{1}$$

$$s.t. \quad (1+\tau)c_t = w_t l_t + \pi_t^F + T_t \tag{2}$$

The consumption tax rate is assumed to be constant (Arellano and Bai 2017; Alfaro and Kanczuk 2017)—also supported by empirical findings on value-added taxes in developing countries in Gunter et al. (2017). The optimality condition of the household is shown as follows:

$$\frac{u_l(c_t, l_t)}{u_c(c_t, l_t)} = \frac{w_t}{1+\tau} \tag{3}$$

4.2 Firm's Problem

A representative firm chooses labor l_t for goods production given both exogenous productivity shock a_t and fixed private capital stock ($\bar{k^p} = 1$) following Mendoza and Yue (2012) and Azzimonti (2015). The production function is Cobb-Douglas:

[20] Relaxing the model to include labor income tax does not provide additional insights (Arellano and Bai 2017; Mendoza et al. 2014) as shown in panel B in Figure C5 in Appendix C. This is because, labor income tax and consumption tax are conceptually identical in that both affect the household's intra-temporal substitution between consumption and labor (equation 3), but not the sovereign's inter-temporal substitution between consumption—public consumption and transfers—and saving (i.e., public investment).

[21] Though the household lacks access to the international capital market as in conventional sovereign debt models, his utility can still be improved through three methods: (i) private consumption (through transfers), (ii) public consumption, and (iii) labor supply.

$$y_t = a_t(l_t)^{\alpha_l}(k_t^g)^{\alpha_k}(\bar{k^p})^{1-\alpha_l-\alpha_k} \tag{4}$$

The firm's optimization problem reduces to:

$$\max_{l_t} \pi_t^F = a_t(l_t)^{\alpha_l}(k_t^g)^{\alpha_k}(\bar{k^p})^{1-\alpha_l-\alpha_k} - w_t l_t \tag{5}$$

The optimality condition of the firm is shown as follows:

$$w_t = \alpha_l a_t(l_t)^{\alpha_l - 1}(k_t^g)^{\alpha_k}(\bar{k^p})^{1-\alpha_l-\alpha_k} \tag{6}$$

4.3 Sovereign's (Government's) Problem

The sovereign maximizes its expected lifetime utility and its value function is denoted by $V(b_t, k_t^g, h_t, a_t)$. First, we start with its problem when the sovereign has a good credit record ($h_t = 0$). It receives debt payments from creditors when it has saving[22], while it decides whether to repay or to default after observing its productivity shock when it has debt. If the sovereign has savings or decides to pay its debt, it receives tax revenues from the household and determines public consumption, capital, transfers, and the level of assets/debt in the next period. In contrast, if it chooses to default, it will be excluded from the international capital market and its credit record deteriorates to $h_{t+1} = 1$, with debt in arrears $b_{t+1} = (1 + r^*)b_t$ in the next period where r^* is a constant risk-free interest rate. After suffering the direct productivity loss and receiving tax revenues, it determines public consumption, capital and transfers.

$$V(b_t, k_t^g, 0, a_t) = \max\left[V^R(b_t, k_t^g, 0, a_t), V^D(b_t, k_t^g, 0, a_t)\right] \tag{7}$$

$V^R(b_t, k_t^g, 0, a_t)$ is its value associated with repayment:

$$V^R(b_t, k_t^g, 0, a_t) = \max_{g_t, b_{t+1}, k_{t+1}^g, T_t} (1-\lambda)u(c_t, l_t) + \lambda v(g_t) + \beta \int_A V(b_{t+1}, k_{t+1}^g, 0, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{8}$$

$$s.t. \quad g_t + k_{t+1}^g + T_t + q(b_{t+1}, k_{t+1}^g, 0, a_t)b_{t+1} = \tau c_t + (1-\delta^k)k_t^g - \frac{\Omega}{2}\left(\frac{k_{t+1}^g - k_t^g}{k_t^g}\right)^2 k_t^g + b_t \tag{9}$$

$$T_t \geq 0 \tag{10}$$

$$\frac{u_l(c_t, l_t)}{u_c(c_t, l_t)} = \frac{\alpha_l a_t(l_t)^{\alpha_l-1}(k_t^g)^{\alpha_k}(\bar{k^p})^{1-\alpha_l-\alpha_k}}{1+\tau} \tag{11}$$

$$(1+\tau)c_t = y_t + T_t \tag{12}$$

where equation (9) is the budget constraint for the sovereign government where it receives consumption tax revenues τc_t, public capital stock net of depreciation and adjustment costs $(1-$

[22] In this case, two assets—external bonds with risk-free returns and investment with state-dependent returns—co-exist due to a state-dependent difference in returns and the sovereign optimally allocates its total savings.

$\delta^k)k_t^g - \frac{\Omega}{2}(\frac{k_{t+1}^g - k_t^g}{k_t^g})^2 k_t^g$—non-linear adjustment costs are assumed[23] and δ^k is the depreciation rate of capital—and savings/debt b_t, and allocates to public consumption g_t, capital k_{t+1}^g, transfers T_t and assets/debt in the next period $q(b_{t+1}, k_{t+1}^g, 0, a_t)b_{t+1}$. Equation (10) is the "no lump-sum taxation constraint"—lump-sum taxation is not allowed. A combination of distortionary consumption taxation and no lump-sum taxation constraint corresponds to "fiscal constraint" indicating a limitation of the government's capacity from transferring resources from the private sector (Arellano and Bai 2017). Mechanically, the government can freely transfer positive net borrowing through transfers, but cannot extract more resources from the private sector beyond the distortionary consumption tax revenues. Equations (11) and (12) denote the combined optimality condition and budget constraint for both the household and the firm, respectively.

$V^D(b_t, k_t^g, 0, a_t)$ is its value associated with default:

$$V^D(b_t, k_t^g, 0, a_t) = \max_{g_t, k_{t+1}^g, T_t} (1-\lambda)u(c_t, l_t) + \lambda v(g_t) + \beta \int_A V((1+r^*)b_t, k_{t+1}^g, 1, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{13}$$

$$s.t. \quad (10) \text{ and}$$

$$g_t + k_{t+1}^g + T_t = \tau c_t + (1-\delta^k)k_t^g - \frac{\Omega}{2}(\frac{k_{t+1}^g - k_t^g}{k_t^g})^2 k_t^g \tag{9a}$$

$$\frac{u_l(c_t, l_t)}{u_c(c_t, l_t)} = \frac{\alpha_l \tilde{a}_t (l_t)^{\alpha_l - 1} (k_t^g)^{\alpha_k} (\bar{k^p})^{1-\alpha_l-\alpha_k}}{1+\tau} \tag{11a}$$

$$(1+\tau)c_t = \tilde{y}_t + T_t \tag{12a}$$

where $\tilde{y}_t = \tilde{a}_t (l_t)^{\alpha_l} (k_t^g)^{\alpha_k} (\bar{k^p})^{1-\alpha_l-\alpha_k}$ indicating output with the direct productivity loss $\tilde{a}_t$.

The sovereign's default policy can be characterized by default set $D(b_t, k_t^g, 0) \subset A$. It is a set of productivity shocks a_t at which default is optimal:

$$D(b_t, k_t^g, 0) = \{a_t \in A : V^R(b_t, k_t^g, 0, a_t) < V^D(b_t, k_t^g, 0, a_t)\} \tag{14}$$

Next comes the sovereign's problem with a bad credit record with debt in arrears ($h_t = 1$ & $b_t < 0$). The sovereign is currently excluded from the international market, suffers the direct productivity loss, and may settle on recovery rates through renegotiations with the creditors. Its value, denoted by $V(b_t, k_t^g, 1, a_t)$, is an expected payoff that the debtor obtains from the bargaining which starts in period t:

$$V(b_t, k_t^g, 1, a_t) = \Gamma(b_t, k_t^g, a_t) \tag{15}$$

4.4 Debt Renegotiation

The debt renegotiation takes the form of a two-player stochastic bargaining game with complete information as in Merlo and Wilson (1995).[24] It is a multi-round stochastic bargaining game

[23] Non-linear adjustment costs are assumed to replicate to smooth investment dynamics.

in that both the productivity process of the sovereign debtor and the identity of the proposer are stochastic. The creditors' incentive to delay the settlement is identical to that in previous studies on multi-round renegotiations (Benjamin and Wright 2013; Bi 2008): the risk-neutral creditors (with constant discount rate), who care only about recovery rates in present value terms, prefer to wait for the sovereign's willingness to repay high recovered debt payments.[25]

More importantly, however, the sovereign's incentive to delay the settlement clearly differentiates our model from these previous papers: in their models, the sovereign is willing to wait for recovery of repayment capacity, (i.e., output) which follows an exogenous process. In contrast, in our model, what determines the sovereign's choice of settlement and delay are not only the recovery of repayment capacity (i.e., productivity) but also state-dependent benefits and costs of public investment (i.e., the marginal product of public capital) interacting with tight fiscal constraint. The sovereign opts to delay the settlement because it prioritizes investing limited resources—owing to tight fiscal constraint and financial exclusion—in public capital over debt settlement until public capital reaches a high level.

In every round, a state is realized and the proposer is randomly selected. For simplicity, each player has a constant probability of being selected as the proposer in each round of the negotiation. That is, the identity of the proposer is independent of the sovereign's productivity process. Let ϕ denote the probability that the borrower, B, can propose and $1-\phi$ denote the probability that the lender, L, can propose. The probability with which one of the players is selected as the proposer is a parsimonious way to reflect the bargaining power obtained through one's ability to enjoy the first-mover advantage. The proposer may either propose recovery rates (haircuts) or pass. If he proposes, then the counterpart chooses to accept or to reject the proposal.[26] If the proposal is accepted, then the sovereign repays its reduced debt arrears and resumes access to the international capital market in the next period ($h_{t+1} = 0$) with no outstanding debt. If the proposal is rejected, both parties repeat the bargaining game in the next period. If the proposer passes, both parties continue the bargaining game in the next period.

First, we define some basic concepts of the game. A stochastic bargaining game is denoted by $(C, \beta, 1/(1+r^*))$, where for each productivity process $a \in A$, $C(a)$ is the set of feasible utility vectors that may be agreed upon in that state. β and $1/(1+r^*)$ are the discount factors for B and L, respectively.[27] A payoff function is an element $\Delta(a) \in C(a)$, where $\Delta_i(a)$ is the utility

[24] While the bargaining game between two parties can be modeled in other different forms, we follow the conventional bargaining game in Merlo and Wilson (1995) for their simplicity and tractability.

[25] Asonuma and Joo (2020) consider the risk averse creditor whose consumption-smoothing motive is state-dependent. In their framework, the creditor's state-dependent consumption-smoothing motive influences not only the outcome (i.e., recovery rates), but also equally importantly, the timing of debt settlement.

[26] We assume that the proposer makes an offer that the counterpart accepts when the value of proposing is higher or equal to the value of passing, and passes otherwise. This assumption can get rid of trivial sources of multiplicity. See Merlo and Wilson (1995) for the same treatment.

[27] Merlo and Wilson (1995) assume a common discount factor between the two players. However, they explain that "there is no real restriction implied by the assumption that players discount utility at a common constant rate. So long as the discounted size of the "cake" converges uniformly to 0. $\cdots$ player-dependent discount factors can always be represented by a different "cake" process with a common fixed discount factor". Our model assumes

to player i for $i = B, L$.

As in Merlo and Wilson (1995), we focus on a game with stationary strategies, that is, the players' actions depend only on the current state $(b_t, k_t^g, 1, a_t)$ where $h_t = 1$ and the current offer. In equilibrium, the proposer's strategy is to propose when the counterpart would accept for certain and to pass otherwise. In contrast, the counterpart's strategy is to accept when the proposal is made and to reject otherwise. Therefore, we can denote the proposer i's and the counterpart j's equilibrium strategies as follows: (a) $\theta_i(b_t, k_t^g, 1, a_t) = 1$ (propose) when the proposer i proposes and $\theta_j(b_t, k_t^g, 1, a_t) = 1$ (accept) when the counterpart j accepts the offer, or (b) $\theta_i(b_t, k_t^g, 1, a_t) = 0$ (pass) when the proposer i passes and $\theta_j(b_t, k_t^g, 1, a_t) = 0$ (reject) when the counterpart j rejects the offer.[28]

A stationary subgame perfect (SP) equilibrium is defined as the players' equilibrium stationary strategies θ and θ^*, and the payoff functions, Γ and Γ^* associated with these strategies for player B and L. The expected payoffs for the borrower B and lender L in period t, are shown as:

$$\Gamma(b_t, k_t^g, a_t) = \phi\Gamma^B(b_t, k_t^g, a_t) + (1-\phi)\Gamma^L(b_t, k_t^g, a_t) \tag{16}$$

$$\Gamma^*(b_t, k_t^g, a_t) = \phi\Gamma^{*B}(b_t, k_t^g, a_t) + (1-\phi)\Gamma^{*L}(b_t, k_t^g, a_t) \tag{17}$$

Here, the superscript denotes the identity of the proposer: $\Gamma^B(\Gamma^{*B})$ represents the borrower's (lender's) payoff when the borrower is the proposer and $\Gamma^L(\Gamma^{*L})$ refers to the borrower's (lender's) payoff when the lender is the proposer.

First, we start with the case when the borrower B is the proposer. We denote the proposed debt recovery rates as δ_t^B, the borrower's values of proposing and passing as V^{PRO} and V^{PASS}, and the lender's values of accepting and rejecting as V^{*ACT} and V^{*REJ}, respectively. When the borrower B proposes and the proposal is accepted, the sovereign repays reduced debt arrears $-\delta_t^B b_t$ and resumes access to the international capital market in the next period with no outstanding debt as in Asonuma and Joo (2020). Appendices C and G relax the assumption of fully recovered debt payments at settlement allowing for net issuance as in Benjamin and Wright (2013) and show that our main qualitative and quantitative results remain robust.

$$V^{PRO}(b_t, k_t^g, a_t) = \max_{g_t, k_{t+1}^g, T_t} (1-\lambda)u(c_t, l_t) + \lambda v(g_t) + \beta \int_A V(0, k_{t+1}^g, 0, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{18}$$

$$s.t. \quad (10),\ (11a),\ (12a), \ \text{and}$$

$$g_t + k_{t+1}^g + T_t = \tau c_t + (1-\delta^k)k_t^g - \frac{\Omega}{2}\left(\frac{k_{t+1}^g - k_t^g}{k_t^g}\right)^2 k_t^g + \delta_t^B b_t \tag{9b}$$

asymmetric discount factors between the borrower and the lender.

[28] Benjamin and Wright (2013) theoretically prove both existence and uniqueness of the equilibrium in the multi-round bargaining over defaulted debt.

$$V^{*ACT}(b_t, k_t^g, a_t) = -\delta_t^B b_t \tag{19}$$

When the borrower B passes, both parties proceed to the next period with accumulated arrears $(1 + r^*)b_t$.

$$V^{PASS}(b_t, k_t^g, a_t) = \max_{g_t, k_{t+1}^g, T_t} (1-\lambda)u(c_t, l_t) + \lambda v(g_t) + \beta \int_A V((1+r^*)b_t, k_{t+1}^g, 1, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{20}$$

$$s.t. \quad (9a),\ (10),\ (11a),\ \text{and}\ (12a)$$

$$V^{*REJ}(b_t, k_t^g, a_t) = \frac{1}{1+r^*} \int_A \Gamma^*((1+r^*)b_t, k_{t+1}^g, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{21}$$

In equilibrium where off-equilibrium paths are eliminated, the agreed recovery rates δ_t^{B*} satisfy the following:

$$\begin{aligned} \delta_t^{B*} &= argmax V^{PRO}(b_t, k_t^g, a_t) \\ s.t. \quad V^{PRO}(b_t, k_t^g, a_t) &\geq V^{PASS}(b_t, k_t^g, a_t) \\ V^{*ACT}(b_t, k_t^g, a_t) &\geq V^{*REJ}(b_t, k_t^g, a_t) \end{aligned} \tag{22}$$

If both parties reach an agreement, the two parties' payoffs are as follows:

$$\Gamma^B(b_t, k_t^g, a_t) = V^{PRO}(b_t, k_t^g, a_t) \tag{23}$$

$$\Gamma^{B*}(b_t, k_t^g, a_t) = V^{*ACT}(b_t, k_t^g, a_t) \tag{24}$$

Otherwise,

$$\Gamma^B(b_t, k_t^g, a_t) = V^{PASS}(b_t, k_t^g, a_t) \tag{23a}$$

$$\Gamma^{B*}(b_t, k_t^g, a_t) = V^{*REJ}(b_t, k_t^g, a_t) \tag{24a}$$

The renegotiation settlement can be characterized by settlement set $R^B(b_t, k_t^g) \subset A$. It is a set of productivity shocks a_t at which both parties reach an agreement:

$$R^B(b_t, k_t^g) = \left\{ \begin{array}{r} a_t \in A : V^{PRO}(b_t, k_t^g, a_t) \geq V^{PASS}(b_t, k_t^g, a_t) \\ V^{*ACT}(b_t, k_t^g, a_t) \geq V^{*REJ}(b_t, k_t^g, a_t) \end{array} \right\} \tag{25}$$

Second, we consider the case when the lender L is the proposer. We denote the proposed debt recovery rates as δ_t^L, the borrower's values of accepting and rejecting as V^{ACT} and V^{REJ}, and the lender's values of proposing and passing as V^{*PRO} and V^{*PASS}, respectively. When the lender L proposes and the proposal is accepted,

$$V^{*PRO}(b_t, k_t^g, a_t) = -\delta_t^L b_t \tag{26}$$

$$V^{ACT}(b_t, k_t^g, a_t) = \max_{g_t, k_{t+1}^g, T_t} (1-\lambda)u(c_t, l_t) + \lambda v(g_t) + \beta \int_A V(0, k_{t+1}^g, 0, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{27}$$

$$s.t. \quad (10),\ (11a),\ (12a),\ \text{ and}$$

$$g_t + k_{t+1}^g + T_t = \tau c_t + (1-\delta^k)k_t^g - \frac{\Omega}{2}(\frac{k_{t+1}^g - k_t^g}{k_t^g})^2 k_t^g + \delta_t^L b_t \tag{9c}$$

When the lender L passes,

$$V^{*PASS}(b_t, k_t^g, a_t) = \frac{1}{1+r^*} \int_A \Gamma^*((1+r^*)b_t, k_{t+1}^g, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{28}$$

$$V^{REJ}(b_t, k_t^g, a_t) = \max_{g_t, k_{t+1}^g, T_t} (1-\lambda)u(c_t, l_t) + \lambda v(g_t) + \beta \int_A V((1+r^*)b_t, k_{t+1}^g, 1, a_{t+1}) d\mu(a_{t+1}|a_t) \tag{29}$$

$$s.t. \quad (9a),\ (10),\ (11a),\ \text{ and }\ (12a)$$

In equilibrium, the agreed recovery rates δ_t^{L*} satisfy the following:

$$\begin{aligned} \delta_t^{L*} &= argmax V^{*PRO}(b_t, k_t^g, a_t) \\ s.t. \quad V^{*PRO}(b_t, k_t^g, a_t) &\geq V^{*PASS}(b_t, k_t^g, a_t) \\ V^{ACT}(b_t, k_t^g, a_t) &\geq V^{REJ}(b_t, k_t^g, a_t) \end{aligned} \tag{30}$$

If both parties reach an agreement, the two parties' payoffs are as follows:

$$\Gamma^{*L}(b_t, k_t^g, a_t) = V^{*PRO}(b_t, k_t^g, a_t) \tag{31}$$

$$\Gamma^{L}(b_t, k_t^g, a_t) = V^{ACT}(b_t, k_t^g, a_t) \tag{32}$$

Otherwise,

$$\Gamma^{*L}(b_t, k_t^g, a_t) = V^{*PASS}(b_t, k_t^g, a_t) \tag{31a}$$

$$\Gamma^{L}(b_t, k_t^g, a_t) = V^{REJ}(b_t, k_t^g, a_t) \tag{32a}$$

The renegotiation settlement can be characterized by settlement set $R^L(b_t, k_t^g) \subset A$. It is a set of productivity shocks a_t at which both parties reach an agreement:

$$R^L(b_t, k_t^g) = \left\{ \begin{array}{c} a_t \in A : V^{*PRO}(b_t, k_t^g, a_t) \geq V^{*PASS}(b_t, k_t^g, a_t) \\ V^{ACT}(b_t, k_t^g, a_t) \geq V^{REJ}(b_t, k_t^g, a_t) \end{array} \right\} \tag{33}$$

4.5 Foreign Creditors' Problem

Foreign creditors are risk-neutral and can borrow from the international market with the risk-free rate (r^*). When the sovereign has a good credit record ($h_t = 0$), given the sovereign bond price, foreign creditors choose the amount of assets/debt in the next period (b_{t+1}) to maximize the expected profit:

$$\pi^c(b_{t+1}, k_{t+1}^g, 0, a_t) = \begin{cases} q(b_{t+1}, k_{t+1}^g, 0, a_t)b_{t+1} - \frac{1}{1+r^*}b_{t+1} & \text{if } b_{t+1} \geq 0 \\ [\frac{1-p^D(b_{t+1},k_{t+1}^g,0,a_t)}{1+r^*}+ \\ \frac{p^D(b_{t+1},k_{t+1}^g,0,a_t)\int_A \gamma(b_{t+1},k_{t+1}^g,1,a_{t+1})d\mu(a_{t+1}|a_t)}{1+r^*}](-b_{t+1}) \\ -q(b_{t+1}, k_{t+1}^g, 0, a_t)(-b_{t+1}) & otherwise \end{cases} \tag{34}$$

where $p^D(b_{t+1}, k_{t+1}^g, 0, a_t)$ and $\gamma(b_{t+1}, k_{t+1}^g, 1, a_{t+1})$ are the probability of default and expected recovery rates, respectively.

Since we assume that the sovereign bond market is competitive, foreign creditors' expected profit is zero in equilibrium. Using a zero expected profit condition, we get

$$q(b_{t+1}, k_{t+1}^g, 0, a_t) = \begin{cases} \frac{1}{1+r^*} & \text{if } b_{t+1} \geq 0 \\ \frac{1-p^D(b_{t+1},k_{t+1}^g,0,a_t)}{1+r^*} \\ +\frac{p^D(b_{t+1},k_{t+1}^g,0,a_t)\int_A \gamma(b_{t+1},k_{t+1}^g,1,a_{t+1})d\mu(a_{t+1}|a_t)}{1+r^*} & otherwise \end{cases} \tag{35}$$

When the sovereign buys bonds from foreign creditors $b_{t+1} \geq 0$, the sovereign bond price is equal to the price of risk-free bonds, $\frac{1}{(1+r^*)}$. When the sovereign issues bonds to foreign creditors $b_{t+1} < 0$, there is default risk and the bonds are priced to compensate foreign creditors for the risk. Since $0 \leq p^D(b_{t+1}, k_{t+1}^g, 0, a_t) \leq 1$ and $0 \leq \gamma(b_{t+1}, k_{t+1}^g, 1, a_{t+1}) \leq 1$, the bond price $q(b_{t+1}, k_{t+1}^g, 0, a_t)$ lies in $[0, \frac{1}{(1+r^*)}]$.

4.6 Equilibrium

A recursive equilibrium is defined as a set of functions for (a) the sovereign's value function, public consumption, capital, transfers, assets/debt, default set, (b) the household's private consumption, labor supply, (c) the firm's labor demand, (d) the sovereign's and the foreign creditors' decision functions, payoffs, recovery rates, settlement sets (all depending on who is the proposer), (e) sovereign bond price such that

[1]. the sovereign's value function, public consumption, capital, transfers, assets/debt, and default set satisfy its optimization problem (7)–(15);

[2]. the household's private consumption and labor supply satisfy his optimization problem (1)–(3);

[3]. the firm's labor demand satisfies its optimization problem (4)–(6);

[4]. both parties' decisions, payoffs, recovery rates, and settlement sets solve the multi-round debt renegotiation problem (16)–(33);

[5]. sovereign bond price satisfies the foreign creditors' optimization problem (34)–(35).

In equilibrium, the probability of default and settlement is defined by using the sovereign's default set and the debt settlement sets, respectively:

$$p^D(b_{t+1}, k^g_{t+1}, 0, a_t) = \int_{D(b_{t+1}, k^g_{t+1})} d\mu(a_{t+1}|a_t) \tag{36}$$

$$p^R(b_{t+1}, k^g_{t+1}, 1, a_t) = \phi \int_{R^B(b_{t+1}, k^g_{t+1})} d\mu(a_{t+1}|a_t) + (1-\phi) \int_{R^L(b_{t+1}, k^g_{t+1})} d\mu(a_{t+1}|a_t) \tag{37}$$

Expected recovery rates conditional on the sovereign's default choice are shown as:

$$\begin{aligned}
\gamma(b_{t+1}, k^g_{t+1}, 1, a_t) &= \int_A \gamma(b_{t+1}, k^g_{t+1}, 1, a_{t+1}) d\mu(a_{t+1}|a_t) \\
&= \int_A \left[\begin{array}{c} \phi \mathbb{1}_{a_{t+1} \in R^B(b_{t+1}, k^g_{t+1})} \delta^{B*}_t(b_{t+1}, k^g_{t+1}, a_{t+1}) \\ +(1-\phi) \mathbb{1}_{a_{t+1} \in R^L(b_{t+1}, k^g_{t+1})} \delta^{L*}_t(b_{t+1}, k^g_{t+1}, a_{t+1}) \\ + \left(\begin{array}{c} \phi \mathbb{1}_{a_{t+1} \notin R^B(b_{t+1}, k^g_{t+1})} \\ +(1-\phi) \mathbb{1}_{a_{t+1} \notin R^L(b_{t+1}, k^g_{t+1})} \end{array} \right) \gamma(b_{t+2}, k^g_{t+2}, 1, a_{t+1}) \end{array} \right] d\mu(a_{t+1}|a_t)
\end{aligned} \tag{38}$$

The sovereign's bond spread, i.e., the difference between the sovereign's interest rate and the risk-free rate, is defined as

$$s(b_{t+1}, k^g_{t+1}, 0, a_t) = \frac{1}{q(b_{t+1}, k^g_{t+1}, 0, a_t)} - (1 + r^*) \tag{39}$$

Theorem 1. *Given an equilibrium debt recovery schedule $\bar{\delta}^*(b, k^g, a)$, productivity $a \in A$ and debt $b \in B$, for $k^g_1 \geq k^g_2$, if settlement is optimal for k^g_2, then settlement is also optimal for k^g_1. This is $R^i(b, k^g_2) \subseteq R^i(b, k^g_1)$ for $i = B, L$.*

Proof. See Appendix D.

This theorem implies that given the equilibrium debt recovery rates, our model predicts that likelihood of debt settlement increases with the level of public capital. This differs from conventional findings in theoretical literature of sovereign debt restructurings: likelihood of debt settlement increases with the level of debtor income (Benjamin and Wright 2013; Bi 2008) or decreases with the level of foreign creditor income (Asonuma and Joo 2020).

5 Quantitative Analysis

The quantitative analysis of the model is applied to the Argentina default and restructuring in 2001–05 and shows four main findings. First, our model predicts that after default, the sovereign is willing to delay renegotiations, ceteris paribus, when public capital is low and/or it has (full) tight fiscal constraint. Second, we also predict that before default (ex ante), the sovereign's willingness to repay remains unchanged or decreases, ceteris paribus, when public capital increases. Third, the model provides predictions on a mechanism of public investment dynamics and the role of (full) tight fiscal constraint. Fourth, our simulation exercise successfully replicates the five stylized facts.

5.1 Parameters and Functional Forms

The parameter values and functional forms follow closely those in previous studies on sovereign debt and fiscal policy. We assume the following constant relative risk aversion (CRRA) functions for private consumption and labor, and for public consumption:

$$u(c_t, l_t) = \frac{(c_t - \frac{l_t^{1+\psi}}{1+\psi})^{1-\sigma}}{1-\sigma}, \qquad v(g_t) = \frac{g_t^{1-\sigma_g}}{1-\sigma_g} \tag{40}$$

As in conventional sovereign debt models (e.g., Mendoza and Yue 2012; Cuadra et al. 2010), $u(\cdot)$ follows Greenwood et al. (1988)'s specification, which provides the marginal rate of substitution between private consumption and labor orthogonal to the level of private consumption. Thus, this implies no wealth effects on labor supply. We set both risk aversion for private and public consumption as $\sigma = \sigma_g = 3$, as in previous studies (Cuadra et al. 2010; Arellano and Bai 2017; Hatchondo et al. 2017) to maintain the same degree of consumption-smoothing between two types of consumption.[29] The risk-free interest rate is $r^* = 0.01$ corresponding to the average quarterly interest rate on the 3-month US Treasury bills (Aguiar et al. 2016; Yue 2010). Labor elasticity ψ is set to 0.48 following Mendoza (1991). Labor and public capital income share is assumed to be 0.64 and 0.058, respectively, based on Gordon and Guerron-Quintana (2018) and public capital income share in Argentina in 1993–2005 from our dataset. Public

[29]Hatchondo et al. (2017) assume asymmetric risk aversion between two types of consumption ($\sigma = 2, \sigma_g = 3$) because there are no public transfers in their paper. However, with public transfers included in our model, the same degree of risk aversion to improve household utility is necessary to have both public consumption and transfers available for the sovereign (Cuadra et al. 2010; Arellano and Bai 2017).

Table 4: Model Parameters

Parameter	Value	Source
Risk aversion for private consumption	$\sigma = 3$	Hatchondo et al. (2017)
Risk aversion for public consumption	$\sigma_g = 3$	Hatchondo et al. (2017)
Risk-free interest rate	$r^* = 0.01$	Aguiar et al. (2016), Yue (2010) - US Treasury bill rate
Labor elasticity	$\psi = 0.48$	Mendoza (1991)
Labor income share	$\alpha^l = 0.64$	Gordon and Guerron-Quintana (2018)
Public capital income share	$\alpha^k = 0.058$	Computed - Argentine public capital income share
Public capital depreciation rate	$\delta^k = 0.04$	US BEA (1999)
Effective consumption tax rate	$\tau = 0.33$	Computed - Argentine tax revenues (IMF WEO)
Auto-correlation of productivity shock	$\rho = 0.85$	Computed - Argentine GDP (MECON)
Standard deviation of productivity shock	$\sigma^a = 0.017$	Computed - Argentine GDP (MECON)
Direct productivity loss	$\lambda_d = 0.035$	Computed
Weight on public consumption	$\lambda = 0.8$	Computed
Public capital adjustment costs	$\Omega = 10$	Computed
Discount rate	$\beta = 0.90$	Computed
Bargaining power	$\phi = 0.93$	Computed

capital depreciation rate is set to 0.04 following US BEA (1999). Effective consumption tax rate $\tau = 0.33$ is from tax revenues in Argentina in 1993–2005 from the IMF WEO.

The productivity process is calibrated to match quarterly seasonally adjusted GDP data from the Ministry of Economy and Production in Argentina (MECON). As in previous work (Gordon and Guerron-Quintana 2018), we assume the productivity process follows a log normal AR (1) process,

$$\log(a_t) = \rho \log(a_{t-1}) + \epsilon_{a,t} \tag{41}$$

where a productivity shock $\epsilon_{a,t}$ is $i.i.d$ $N(0, \sigma^{a,2})$. We obtain auto-correlation and standard deviation of the productivity shock: $\rho = 0.85$ and $\sigma^a = 0.017$. We approximate the stochastic process as a discrete Markov chain of equally spaced grids by using the quadrature method in Tauchen (1986).

The direct productivity loss due to default follows the functional form in Arellano and Bai (2017) which is originally from Arellano (2008)'s asymmetric output costs:

$$\tilde{a}_t = \begin{cases} (1-\lambda_d)E(a_t) & \text{if } a_t \geq (1-\lambda_d)E(a_t) \\ a_t & otherwise \end{cases} \tag{42}$$

where λ_d is set to 0.035 to generate average GDP deviation from the trend during debt restructurings of -4.45%. The weight on public consumption in the household's utility, and public capital adjustment costs are set as $\lambda = 0.8$ and $\Omega = 10$ to replicate average public consumption and transfers-to-GDP ratio of 20.0% and standard deviation of public investment relative to that of output of 5.1 for Argentina in 1993–2005, respectively.

Sturzenegger and Zettelmeyer (2006) report that Argentina experienced 6 restructurings in 1820–2004. Moreover, Struzenegger and Zettlemeyer (2008) find that the recovery rate (haircut) in Argentina 2001–05 debt restructuring was 25.0% (75.0%). We specify the sovereign's discount factor $\beta = 0.80$ and bargaining power $\phi = 0.93$ (the debtor - Argentina)—similar to that in Aguiar and Gopinath (2006) and that in Asonuma and Joo (2020), respectively—to replicate the average default frequency of 3.26% and a recovery rate of 25.0%. Table 4 summarizes the model parameters and our computation algorithm is reported in Appendix E.

5.2 Numerical Results on Equilibrium Properties

We start from providing the qualitative equilibrium properties of our theoretical model for the case when the sovereign proposes. Similarly, Appendix F.2 discusses those for the case when the creditors propose—underlying mechanisms apply symmetrically and generate identical results. Moreover, Appendix C explores the equilibrium properties for key assumptions in the model: output costs, net issuance at settlement, private capital, and taxation methods.

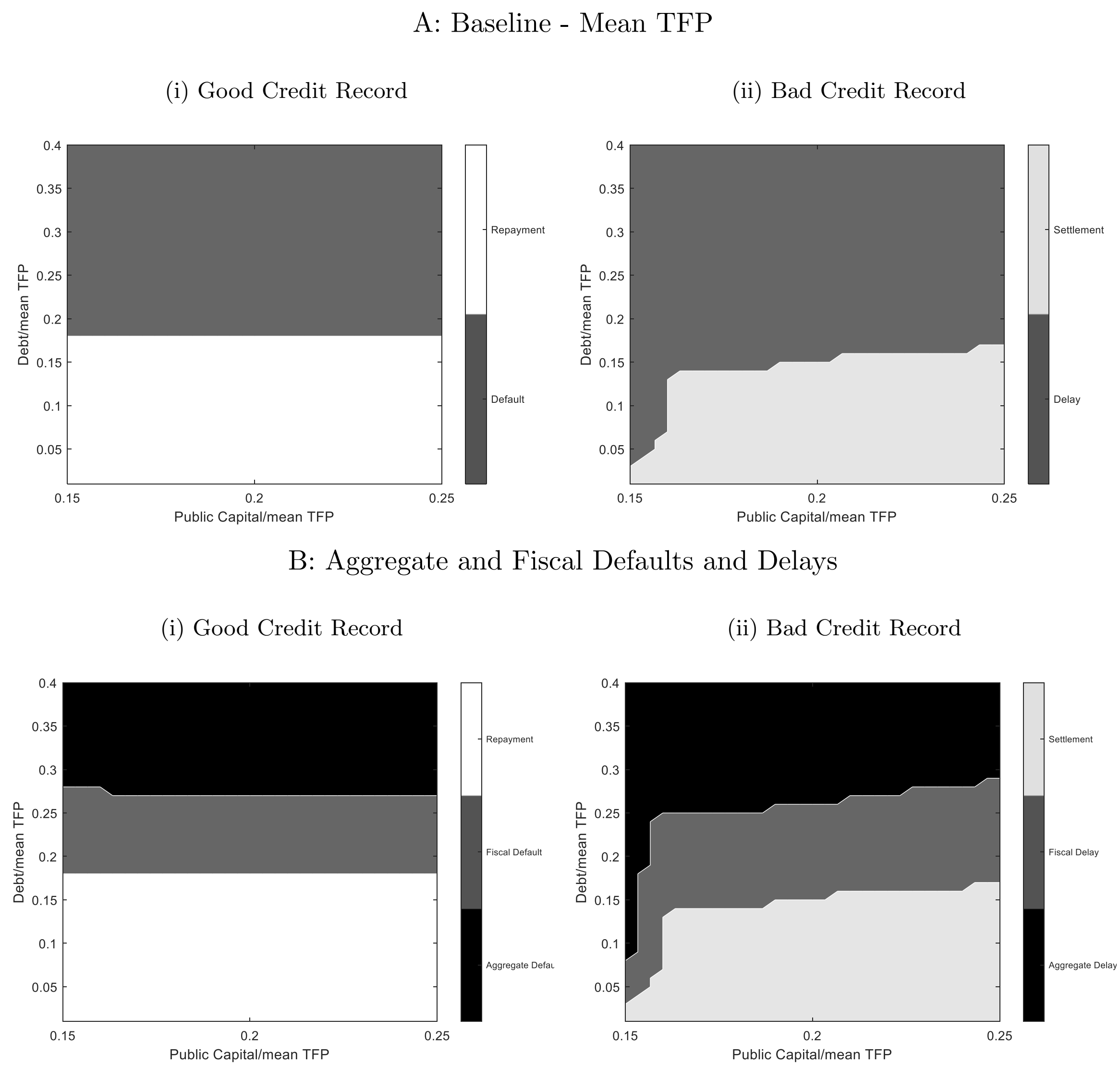
Figure 6 reports the sovereign's choice between repayment and default, and between settlement and delay—the agreed recovery rates are reported in Figure F1 in Appendix F.1. In both panel charts, the debtor TFP is fixed at the mean level, the horizontal and vertical axes are public capital-to-mean TFP ratio and debt-to-mean TFP ratio, respectively.

First, we focus on the role of public capital in panel A. More importantly, on its choice between settlement and delay reported in panel A-(ii), what our model explains newly is that the sovereign opts to delay (settle), ceteris paribus, when public capital is low (high). A first new driver—a choice between investment in public capital and use of resources for debt settlement—determines the sovereign's choice between settlement and delay in our model differentiating our model from previous studies. In the case of low public capital, the sovereign opts to invest limited resources—due to both tight fiscal constraint and financial exclusion—in public capital and refrains from using them for recovered debt payments given the high marginal product of public capital (i.e., high shadow value of public capital). The sovereign's willingness to delay is reflected in the enlarged "delay" region in dark gray color.

Moreover, on its choice between repayment and default reported in panel A-(i), our new finding is that the sovereign's willingness to repay remains unchanged or is weakly decreasing when public capital increases—presented in unchanged or slightly enlarged "default" region in dark gray color. On the one hand, higher public capital increases benefits of repayment by improving the sovereign's repayment capacity ("smoothing channel"). On the other hand, higher public capital also increases benefits of default by stabilizing household consumption in financial autarky ("autarky channel") and achieving the quick debt settlement ("renegotiation channel"). What is newly introduced in our model is the renegotiation channel which makes benefits of default equivalent to or slightly higher than benefits of repayment. This differentiates our finding from a conventional finding that the sovereign's willingness to repay increases as (private) capital increases (Gordon and Guerron-Quintana 2018).

Second, we explore the role of (full) tight fiscal constraint in panel B. On its choice between

Figure 6: Debtor's Choice between Repayment and Default, and between Settlement and Delay



settlement and delay reported in panel B-(ii), the sovereign is more willing to delay (settle), ceteris paribus, when it has (does not have) (full) tight fiscal constraint. A second new driver—the limited ability for the sovereign to extract resources from the private sector—restricts available resources for the sovereign to allocate between investment in public capital and recovered debt payments, resulting in delay. We decompose the delay region into two regions, "aggregate delay" in black color and "fiscal delay" in dark gray. Aggregate delay is the delay generated purely by slow TFP recovery (Benjamin and Wright 2013; Bi 2008), while fiscal delay is the additional delay generated by the interaction between slow TFP recovery and (full) tight fiscal constraint.

On its choice between repayment and default reported in panel B-(i), the sovereign is more willing to default (repay) when it has (does not have) (full) tight fiscal constraint, consistent with previous studies (Arellano and Bai 2017). Similar to this work, we decompose the default region into two regions, “aggregate default” in black color and “fiscal default” in dark gray. Aggregate default is the default generated purely by slow TFP recovery, while fiscal default is the additional default generated by the interaction between slow TFP recovery and (full) tight fiscal constraint. Both, higher debt and lower TFP, result in longer delays conditional on default (Benjamin and Wright 2013; Bi 2008), and more likelihood of defaulting before the actual default (Arellano 2008; Yue 2010).

5.3 Simulation Exercise

Next, we provide simulation results to show how precisely our theoretical model predicts the Argentine default and restructuring in 2001–05. Following a conventional approach, this subsection applies 1000 rounds of simulations, with 2000 periods per round and extracts the last 200 observations. In the last 200 samples, we withdraw 40 observations before and observations during the last default and restructuring event.[30]

For private sector data for Argentina, output, consumption and the trade balance are all seasonally adjusted from the MECON for 1993Q1–2001Q4 (prior to default) and 2002Q1–2005Q2 (during restructuring). The trade balance is measured as a percentage of GDP. For public sector data for Argentina, consumption, investment, transfers and capital are at annual frequency from our dataset for 1993–2001 (prior to default) and 2002–05 (during restructuring), while Argentine external debt data are from the IMF WEO for 1993–2001 (prior to default) and 2002–05 (during restructuring). Average external debt is also measured as a percentage of GDP. Bond spreads are from the J.P. Morgan’s Emerging Markets Bond Index Global (EMBIG) for 1997Q1–2001Q4 (prior to default, based on data availability). We compare our non-target statistics with those in (i) a model with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010; Hatchondo et al. 2017), (ii) a model with no fiscal constraint (Arellano 2008; Gordon and Guerron-Quintana 2018) and (iii) a recalibration result of Cuadra et al. (2010). Both (iv) models with no public capital, and recalibration results in previous studies of (a) sovereign debt and fiscal policy and (b) debt renegotiations are reported in Tables G2, G3, and G4 in Appendix G. We add specific features, respectively in our model of multi-round debt renegotiations keeping the same parameter values.

Panels (i) and (ii) in Table 5 report business cycle statistics for public sector—those for private sector are reported in Table G1 in Appendix G1—and non-business cycle statistics, respectively. For public sector statistics, our simulated moments fit the data well. Our model successfully replicates notable public sector characteristics in EMs: procyclical and volatile public consumption and transfers. This is in line with previous models of sovereign debt with fiscal policy (Arellano and Bai 2017; Cuadra et al. 2010).

Most importantly, our calibration results provide four novelties contributing to the literature. First of all, our model successfully replicates lower average public investment during a downturn in restructurings than that in the pre-default periods and during an upturn in restructurings (0.8 vs. 1.6 and 1.7 percent in the model and 0.7 vs. 1.3 and 1.6 in the data). Moreover, our model accounts for sizable public capital accumulation during restructurings consistent with the

[30]See Arellano (2008) and Yue (2010) for this treatment of simulation.

data (2.0 percent in the model and 2.3 percent in the data). Neither the model with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010) nor the model with no fiscal constraint (Arellano 2008; Gordon and Guerron-Quintana 2018) replicates any of these features.

Second, our model replicates lower investment share in public expenditure during restructurings than that in the pre-default periods (5.9 vs. 6.4 percent in the model and 5.7 vs. 6.2 percent in the data). While public consumption and transfers-to-GDP ratio is marginally higher during restructurings than in the pre-default periods (23.3 vs. 22.9 percent), public investment-to-GDP ratio is lower during restructurings than in the pre-default periods. In contrast, the model with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010) generates higher investment share in public expenditure during restructurings than that in the pre-default periods (9.5 vs. 8.0 percent) because of both fixed investment level and endogenous output dynamics. The model with no fiscal constraint (Arellano 2008; Gordon and Guerron-Quintana 2018) fails to account for this feature.

Third, the model replicates average restructuring duration of 11.2 quarters which is close to the data (14.0 quarters). Contrary to conventional models of multi-round renegotiations with exogenous income process, what generates longer duration of restructurings are both endogenous public capital accumulation ("capital accumulation delays") and fiscal constraint ("fiscal delays")—see detailed discussion on decomposition of delays in Section 5.4. In contrast, the model with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010) and the model with no fiscal constraint (Arellano 2008; Gordon and Guerron-Quintana 2018) result in shorter duration (8.7 and 8.9 quarters, respectively) because they include either fiscal constraint or endogenous public capital accumulation, respectively, but not both simultaneously.

Fourth, we generate both negative and positive correlations between a decline in public investment and duration, and between a recovery in public investment and duration as observed in the data (-0.11 and 0.56 in the model and -0.25 and 0.22 in the data). Neither the model with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010) nor the model with no fiscal constraint (Arellano 2008; Gordon and Guerron-Quintana 2018) replicates any of these features. Both average and standard deviation of bond spreads in our model (1.7% and 2.3%)—similar to those in Yue (2010) with a one-round negotiation of 1.9% and 1.6%—are lower than those in the data due to two factors: one-period bonds and the risk-neutral creditors (i.e., no risk premium).[31]

Lastly, we use simulated data series obtained from our baseline model and apply a logit regression on debt settlement (binary). Our main explanatory variables are either public investment or capital—measured as lagged public investment in percent of mean TFP or a lagged growth rate of public capital—, and external debt-to-GDP ratio. Logit regression results reported in panel (iii) in Table 5 show that an increase in both lagged public investment and lagged public capital growth rates significantly increases the likelihood of settlement. Therefore,

[31]In a model with one-period bonds and the risk-neutral creditors, spreads in periods prior to a default are low. This is driven by both a highly persistent productivity shock of the debtor and no option to "dilute" previously-issued debt. To match moment statistics of spreads with the data, previous studies introduce long-duration bonds (Hatchondo and Martinez 2009; Chatterjee and Eyigungor 2012).

Table 5: Simulation Results of Models

(i) Business Cycle Statistics

	Data	Baseline Model	Model with Fixed Public Capital[1/]	Model with No Fiscal Constraint [2/]	Cuadra et al. (2010) Recalibration
Target statistics					
Pre-default periods					
Average public consumption & transfers/GDP ratio (%)	20.0	22.9	22.5	-	24.7
Public investment (std. dev.)/output (std. dev.)	5.1	5.9	-	-	-
Renegotiation periods					
Average output deviation during debt renegotiations (%)	-4.45	-3.47	-4.43	-4.23	-
Non-target statistics					
Pre-default periods					
Public sector					
Public consumption & transfers (std. dev.)/output (std. dev.)	1.26	1.23	1.22	-	1.01
Corr.(public consumption & transfers, output)	0.52	0.85	0.94	-	0.94
Average public investment/GDP ratio (%)	1.31	1.60	2.01	-	-
Average public investment/public expenditure ratio (%)	6.2	6.4	8.0	-	-
Corr.(public investment, output)	0.51	0.63	-	-	-
Renegotiation periods					
Public sector					
Public consumption & transfers (std. dev.)/output (std. dev.)	0.99	2.36	1.07	-	1.00
Corr.(public consumption & transfers, output)	0.99	0.77	0.68	-	0.99
Average public consumption & transfers/GDP ratio (%)	20.2	23.3	22.4	-	24.8
Average public investment/GDP ratio (%)	1.19	1.47	2.36	-	-
Average public investment/GDP ratio (downward trend, %)[3/]	0.73	0.79	-	-	-
Average public investment/GDP ratio (upward trend, %)[3/]	1.64	1.65	-	-	-
Average public investment/public expenditure ratio (%)	5.7	5.9	9.5	-	-
Corr.(public investment, output)	0.99	0.82	-	-	-
Public capital (percent change from the trough to the end, %)	2.31	2.00	-	-	-

(ii) Non-business Cycle Statistics

	Data	Baseline Model	Model with Fixed Public Capital[1/]	Model with No Fiscal Constraint [2/]	Cuadra et al. (2010) Recalibration
Target statistics					
Default probability (%)	3.26	3.05	2.71	3.32	3.03
Average recovery rate (%)	25.0	27.1	22.4	36.8	-
Pre-default periods					
Average debt/GDP ratio (%)	45.4	44.7	45.6	48.3	5.7
Bond spreads: average (%)	9.4	1.65	1.20	1.55	1.17
Bond spreads: std. dev. (%)	7.6	2.25	1.60	2.20	1.42
Corr.(debt/GDP, spreads)	0.92	0.18	0.37	0.26	0.29
Renegotiation periods					
Average debt/GDP ratio (%)	130.5	50.7	53.7	57.0	6.7
Duration of renegotiations/ exclusion (quarters)	14.0	11.2	8.7	8.9	-
Corr.(decline in public investment, duration)[4/]	-0.25	-0.11	-	-	-
Corr.(recovery in public investment, duration)[5/]	0.22	0.56	-	-	-

Sources: Datastream, IMF WEO, MECON.

Notes: [1/] Model with fixed public capital corresponds to our model (with the same parameter values) with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010; Hatchondo et al. 2017).

[2/] Model with no fiscal constraint corresponds to our model (with the same parameter values) with no distortionary consumption taxation and lump-sum taxation (Arellano 2008; Gordon and Guerron-Quintana 2018).

[3/] Average public investment-to-GDP ratio in its downward trend since the start of restructurings and its upward trend since its trough.

[4/] Decline in public investment is measured in percentage change of public investment from level in t-4 (quarter) to the lowest level, i.e., the level at end of declining trend.

[5/] Recovery in public investment is measured in periods (quarters) from the time which public investment is at the lowest level to the time which it recovers to the pre-crisis average.

Table 5: Simulation Results of Models (Cont.)

(iii) Logit Regression Results on Debt Settlement—Baseline Model

	Debt Settlement (binary, current)			
	(1)	(1')	(2)	(2')
	coef/ se	dy/dx / Delta-method se	coef/ se	dy/dx / Delta-method se
Public investment (lagged, percent of mean TFP)	3.83***	0.47***	-	-
	(0.45)	(0.06)		
Public capital growth rates, annual (lagged, percent)	-	-	0.05***	0.008***
			(0.02)	(0.003)
External debt (lagged, percent of GDP)	-0.09***	-0.01***	-0.03***	-0.004***
	(0.007)	(0.001)	(0.001)	(0.0002)
Constant	-	-	-	-
Episode-specific fixed effects	Yes		Yes	
Number of episodes	76		76	
Number of observations	831		831	
Wald χ^2	327.88		470.80	
Prob.> χ^2	0.00		0.00	

Notes: The table shows results from random effects multinomial logit regressions. The dependent variable is debt settlement in the current year (binary). The main explanatory variables are public investment and public capital growth rates. Public investment, public capital growth rates and external debt (percent of GDP) are lagged by one year. Significance levels denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, respectively. Robust standard errors (Delta-method standard errors) in parentheses.

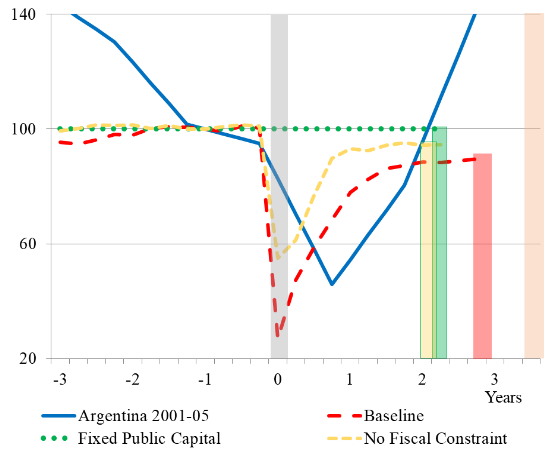
our theoretical model shows that both a severe decline and a slow recovery of public investment delay the settlement.

To emphasize the aforementioned novelties of our model, Figures 7 and 8 contrast data and simulation results on the dynamics of public investment, consumption and transfers, expenditure composition, and association between public investment dynamics and restructuring duration. For Figure 7, we follow the same presentation approach as in Figures 1 and 2 in terms of both time horizon, timing of events—both the start and end of debt crisis denoted as year 0 and 3.5 (14 quarters) and marked by gray and orange vertical bars for data (red, green, and yellow vertical bars for simulation results)—, scale (real and level), and normalization of the series at the pre-default levels (-1). Blue solid, red dashed, green dotted, and yellow dashed lines show the Argentine data, our baseline model, the model with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010), and the model with no fiscal constraint (Arellano 2008; Gordon and Guerron-Quintana 2018), respectively. For panels (i) and (ii) in Figure 8, we follow the same presentation approaches in Figure 3 and 4, respectively, in terms of both periods (pre-restructuring and restructuring) and measurements (percent of GDP and expenditure, and declines and recoveries in public investment).

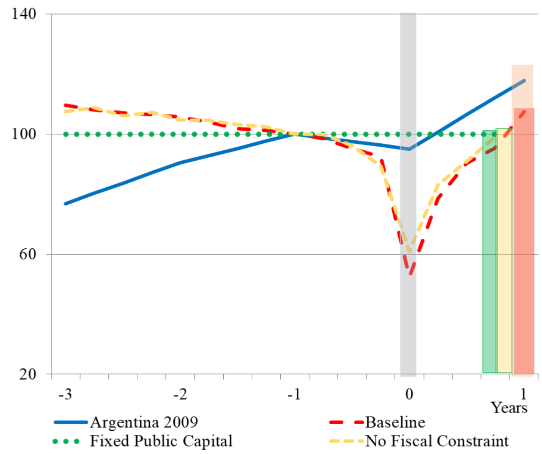
Figure 7: Public Investment, Consumption, and Transfers[1]

(i) Public Investment

a. Restructurings

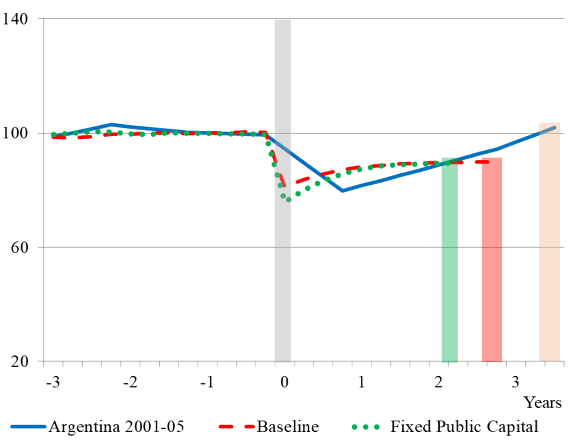


b. Non-debt Crisis Recessions



(ii) Public Consumption and Transfers[2]

a. Restructurings



1/ Public investment and consumption and transfers are normalized at levels at one year before the start of debt restructurings and non-debt crisis recessions (=100). The gray vertical bar mark the default/start of restructuring. The orange, red, green and yellow vertical bars mark the end of restructuring in Argentina 2001-05 (data), our baseline model, the model with fixed public capital, and the model with no fiscal constraint, respectively.

2/ Public consumption and transfer dynamics in the model with no fiscal constraint are absent since there is only total (private) consumption.

First and most importantly, panel (i-a) in Figure 7 shows that our baseline model (red dashed line) replicates both downward and upward trends of public investment—a sharp decline at the onset of the restructuring and a gradual recovery of public investment to the pre-restructuring level during the restructuring—as observed in the data (blue solid line). This is one of the main drivers of longer duration of renegotiations in our baseline model (11.2 quarters), which matches closely with the data (14 quarter). On the contrary, the model with fixed public capital does not replicate the dynamics of public investment because the sovereign fixes public investment to maintain the constant level of public capital. As a result, the duration of renegotiations is 8.7 quarters, shorter than that in our baseline model. The model with no fiscal constraint generates a moderate decline and a quick recovery in public investment. This is because the sovereign can freely extract resources from private sector and allocate them to public investment. The duration of renegotiation is 8.9 quarters shorter than that in our baseline model.

Second, panels (i-a) and (i-b) in Figure 7 show that our baseline model generates two distinct dynamics of public investment around debt restructurings and non-debt crisis recessions; a severe decline and a slow recovery vs. a temporal decline and a quick recovery. These two different dynamics match with the observed patterns in the data (blue solid line).

Third, panel (ii) in Figure 7 shows that our baseline model (red dashed line) replicates a small decline and a quick recovery in public consumption and transfers as observed in the data (blue solid line). The dynamics of public consumption and transfers differ significantly from those of public investment (panel i-a). Moreover, the model with fixed public capital (green dotted line) also generates the same dynamics of public consumption and transfers with our model until the debt settlement in quarter 8.7. On the contrary, in the model with no fiscal constraint, there is only total (private) consumption because of both no distortionary consumption taxation and lump-sum taxation.

Fourth, panel (i-b) in Figure 8 shows that our baseline model generates public expenditure skewing towards consumption and transfers as observed in the data (panel i-a). On the contrary, the model with fixed public capital (panel i-c) shows public expenditure skewing towards investment. This is because the sovereign mildly reduces public consumption and transfers, while maintaining public investment constant.

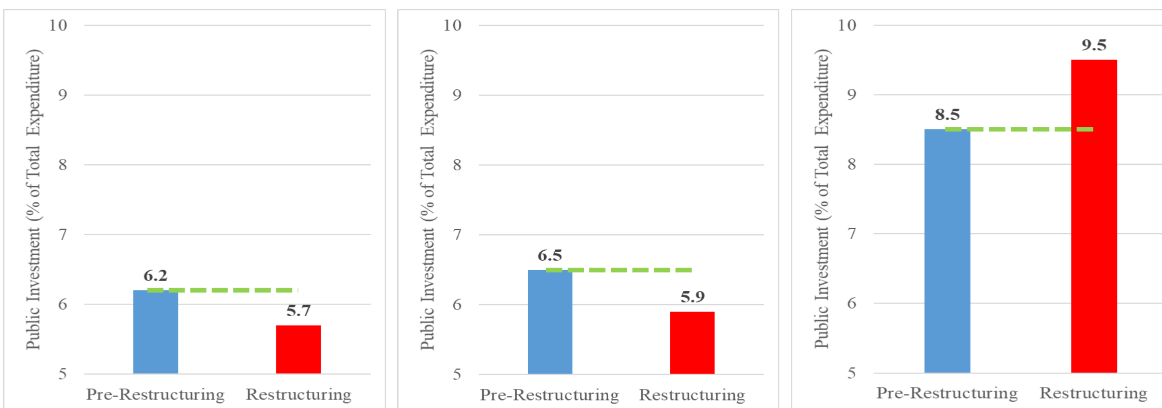
Fifth, panel (ii) in Figure 8 shows that our baseline model replicates relationships between declines and recoveries in public investment and duration of restructurings. These relationships are consistent with what we observe in the sample of post-default restructurings in Figure 4. On the contrary, the model with fixed public capital does not replicate these features because there is neither decline nor recovery in public investment.

[32]Our model successfully replicates a larger variation in duration of restructurings as in Figure 4 when it is calibrated to post-default restructuring episodes with longer duration than that of the Argentine 2001–05 episode.

Figure 8: Public Expenditure Composition and Duration of Restructurings

(i) Public Expenditure Composition[1]

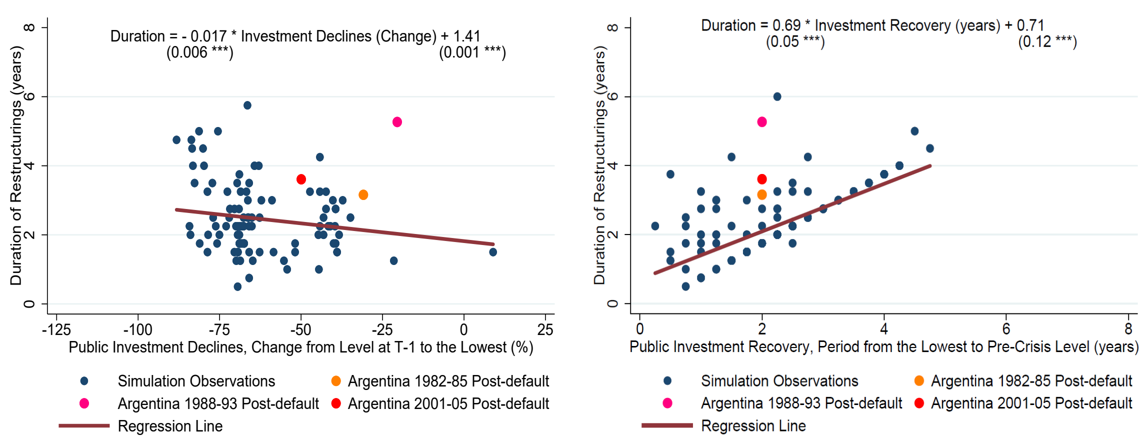
a. Argentina 2001–05 b. Baseline c. Fixed Public Capital



1/ Case with no fiscal constraint is absent because there is only total (private) consumption in the model.

(ii) Declines and Recoveries in Public Investment and Duration of Restructurings[32]

a. Declines in Public Investment b. Recoveries in Public Investment



5.4 Roles of Public Capital and Fiscal Constraint

Public Capital

We explore the multiple roles of public capital on the sovereign's choice between repayment and default, and between settlement and delay when the sovereign proposes. Similarly, Appendix F.2 discusses the multiple roles of public capital when the creditors propose—underlying mechanisms apply symmetrically and generate identical results. Panel A in Figure 9 reports value functions of repayment (A-i, upper left panel) and default (A-ii, upper right panel) with a difference between the two (A-iii, lower panel). Panel B in Figure 9 reports value functions of proposing (B-i, upper left panel) and passing (B-ii, upper right panel) with a difference between the two (B-iii, lower panel). The horizontal axis is public capital-to-mean TFP ratio and the vertical axis is value function in both panels A and B.

First, we focus on the role of public capital on the sovereign's choice between repayment and default. Panel A-(i) reports that the value function of repayment increases as public capital increases. An increase in public capital improves the sovereign's repayment capacity ("smoothing channel"). Panel A-(ii) reports that the value function of default also increases as public capital increases. An increase in public capital improves household utility by smoothing consumption in financial autarky ("autarky channel"). Simultaneously, it also achieves the debt settlement after default ("renegotiation channel").

Panel A-(iii) reports that the difference between the value functions of repayment and default shown by the blue solid line is above a reference line of zero value at any level of public capital when debt is at 15 percent of the mean TFP, while the difference shown by the red dashed line is below when debt is at 20 percent of the mean TFP. That is, a combination of the autarky channel and the renegotiation channel dominates the smoothing channel at any level of public capital when debt is high, while is dominated by the smoothing channel at any level of public capital when debt is low. The sovereign's willingness to default remains constant as public capital increases (panel A-i in Figure 6). What newly determines the relative importance of these two opposing effects is the renegotiation channel through multi-round renegotiations.

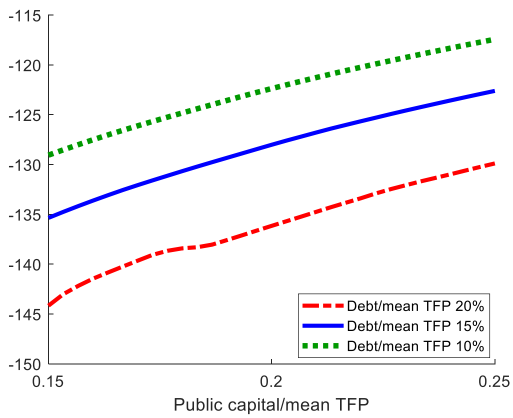
On the contrary, models with exogenous entry and zero recovery rates (Arellano 2008; Gordon and Guerron-Quintana 2018) and with a one-round negotiation (Yue 2010; Arellano and Bai 2017) show different results. The difference between value functions of repayment and default (blue solid lines in panels ii and iii in Figure F7 in Appendix F.3) is above the reference line of zero value when public capital is mean and high, while below the reference line when public capital is low. That is, the smoothing channel of public capital dominates the autarky channel—the renegotiation channel is missing—when public capital is mean and high, while is dominated by the autarky channel when public capital is low (Gordon and Guerron-Quintana 2018). As a result, the sovereign is more willing to repay than to default as public capital increases (panels ii and iii in Figure F6 in Appendix F.3).

Second, we analyze the role of public capital on the sovereign's choice of proposing and passing. Panels B-(i) and B-(iii) report the value function of proposing and the difference between proposing and passing conditional on debt settlement. When debt settlement is not

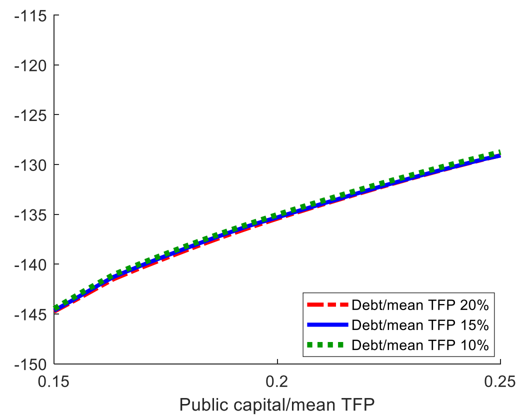
Figure 9: Value Functions at the Mean TFP

A: Value Functions of Repayment and Default

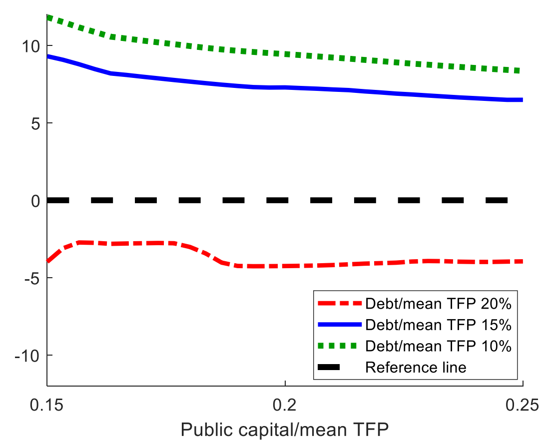
(i) Value Function of Repayment V^R



(ii) Value Function of Default V^D



(iii) Difference between Two Value Functions $V^R - V^D$

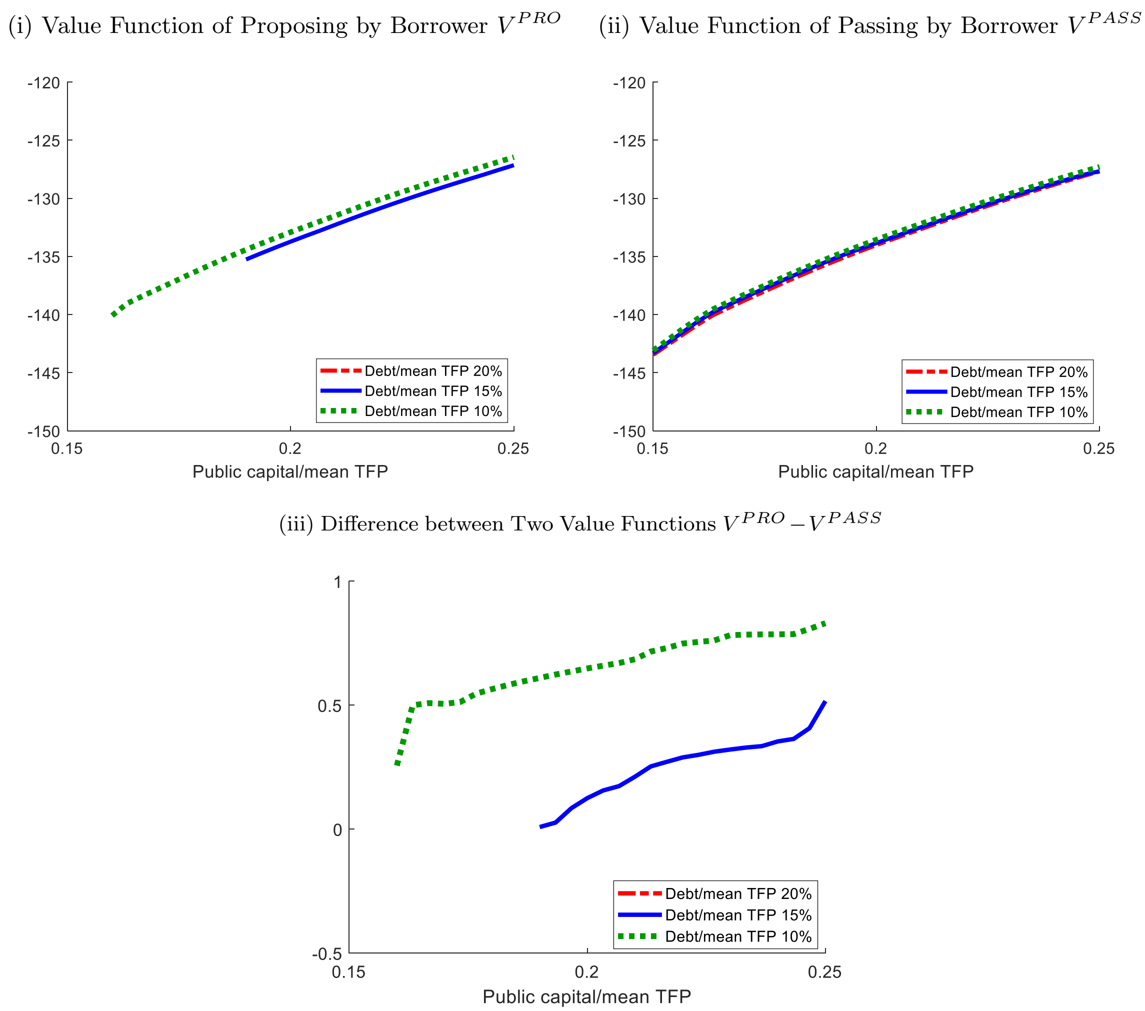


achieved, both the value function of proposing and the difference are truncated or do not exist (i.e., the truncated blue solid lines and non-existing red dash lines). It shows that as public capital increases, the settlement is more likely to be reached and the value function of proposing exists (renegotiation channel). Panel B-(ii) shows that the value function of passing increases as public capital increases: an increase in public capital improves household utility by smoothing consumption (autarky channel).

Panel B-(iii) reports that when debt is at 15 percent of the mean TFP, as public capital increases, the settlement is more likely to be reached and the difference between the value functions of proposing and passing increases and is above zero value (blue solid line). That is, the renegotiation channel of public capital dominates the autarky channel when public capital is high. The sovereign is more willing to settle than to delay as public capital increases (panel A-ii

Figure 9: Value Functions at the Mean TFP (Cont.)

B: Value Functions of Proposing and Passing



in Figure 6).

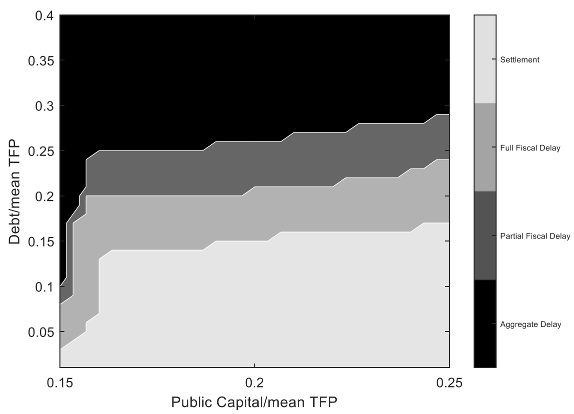
Tight Fiscal Constraint

The sovereign's (full) tight fiscal constraint is composed of two parts: distortionary consumption taxation and no lump-sum taxation. By keeping distortionary consumption taxation unchanged and relaxing no lump-sum taxation, we consider two cases of "partial fiscal constraint"; (i) lump-sum taxation—no lump-sum taxation is removed—; (ii) no transfers as in Cuadra et al. (2010).

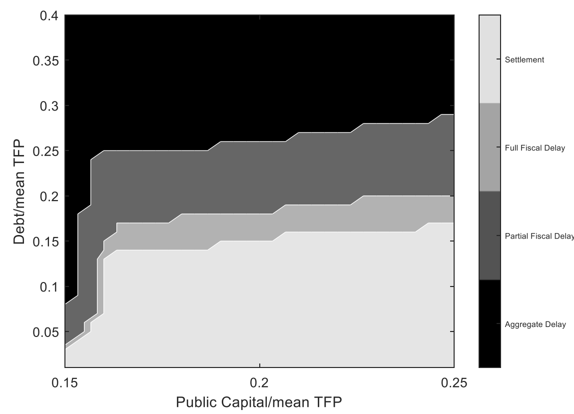
Figure 10: Full and Partial Fiscal Constraint

A: Full and Partial Fiscal Delays

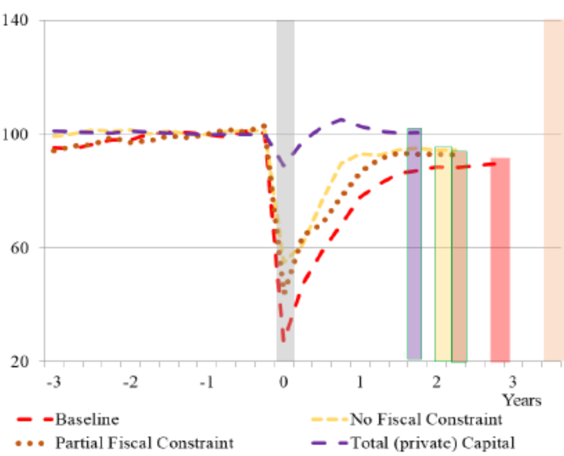
(i) lump-sum taxation



(ii) No transfers



B: Public Investment—Full and Partial Fiscal Constraint and Total Capital



On the sovereign's choice between settlement and delay reported in panels A-(i-ii) in Figure 10, compared to our baseline case of (full) tight fiscal constraint, the sovereign is less willing to delay, ceteris paribus, when it has partial fiscal constraint. When lump-sum taxation is allowed, the sovereign is able to extract additional resources from the private sector and allocate these between investment in public capital and recovered debt repayments (region in light gray in panel A-i). Alternatively, when transfers are not available, the sovereign opts to use additional resources (needed for transfers otherwise) for investment in public capital and recovered debt repayments (region in light gray in panel A-ii). In both cases, the sovereign's resource allocation choice results in its more willingness to settle.

We decompose the fiscal delay region into two regions, "partial fiscal delay" in dark gray and "full fiscal delay" in light gray. Partial fiscal delay corresponds to the case of partial fiscal constraint where the additional delay is generated by the interaction between slow TFP recovery and distortional consumption taxation (lump-sum taxation is allowed or transfers are not allowed). Full fiscal delay corresponds to the case of full fiscal constraint where the further additional delay is generated by the interaction among slow TFP recovery, distortional consumption taxation and no lump-sum taxation (i.e., lump-sum taxation not allowed).

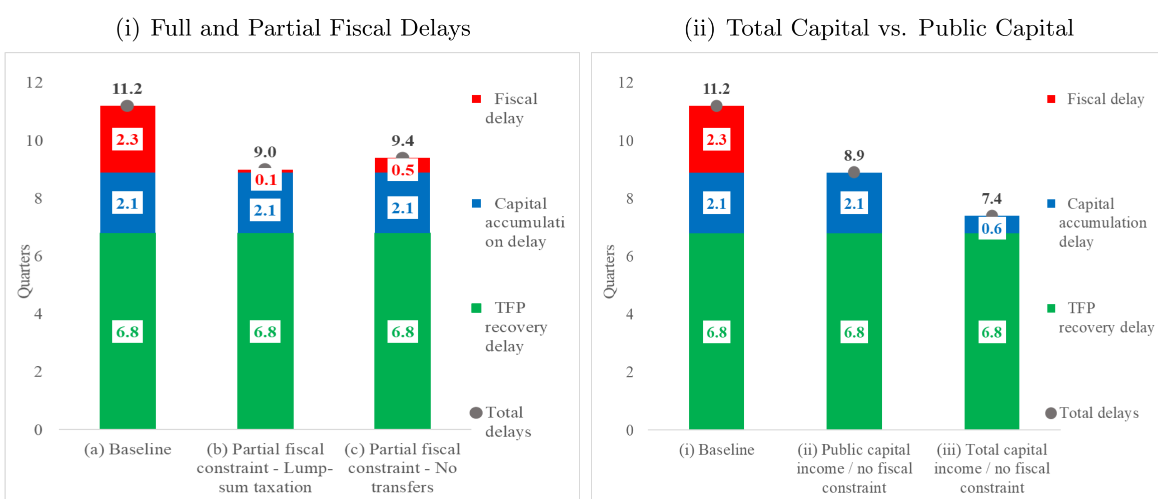
Panel B, in Figure 10, shows that public investment dynamics in the model with partial fiscal constraint (brown dotted line) falls between our baseline model with full fiscal constraint (red dashed line) and the model with no fiscal constraint (yellow dashed line). This is because partial fiscal constraint mitigates the decline in public investment which is milder than our baseline model and sharper than the model with no fiscal constraint.

Decomposition of Delays

Slow TFP recovery, slow public capital accumulation and (full) tight fiscal constraint interact and generate delays in our model. Bar (a) in panel (i) in Figure 11 shows how these drivers contribute to total delays of 11.2 quarters. Decomposition of delays is based on simulation results for models of multi-round renegotiations in Table G5 in Appendix G.2. Delays of 2.1 quarters are driven by slow public capital accumulation, i.e., "capital accumulation delays", while delays of 2.3 quarters are driven by (full) tight fiscal constraint, i.e., "fiscal delays". With these drivers of delays, our model replicates total delays of 11.2 quarters, longer than results in previous studies (6.8 quarters) which are solely driven by slow TFP recovery (Benjamin and Wright 2013; Bi 2008).

In cases of partial fiscal constraint, total delays of 9.0 and 9.4 quarters are shorter than those in our baseline model (bars b-c in panel i in Figure 11). This is because only delays of 0.1 and 0.5 quarters are driven by partial fiscal constraint, i.e., "partial fiscal delays".

Figure 11: Decomposition of Delays



5.5 Total Capital vs. Public Capital

We consider a case of total (private) capital in which a sovereign does not have fiscal constraint, i.e., neither distortionary consumption taxation nor no lump-sum taxation, and capital share corresponds to the total capital income share (e.g., Gordon and Guerron-Quintana 2018; Park 2017). Panel (ii) in Figure 11 contrasts the composition of total delays in three models: (a) baseline model with public capital income share ($\alpha^k = 0.058$) and fiscal constraint, (b) a model with public capital income share and no fiscal constraint, and (c) a model with total capital income share ($\alpha^k = 0.36$) and no fiscal constraint. Both models (b) and (c) result in shorter total delays (8.9 and 7.4 quarters) than model (a) due to no fiscal delays (in red color). Total delays in models (b) and (c) differ because of the difference in capital accumulation delays (in blue color). In model (b), slightly longer capital accumulation delays are due to the marginal product of public capital with small public capital income share, while in model (c), slightly shorter capital accumulation delays are due to the marginal product of total capital with large total capital income share. Model (c) corresponds to Gordon and Guerron-Quintana (2018) with one-period bonds and multi-round debt renegotiations.

Panel B in Figure 10 shows that the model with total capital (purple dashed line) generates a marginal decline and a quick rebound in total (private) investment. This is driven by two factors: first, "no fiscal constraint" under which resources are transferred freely between private and public sectors; and second, larger total capital income share which the sovereign has control over than the public capital income share.

5.6 Robustness Checks

First, we discuss how a change in parameter values (keeping other parameter values unchanged) influences qualitatively the sovereign's choice between repayment and default, and between settlement and delay. Panels B and C in Figure G1 in Appendix G show that our baseline results remain robust in two cases: (i) lower capital adjustment costs ($\Omega = 5$) and (ii) high capital depreciation rate ($\delta^k = 0.075$).

Second, Table 6 reports how a change in these parameter values (keeping other parameter values constant) influences qualitatively the main moment statistics. Low adjustment costs on public capital increase both investment volatility and a change in public capital during restructurings. In this case, the sovereign is more willing to cut public investment severely at the onset of the debt crises and allocate more resources to public investment during restructurings. Moreover, in the case of high capital depreciation rate, public investment is higher in both the pre-default and renegotiation periods than that in our baseline model because the sovereign is constrained to allocate more resources to public investment. When the household becomes less risk averse, the sovereign opts to allocate less resources to public consumption and transfers and more resources to public investment because it finds less necessary to improve current household utility. This, in turn, results in shorter duration of restructuring (9.4 quarters) than our baseline model.

Table 6: Sensitivity Analysis

	Adjustment Costs			Depreciation Rate			Weight on Public Cons.			Risk Aversion			Discount Rate		
	5	10	15	0.025	0.04	0.075	0.7	0.8	0.9	2	3	4	0.70	0.80	0.90
Default probability (%)	3.43	3.05	1.90	4.15	3.05	3.92	2.94	3.05	4.30	4.60	3.05	3.97	2.60	3.05	3.15
Average recovery rate (%)	32.0	27.1	25.9	29.7	27.1	25.8	26.9	27.1	32.6	49.1	27.1	33.5	28.5	27.1	31.4
Public investment (std. dev.)/output (std. dev.)	8.1	5.9	3.80	8.6	5.9	2.70	11.6	5.9	7.3	4.50	5.9	8.0	12.6	5.9	6.0
Non-target statistics															
Pre-default periods															
Average public investment/GDP ratio (%)	1.66	1.60	1.60	1.18	1.60	2.58	1.39	1.60	1.31	1.87	1.60	1.40	1.35	1.60	1.92
Average public investment/public expenditure ratio (%)	6.6	6.4	6.3	4.71	6.4	10.4	5.2	6.4	5.5	7.2	6.4	5.5	5.4	6.4	7.1
Average debt/GDP ratio (%)	40.2	44.7	43.6	40.2	44.7	44.9	42.4	44.7	35.4	25.9	44.7	23.4	42.7	44.7	36.4
Renegotiation periods															
Average public investment/GDP ratio (%)	1.58	1.47	1.46	0.85	1.47	2.95	1.58	1.47	1.36	1.60	1.47	1.51	1.61	1.47	1.73
Average public investment/expenditure ratio (%)	6.3	5.9	5.9	3.40	5.9	11.8	5.3	5.9	6.3	6.2	5.9	6.1	6.4	5.9	7.0
Public capital (percent change from the trough to the end, %)	5.0	2.00	1.70	0.48	2.00	7.3	6.4	2.00	0.11	4.21	2.00	7.9	7.1	2.00	0.80
Average debt/GDP ratio (%)	46.2	50.7	51.0	46.0	50.7	51.6	48.7	50.7	42.1	30.1	50.7	26.5	48.9	50.7	42.1
Duration of renegotiations/ exclusion (quarters)	11.5	11.2	10.2	11.7	11.2	13.2	12.7	11.2	7.8	9.4	11.2	17.6	13.2	11.2	10.5
Corr.(decline in public investment, duration)	-0.05	-0.11	-0.08	-0.05	-0.11	-0.06	-0.05	-0.11	-0.10	-0.11	-0.11	-0.05	-0.10	-0.11	-0.05
Corr.(recovery in public investment, duration)	0.33	0.56	0.56	0.24	0.56	0.27	0.42	0.56	0.18	0.34	0.56	0.45	0.52	0.56	0.60

Source: Authors' computation

6 Testing the Theoretical Predictions

Our theoretical model provides predictions that both the severe decline and the slow recovery of public investment delay debt settlement. To test these predictions, we assess determinants of debt settlement using a multinomial logit model as in conventional empirical studies on debt restructurings (Asonuma and Joo 2020). Our dataset is an unbalanced panel comprised of 111 post-default restructuring episodes over the duration for each episode i.e., from the start of restructurings to the completion of exchanges. As in previous studies (Cruces and Trebesch 2013; Asonuma and Trebesch 2016), we treat each restructuring as an independent event when both exchanged debt instruments and dates of announcement and of settlement in one restructuring differ from those in other restructurings. In this regard, there are overlapping observations included in our panel.

Following the convention in the literature (e.g., Struzenegger 2004, Asonuma and Trebesch 2016), our data are at an annual frequency due to the data availability of public investment and capital, and external debt for the restructuring countries. The dependent variable captures whether restructurings are settled or not in the current year: 1 for completion of exchanges and 0 otherwise. Our main explanatory variables are either public investment or capital—measured as a lagged deviation from the HP-filtered trend or a lagged cumulative growth rate from the start of restructurings—, public and publicly guaranteed (PPG) external debt (in percent of GDP), and a deviation and growth rates of the HP-filtered GDP trend for restructuring countries, which proxy productivity shocks. We also include world GDP growth rates and London Interbank Offered Rate (LIBOR) to control for growth and liquidity of the world economy.

Table 7 shows the logit regression results. We show that both high public investment in the previous year and high capital accumulation from the start of restructurings to the previous year increase the likelihood of settlement in the current year (columns 1–1' and 2–2'). Quantitatively, a 1-percent increase in public investment (from the trend) and cumulative public capital growth rates increases the probability of settlement by 8.6 and 0.1 percent, respectively (columns 1' and 2'). Both results are consistent with our theoretical findings reported in panel (iii) in Table 5 in Section 5.3. Moreover, the sovereign countries are more likely to reach a settlement when PPG external debt is low, and growth and liquidity of the world economy is high and ample, respectively (columns 1–1' and 2–2'). Neither the deviation nor the growth rates of the HP-filtered GDP trend enters as significant, possibly due to high correlation with public investment and capital accumulation, as discussed in Section 2.2.

Table 7: Public Investment and Capital, and Debt Settlement

	Debt Settlement (binary, current)			
	(1)	(1')	(2)	(2')
	coef/ se	dy/dx / Delta-method se	coef/ se	dy/dx / Delta-method se
Public investment, deviation from the trend (lagged, percent)[1/]	0.347*	0.086*	-	-
	(0.195)	(0.048)		
Public capital, cumulative growth rates (lagged, percent)[2/]	-	-	0.005*	0.001*
			(0.003)	(0.0007)
PPG external debt (lagged, percent of GDP)[3/]	-0.003**	-0.001**	-0.003*	-0.0007***
	(0.002)	(0.0004)	(0.002)	(0.0004)
GDP deviation from the trend (current, percent)[1/]	-0.017	-0.004	0.561	0.139
	(0.951)	(0.236)	(0.864)	(0.215)
GDP trend growth rates (current, percent)[1/]	-0.045	-0.011	-0.073	-0.018
	(0.042)	(0.010)	(0.045)	(0.011)
LIBOR, 12-month average (current, percent)	-0.061***	-0.051***	-0.058**	-0.014**
	(0.023)	(0.006)	(0.024)	(0.006)
World GDP growth rates (current, percent)	0.207***	0.051***	0.206***	0.051***
	(0.069)	(0.017)	(0.069)	(0.017)
Constant	-0.705*	-	-0.722*	-
	(0.369)		(0.372)	
Episode-specific fixed effects	No		No	
Number of restructuring episodes	90		89	
Number of observations	496		492	
Wald χ^2	21.01		20.74	
Prob.$> \chi^2$	0.002		0.002	

Notes: The table shows results from random effects multinomial logit regressions. The dependent variable is debt settlement in the current year (binary). The main explanatory variables are public investment deviation from the trend and public capital cumulative growth rates. Public investment deviation from the trend, public capital cumulative growth rates and PPG external debt (percent of GDP) are lagged by one year. The other explanatory variables are in the current year. Significance levels denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, respectively. Robust standard errors (Delta-method standard errors) are in parentheses.

[1/] A deviation from the trend and a trend growth rate are a percentage deviation from the trend and an annual percent change of the trend obtained by applying a Hodrick-Prescott (HP) filter to annual series with filter of 6.25.

[2/] Cumulative growth of public capital since the start of restructurings.

[3/] Public and publicly guaranteed external debt.

7 Conclusion

The current paper explores the role of public capital and fiscal constraint on sovereign debt crises and resolution. We code a new dataset on public expenditure composition around debt restructurings with private external creditors. We find five new stylized facts on public capital and public expenditure composition around post-default restructurings. To explain these facts, we embed endogenous public capital accumulation, expenditure composition and production with public capital and labor in a conventional model of sovereign debt with endogenous defaults and renegotiations. Our model quantitatively replicates these stylized facts and shows both public investment dynamics and tight fiscal constraint delay debt settlement—"capital accumulation delays" and "fiscal delays". Empirical evidence supports our theoretical predictions.

Recent research documents that private investment experiences a sharp decline when some emerging economies (EM) default on private external debt (Gordon and Guerron-Quintana 2018). This poses a potential research question on how private and public investment are correlated during a debt crisis. For future work, on the basis of our understanding on the role of public capital, we can explore whether private and public capital are complementary or substitutable during a debt crisis. This future project could contribute to the ongoing policy debate on the desirable level of public investment when private investment contracts sharply during a debt crisis.

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Appendix A Dataset

A.1 Public Capital and Investment Dataset

IMF (2015) measures public investment using gross fixed capital formation (GFCF) of the general government (i.e., central plus subnational governments). The approach allows for the use of the comparable data available for a large number of countries but ignores alternative modes by which governments support overall investment (e.g., investment grants, loan guarantees, tax concessions, the operations of public financial institutions, government-backed saving schemes).

IMF (2015) explains a methodology applied to construct public capital stocks following a conventional approach (Kamps 2006; Gupta et al. 2014). The capital stocks are computed based on the traditional inventory equation:

$$K_{i,t+1} = (1 - \delta_{i,t})K_{i,t} + (1 - \delta_{i,t}/2)I_{i,t} \tag{A1}$$

where for each country i, $K_{i,t+1}$ is the stock of public capital at the beginning of period $t + 1$; $\delta_{i,t}$ is a time-varying depreciation rate; and $I_{i,t}$ is gross fixed public capital formation in period t, assuming that new investment is operational in the middle of the period.

Below summarize three main components and underlying datasets. All series (output, investment, capital stocks) are expressed in constant international 2005 prices (using purchasing power parity).

(1) Investment (flow): Several databases are used to provide a comprehensive database of the public capital stock series covering the period 1860–2014.

For the Organization for Economic Cooperation and Development (OECD) countries, the OECD Analytical Database (August 2014 version) is used and covers 26 countries for the period 1960–2013. The series retrieved (in national currency and constant prices) are comprised of government GFCF, private GFCF, and real GDP, and are converted to 2005 international dollars using OECD purchasing power parties. Data are filled to the extent possible using the IMF WEO database (the April 2014 version) when there are data patches in the OECD database.

For non-OECD countries, the Penn World Tables (PWT, vesrion 8.0) are used and cover 132 countries for the period 1960–2011. The series retrieved are comprised of GDP and total gross fixed capital formation in 2005 constant prices, and are converted to 2005 international dollars using PWT purchasing power parities. Total investment from PWT is disaggregated into private and public investment by using the WEO database. Private and public investment shares, as percent of total investment, are calculated from the WEO database, and these shares are applied to the total PWT investment series. Data are extended to 2013 using the WEO database.

(2) Capital stock at initial period: Following a conventional approach in Kamps (2006), the initial capital stock is set to 0 for all countries in 1860. A total investment series is mechanically constructed between 1860 and the first available data point under an assumption that investment grew by 4 percent a year to reach its five-year-forward moving average (first available) observed level. Similarly, for private and public investment, two investment series are

Table A1: Depreciation Rates (in percent)

	1860	1960	2013
Public Capital			
Low-income	2.50	2.50	2.50
Middle-income	2.50	2.50	3.51
High-income	2.50	2.50	4.59
Private Capital			
Low-income	4.25	4.25	4.25
Middle-income	4.25	4.25	8.10
High-income	4.25	4.25	10.41

Note: Income classifications are based on the World Bank's World Development Indicators' country groupings.

mechanically constructed between 1860 and the first available data point under an assumption that private and public investment grew at the same rate as total investment to reach their five-year forward moving average (first available) observed levels, respectively.

(3) Capital depreciation rates: Data on country-specific capital depreciation rates are not available. We follow the convention in the literature on discount rate assumptions used in three groups with different income levels. Following Kamps (2006), we assume that the depreciation rate for high-income countries rises from 2.5 percent in 1960 to 4.6 percent in 2013, and from 4.25 percent to 10.4 percent for government and private capital, respectively (Table A1). Similarly, different depreciation rates are assumed for middle-income and low-income countries following Gupta et al. (2014).

A.2 Details of Coding

We follow public expenditure classification and definition in US BEA (2005) for our coding (Table A2).

Table A2: Public Expenditure Classification and Definition (US BEA 2005)

Government consumption expenditure
Gross output of general government
Value added
Compensation of general government employee
Supplement to wages and salaries
(Employer contributions for government social insurance)
Consumption of general government fixed capital
Intermediate goods and Services
Durable goods
Nondurable goods
Services
Less: Own account investment
Sales to other sectors
Government (gross) investment
Structures
New
Industrial
Military facilities
Net purchases of used structures
Residuals
Equipment and software
Aircraft, missiles, ships, and vehicles
Equipment
Software (including electronics)
Government (current) transfer payments
Government social benefits
To persons
To the rest of the world
Other current transfer payments to the rest of the world (net)

Table A3: Public Consumption, Investment, Transfers, and Captal for Restructurings in 1978–2010

(A) 1st group – 20 episodes (1–20)

ISO Code	Country	Restructuring Periods start	Restructuring Periods end	Definition of Fiscal Sector Yes/No	Public Consumption Yes/No	Public Investment Yes/No	Public Transfers Yes/No	Public Capital Yes/No	Source
ALB	Albania	Nov-1991	Aug-1995	Fiscal Account	Yes	Yes	Yes	Yes	IMF (1992 EBS/92/121), IMF (1994 EBS/94/39), IMF (1998 SM/98/90), IMF (2015, Policy Paper)
ARG	Argentina	Jul-1982	Aug-1985	Public Sector Operation/ Central Government	Yes	Yes	Yes	Yes	IMF (1986, EBS/86/39), IMF (1989, EBS/89/199), IMF (1990, EBS/90/191), IMF (1994, EBS/94/132), IMF (1996, EBS/96/161), IMF (2015, Policy Paper)
ARG	Argentina	Aug-1985	Aug-1987	Public Sector Operation/ Central Government	Yes	Yes	Yes	Yes	IMF (1986, EBS/86/39), IMF (1989, EBS/89/199), IMF (1990, EBS/90/191), IMF (1994, EBS/94/132), IMF (1996, EBS/96/161), IMF (2015, Policy Paper)
ARG	Argentina	Jan-1988	Apr-1993	Public Sector Operation/ Central Government	Yes	Yes	Yes	Yes	IMF (1986, EBS/86/39), IMF (1989, EBS/89/199), IMF (1990, EBS/90/191), IMF (1994, EBS/94/132), IMF (1996, EBS/96/161), IMF (2015, Policy Paper)
ARG	Argentina	Nov-2001	Jun-2005	Public Sector Operation/ Central Government	Yes	Yes	Yes	Yes	IMF (2002, EBS/02/214), IMF (2006, SM/06/235), IMF (2015, Policy Paper)
BGR	Bulgaria	Mar-1990	Jun-1994	Consolidated General Government	Yes	Yes	Yes	Yes	IMF (1991, EBS/91/26), IMF (1995, SM/95/300), IMF (2015, Policy Paper)
BIH	Bosnia and Herzegovian	Jun-1992	Dec-1997	Fiscal Position	Yes	Yes	Yes	Yes	IMF (1998, SM/98/96), IMF (2015, Policy Paper)
BLZ	Belize	Aug-2006	Feb-2007	Central Government	Yes	Yes	Yes	Yes	IMF (2006, SM/06/341), IMF (2015, Policy Paper)
BOL	Bolivia	Apr-1980	Mar-1988	Central Government/ Central Administration	Yes	Yes	Yes	Yes	IMF (1986, EBS/86/263), IMF (1992, SM/92/169), IMF (1994, SM/94/291), IMF (1997, SM/97/224), IMF (2015, Policy Paper)
BOL	Bolivia	Apr-1988	Apr-1993	Central Government/ Central Administration	Yes	Yes	Yes	Yes	IMF (1986, EBS/86/263), IMF (1992, SM/92/169), IMF (1994, SM/94/291), IMF (1997, SM/97/224), IMF (2015, Policy Paper)
BRA	Brazil	Dec-1982	Feb-1983	Central Administration Account	Yes	Yes	Yes	Yes	IMF (1983, EBS/83/33), IMF (1984, EBS/84/218), IMF (2015, Policy Paper)
BRA	Brazil	Jan-1983	Jan-1984	Central Administration Account	Yes	Yes	Yes	Yes	IMF (1983, EBS/83/33), IMF (1984, EBS/84/218), IMF (2015, Policy Paper)
BRA	Brazil	Jun-1984	Sep-1986	Central Administration Account	Yes	Yes	Yes	Yes	IMF (1983, EBS/83/33), IMF (1984, EBS/84/218), IMF (2015, Policy Paper)
BRA	Brazil	Sep-1986	Nov-1988	Central Administration Account	Yes	Yes	Yes	Yes	IMF (1983, EBS/83/33), IMF (1984, EBS/84/218), IMF (2015, Policy Paper)
BRA	Brazil	Jun-1989	Nov-1992	-	No	Yes	No	Yes	IMF (2015, Policy Paper)
BRA	Brazil	Jun-1989	Apr-1994	-	No	Yes	No	Yes	IMF (2015, Policy Paper)
CHL	Chile	Jan-1983	Nov-1983	General Government	Yes	Yes	Yes	Yes	IMF (1984, EBS/84/50), IMF (1985, EBS/85/122), IMF (1987, EBS/87/148), IMF (2015, Policy Paper)
CHL	Chile	Jan-1983	Jan-1984	General Government	Yes	Yes	Yes	Yes	IMF (1984, EBS/84/50), IMF (1985, EBS/85/122), IMF (1987, EBS/87/148), IMF (2015, Policy Paper)
CHL	Chile	Aug-1984	Apr-1986	General Government	Yes	Yes	Yes	Yes	IMF (1984, EBS/84/50), IMF (1985, EBS/85/122), IMF (1987, EBS/87/148), IMF (2015, Policy Paper)
CHL	Chile	Oct-1986	Jun-1987	General Government	Yes	Yes	Yes	Yes	IMF (1984, EBS/84/50), IMF (1985, EBS/85/122), IMF (1987, EBS/87/148), IMF (2015, Policy Paper)

Appendix B Further Empirical Analysis

B.1 Public Consumption, Investment and Transfers

Figures B1 and B2 show the dynamics of public investment, and consumption and transfers—both as percent of GDP—around restructurings and non-debt crisis recessions. We follow the same presentation approach as in Figure 1 in terms of time horizon, timing of events, i.e., start of debt crisis (recession), normalization of the series at levels at the start of restructurings (recessions), and average in the pre-default (pre-recession) and restructuring (recession) periods. Figures B1 and B2 show that both public investment-to-GDP and consumption and transfers-to-GDP ratios follow similar dynamics as the levels of public investment and consumption and transfers in both debt restructurings and non-debt crisis recessions (Figures 1 and 2).

Figure B1: Public Investment (percent of GDP)

(i) Restructurings (ii) Non-debt Crisis Recessions

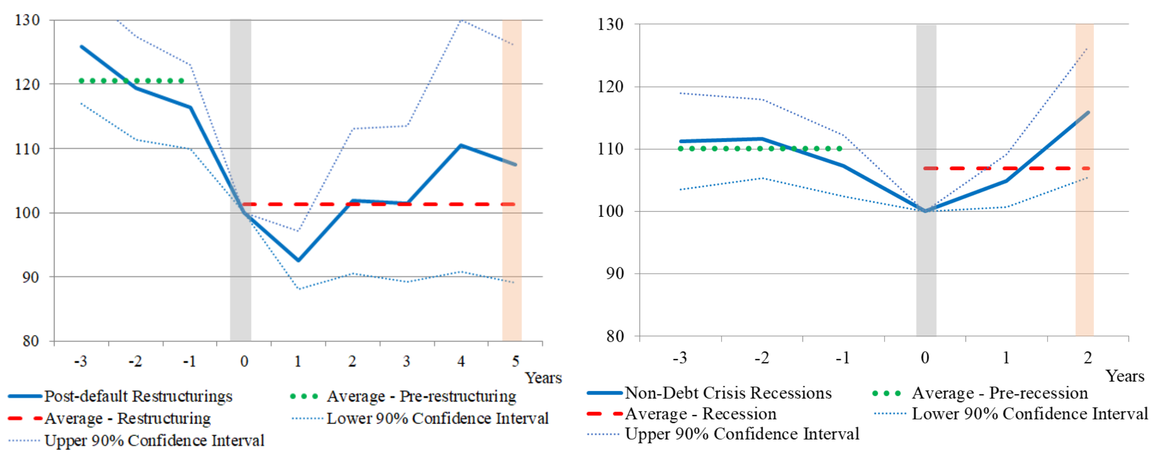
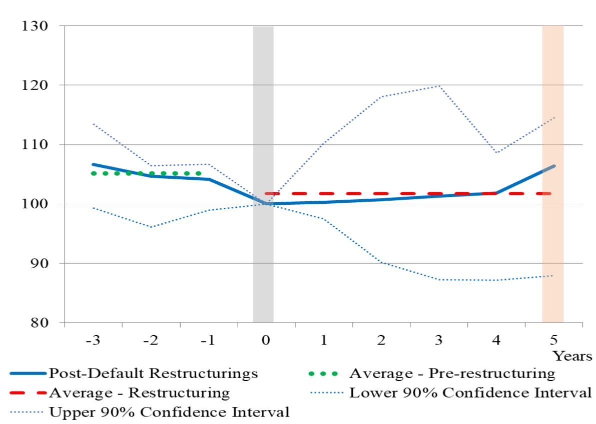


Figure B2: Public Consumption and Transfers (percent of GDP)

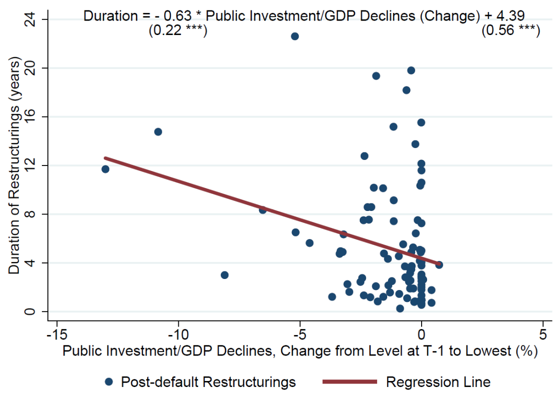
(i) Restructurings



B.2 Declines and Recoveries in Public Investment and Duration of Restructurings

Figure B3: Declines and Recoveries in Public Investment-to-GDP Ratio and Duration of Restructurings

(i) Declines in Public Investment-to-GDP Ratio



(ii) Recoveries in Public Investment-to-GDP Ratio

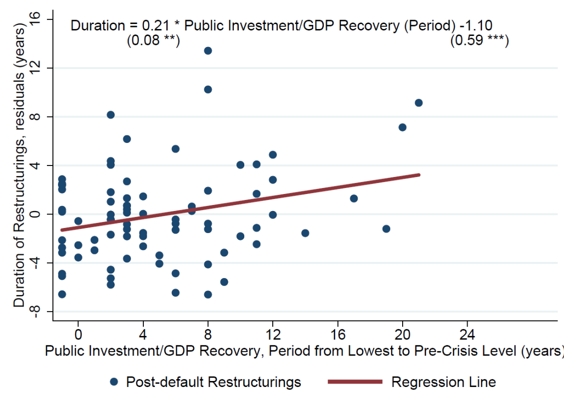


Table B1: Declines and Recoveries in Public Investment and Duration of Restructurings—Baseline

	Duration of restructurings (years)			
	Declines		Recoveries	
	(1)	(2)	(3)	(4)
	coef/se	coef/se	coef/se	coef/se
Declines in public investment (percentage change from t-1 to the lowest, percent)[1/]	-0.03**	-	-	-
	(0.02)			
Declines in public investment/GDP (percentage change from t-1 to the lowest, percent)[2/]	-	-0.82***	-	-
		(0.29)		
Recoveries in public investment (periods from the lowest to the pre-crisis average, years)[3/]	-	-	0.27***	-
			(0.09)	
Recoveries in public investment/GDP (periods from the lowest to the pre-crisis average, years)[4/]	-	-	-	0.22**
				(0.09)
Public capital (pre-restructuring, percent of GDP)[5/]	0.005	-0.009	0.004	0.002
	(0.006)	(0.008)	(0.006)	(0.01)
GDP deviation from trend (end, percent)[6/7/]	0.11*	0.09	0.09	0.08
	(0.06)	(0.06)	(0.06)	(0.06)
External debt (end, percent of GDP)[7/]	0.02*	0.02*	0.02**	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)
Export-to-debt service ratio (end)[7/]	0.13	0.12	0.14	0.12
	(0.09)	(0.09)	(0.09)	(0.09)
LIBOR 12-month (end, percent)[7/]	-0.62***	-0.63***	-0.62***	-0.59***
	(0.16)	(0.15)	(0.16)	(0.17)
IMF-supported program (end, dummy)[8/]	-2.52**	-2.79***	-2.89***	-2.58***
	(0.95)	(0.95)	(0.96)	(1.00)
Bond restructurings (dummy)[9/]	-4.08**	-4.26**	-4.17**	-4.24**
	(1.64)	(1.59)	(1.61)	(1.62)
Constant	8.97***	9.89***	8.23***	8.38***
	(1.93)	(1.86)	(1.96)	(2.17)
Number of observations	87	86	85	79
Adjusted-R^2	0.37	0.39	0.39	0.38
Root MSE	4.02	3.96	3.98	3.94

Notes: The table shows results from ordinary least square (OLS) regressions. The dependent variable is duration of restructurings (years). The main explanatory variables are declines and recoveries in public investment. Significance levels are denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, respectively. Standard errors are in parentheses.

[1/] Percentage change of public investment (level) from the level in year t-1 to the lowest level i.e., end of its downward trend.

[2/] Percentage point change of public investment-to-GDP ratio from the level in year t-1 to the level when public investment is at the lowest level i.e., end of its downward trend.

[3/] Periods (years) from the time which public investment is at the lowest level i.e., end of its downward trend, to the time which it recovers to the pre-crisis average.

[4/] Periods (years) from the time which public investment-to-GDP ratio is at the lowest level i.e., end of its downward trend, to the time which it recovers to the pre-crisis average.

[5/] Public capital-to-GDP ratio one year before the start of restructurings.

[6/] GDP deviation from the trend is a percentage deviation from the trend, obtained by applying a Hodrick-Prescott (HP) filter to annual GDP series with a smoothing parameter of 6.25.

[7/] Levels at the end of restructurings.

[8/] A dummy for an IMF-supported program is set to 1 when an IMF-supported program is approved in the year of the end of restructurings and 0 otherwise.

[9/] A dummy for bond restructurings is set to 1 if a restructuring is a bond exchange.

Table B2: Declines and Recoveries in Public Investment and Duration of Restructurings—Robustness Check

	Duration of restructurings (years)			
	Declines		Recoveries	
	(1)	(2)	(3)	(4)
	Dropping outliers (duration)[8/]	Dropping outliers (declines)[9/]	Dropping outliers (duration)[8/]	Dropping outliers (recoveries)[10/]
	coef/se	coef/se	coef/se	coef/se
Declines in public investment (percentage change from t-1 to the lowest, percent)[1/]	-0.02**	-0.03**	-	-
	(0.01)	(0.01)		
Recoveries in public investment (periods from the lowest to the pre-crisis average, years) [2/]	-	-	0.29***	0.24***
			(0.09)	(0.11)
Public capital (pre-restructuring, percent of GDP)[3/]	0.004	0.004	0.002	0.004
	(0.005)	(0.006)	(0.005)	(0.006)
GDP deviation from trend (end, percent)[4/5/]	0.09*	0.11*	0.07	0.08
	(0.06)	(0.06)	(0.05)	(0.06)
External debt (end, percent of GDP)[5/]	0.02**	0.02*	0.03**	0.02**
	(0.009)	(0.01)	(0.009)	(0.01)
Export-to-debt service ratio (end)[5/]	0.14	0.12	0.16*	0.14
	(0.08)	(0.09)	(0.08)	(0.09)
LIBOR 12-month (end, percent)[5/]	-0.55***	-0.65***	-0.52***	-0.62***
	(0.15)	(0.16)	(0.14)	(0.16)
IMF-supported program (end, dummy) [5/6/]	-2.46**	-2.41**	-2.84***	-2.97***
	(0.89)	(1.00)	(0.87)	(0.98)
Bond restructurings (dummy)[7/]	-3.77**	-4.00**	-3.62**	-4.25**
	(1.53)	(1.70)	(1.46)	(1.62)
Constant	7.96***	9.29***	6.78***	8.45***
	(1.81)	(2.05)	(1.80)	(2.01)
Number of observations	85	84	83	84
Adjusted-R^2	0.37	0.36	0.43	0.37
Root MSE	3.73	4.08	3.59	4.00

Notes: The table shows results from ordinary least square (OLS) regressions. The dependent variable is duration of restructurings (years). The main explanatory variable are declines and recoveries in public investment. Significance levels are denoted by *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, respectively. Standard errors are in parentheses.

[1/] Percentage change of public investment (level) from the level in t-1 to the lowest level, i.e., end of its downward trend.

[2/] Periods (years) from the time which public investment is the lowest level, i.e., end of its downward trend to the time which it recovers to the pre-crisis average.

[3/] Public capital-to-GDP ratio one year before the start of restructurings.

[4/] GDP deviation from the trend is a percentage deviation from the trend, obtained by applying a Hodrick-Prescott (HP) filter to annual GDP series with a smoothing parameter of 6.25.

[5/] Levels at the end of restructurings.

[6/] A dummy for an IMF-supported program is set to 1 when an IMF-supported program is approved in the year of the end of restructurings and 0 otherwise.

[7/] A dummy for bond restructurings is set to 1 if a restructuring is a bond exchange.

[8/] Dropping duration observations below 1^{st} percentile and above 99^{st} percentile.

[9/] Dropping observations of declines in public investment below 2.5^{th} percentile and above 97.5^{th} percentile.

[10/] Dropping observations of recoveries in public investment above 97.5^{th} percentile.

Appendix C Implications for Key Theoretical Assumptions

We explore model implications for following four key theoretical assumptions; (1) output costs; (2) net issuance at settlement; (3) private capital; (4) taxation methods. In particular, for each case, we discuss how a change in the assumption keeping other assumptions and parameter values unchanged influences the sovereign's choice between repayment and default, and between settlement and delay. Our main qualitative implications are robust.

Panels (i) and (ii) in Figure C1 repeat panels A-(i) and A-(ii) in Figure 6: the sovereign's choice when the sovereign's TFP is at the mean level. Panels (i) and (ii) report the sovereign choice at good credit record ($h_t = 0$) and at bad credit record ($h_t = 1$), respectively. Figure C2 reports a case for symmetric output costs for the sovereign. Our baseline results remain robust. Assuming a different type of output costs, i.e., symmetric to the level of TFP shocks (Aguiar and Gopinath 2006; Yue 2010) does not influence the sovereign's choice between repayment and default, and between settlement and delay.[33]

Figure C3 reports a case with net issuance at settlement. When we incorporate net issuance at settlement as in Benjamin and Wright (2013), the sovereign is more willing to settle since the net lending reduces the costs of debt settlement (the enlarged "Settlement" region in panel ii). Due to lower default costs—shorter periods of financial exclusion owing to high likelihood of debt settlement—, the sovereign is more willing to default ex ante (the enlarged "Default" region in panel i).

Figure C4 reports the sovereign's choice in two different assumptions of private capital. We assume following two specifications of private capital to replicate observed dynamics of private and public investment around debt restructurings (i.e., matching correlation between private and public capital): panel A: a linear function of public capital $k_t^p = k_t^g$; panel B: a square root function of public capital $k_t^p = (k_t^g)^{1/2}$. In the case of the linear function of public capital, the production function has constant returns to scale (CRS). Our baseline results on the sovereign's choice between repayment and default, and between settlement and delay remain robust (panels A-i and A-ii). In the case of the square root function of public capital, the production function has decreasing returns to scale (DRS) as in our baseline. Again, our baseline results on the sovereign's choice remain robust (panels B-i and B-ii). This is because, under reasonable assumptions of public capital where the production function has constant or decreasing returns to scale, the sovereign allocates available resources among public consumption, investment, transfers, and external debt payments. In contrast, under an extreme assumption of public capital where the production function has increasing returns to scale (IRS), the sovereign concentrates its spending on public investment, but not on external debt payments. In this case, the sovereign opts to default at low debt level and delay renegotiations after default.

Lastly, Figure C5 reports the sovereign's choice in three different assumptions of taxation; panel A: two-stage consumption tax; panel B: labor income tax. First, we allow the sovereign

[33] In the case of quadratic function of output costs respect to the level of TFP shocks (Chatterjee and Eyigungor 2012; Hatchondo, et al. 2017), the sovereign's choice between repayment and default, and between settlement and delay is similar to that in our baseline model or in model with symmetric output costs.

to increase consumption tax rate to raise tax revenues during debt restructurings—equivalent to fiscal consolidation conditional on default. In this case, the sovereign is more willing to settle because of the improvement in repayment capacity driven by relaxation of fiscal constraint (the enlarged "Settlement" region in panel ii). Due to lower default costs—shorter periods of financial exclusion owing to high likelihood of debt settlement—, the sovereign is more willing to default ex ante (the enlarged "Default" region in panel i).

Second, replacing consumption tax with labor income tax (Arellano and Bai 2017) does not influence the sovereign's choice between repayment and default, and between settlement and delay. This is because, labor income tax and consumption tax are conceptually identical in that both affect the household's intra-temporal substitution between consumption and labor (equation 3), but not the sovereign's inter-temporal substitution between consumption—public consumption and transfers—and saving (i.e., public investment).

Figure C1: Debtor's Choice between Repayment and Default, and between Settlement and Delay—Baseline Model

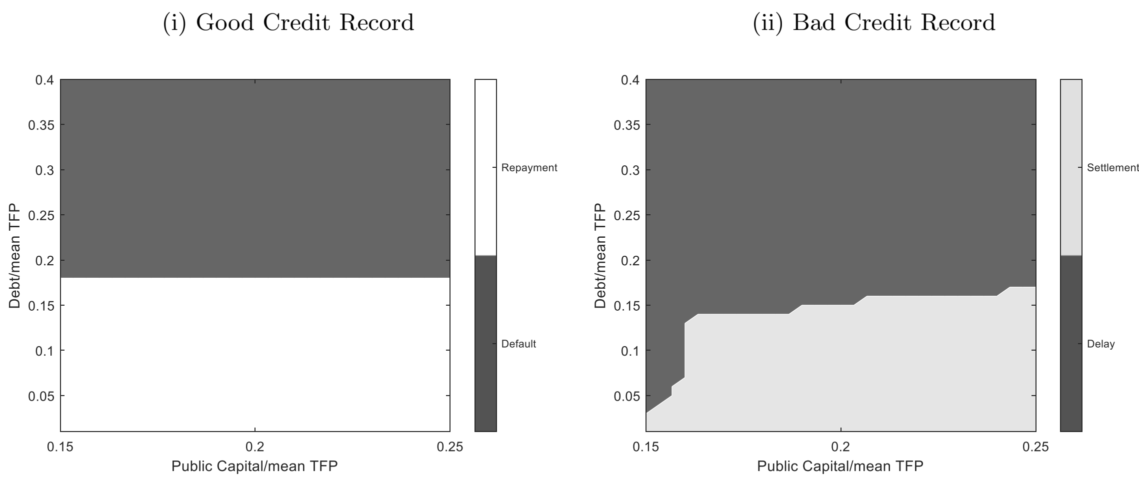


Figure C2: Debtor's Choice between Repayment and Default, and between Settlement and Delay—Symmetric Output Costs

(i) Good Credit Record (ii) Bad Credit Record

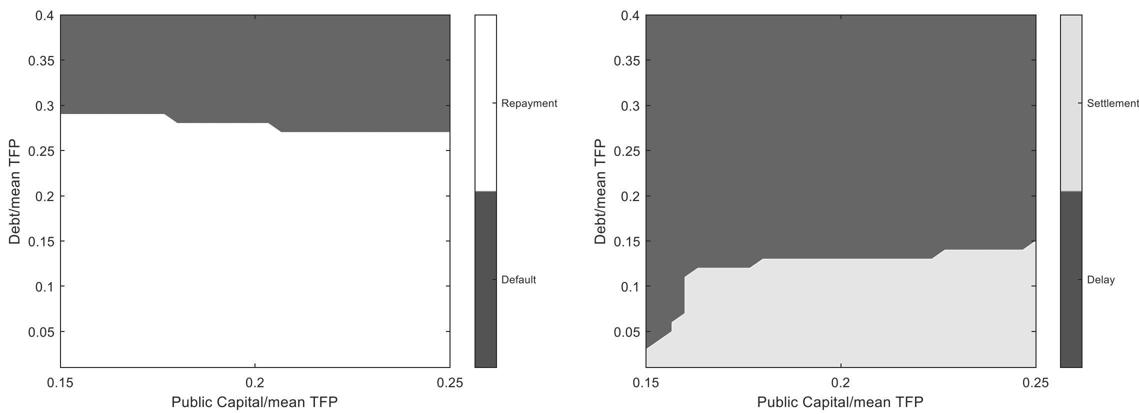


Figure C3: Debtor's Choice between Repayment and Default, and between Settlement and Delay—Net Issuance at Settlement

(i) Good Credit Record (ii) Bad Credit Record

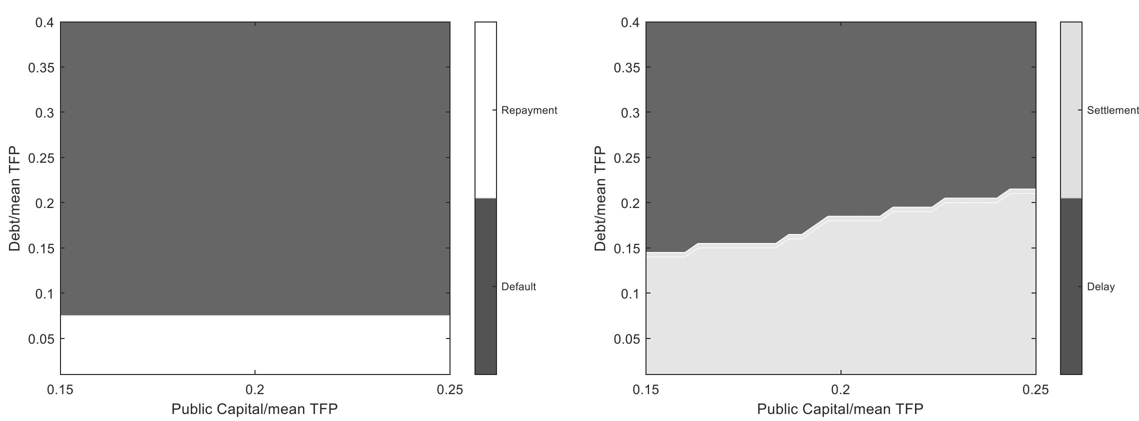
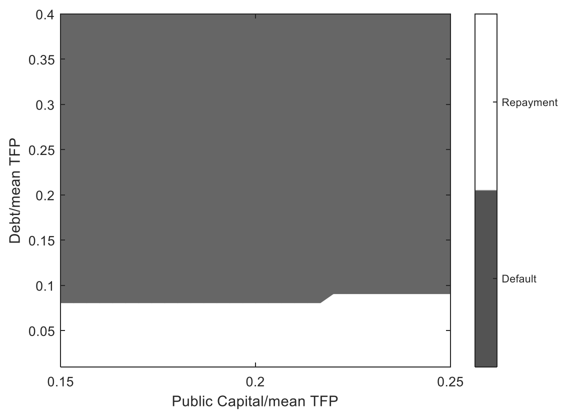


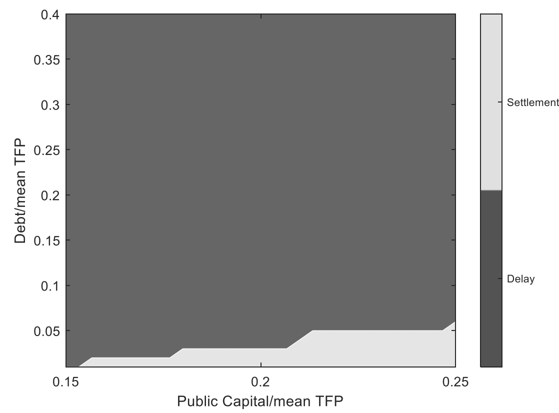
Figure C4: Debtor's Choice between Repayment and Default, and between Settlement and Delay—Private Capital

A: Linear Function of Public Capital

(i) Good Credit Record

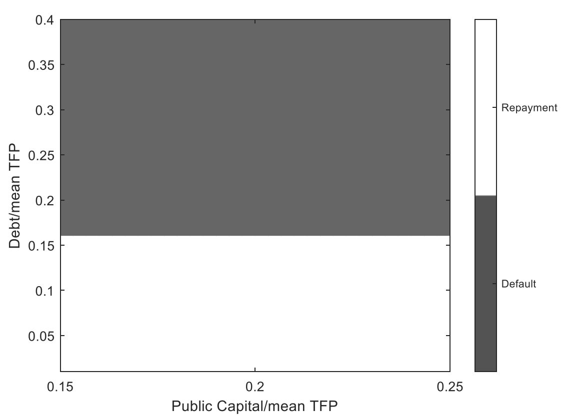


(ii) Bad Credit Record



B: Square Root Function of Public Capital

(i) Good Credit Record



(ii) Bad Credit Record

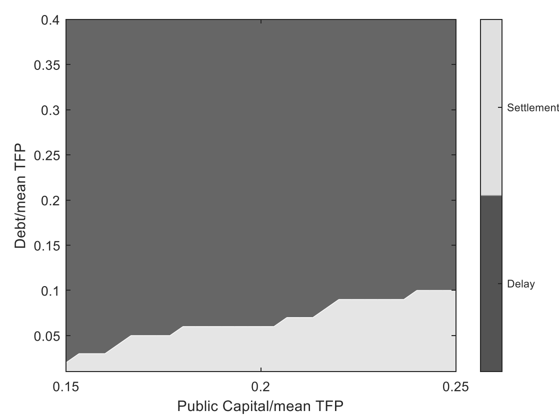
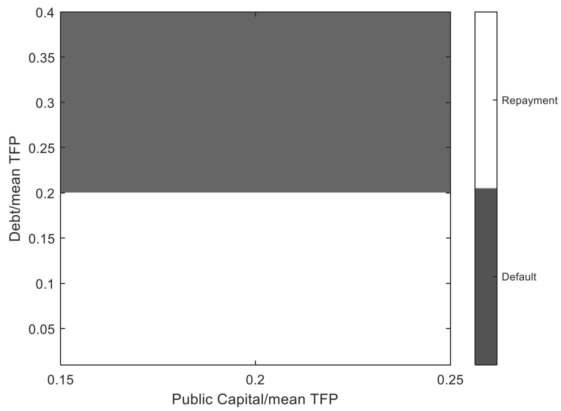


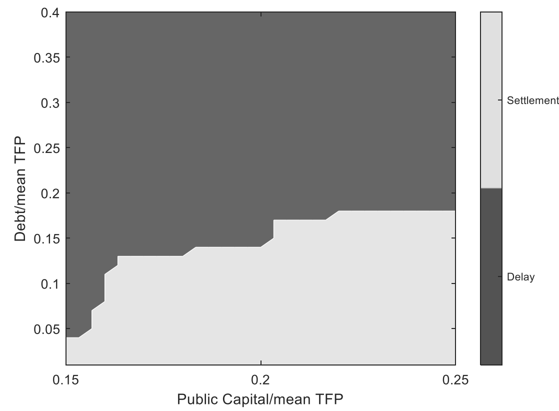
Figure C5: Debtor's Choice between Repayment and Default, and between Settlement and Delay—Taxation Methods

A: Two-stage Consumption Tax

(i) Good Credit Record

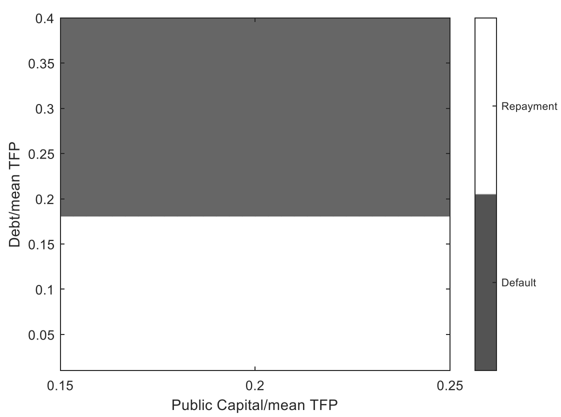


(ii) Bad Credit Record

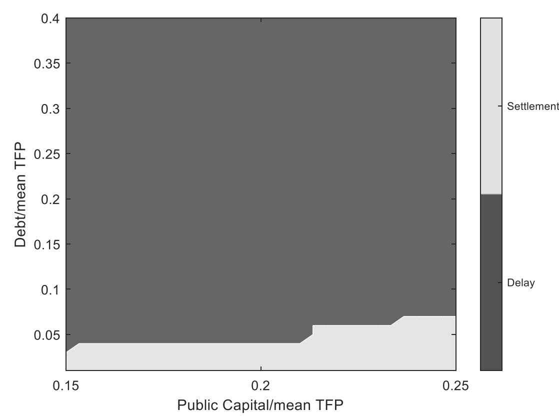


B: Labor Income Tax

(i) Good Credit Record



(ii) Bad Credit Record



Appendix D Further Theoretical Analysis

Proof of Theorem 1.

First, we consider the case that the borrower is the proposer. $k_1 \geq k_2$. Assume $R^B(b, k_1^g) \subset R^B(b, k_2^g)$, i.e., there exists $\bar{a} \in R^B(b, k_2^g)$ and $\bar{a} \notin R^B(b, k_1^g)$. From equation (22), $\bar{a} \in R^B(b, k_2^g)$ implies that the agreed debt recovery rates $\bar{\delta}^*(b, k_2^g, a)$ satisfy the following:

$$\begin{aligned} \bar{\delta}^*(b, k_2^g, \bar{a}) &= argmax V^{PRO}(b, k_2^g, \bar{a}) \\ s.t. \quad V^{PRO}(b, k_2^g, \bar{a}) &\geq V^{PASS}(b, k_2^g, \bar{a}) \\ V^{*ACT}(b, k_2^g, \bar{a}) &\geq V^{*REJ}(b, k_2^g, \bar{a}) \end{aligned} \tag{A1}$$

With $\bar{\delta}^*(b, k_1^g, \bar{a}) = \bar{\delta}^*(b, k_2^g, \bar{a})$ and that both production and capital accumulation functions are increasing respect to public capital, we obtain

$$\begin{aligned} V^{PRO}(b, k_1^g, \bar{a}) &\geq V^{PASS}(b, k_1^g, \bar{a}) \\ V^{*ACT}(b, k_1^g, \bar{a}) &\geq V^{*REJ}(b, k_1^g, \bar{a}) \end{aligned} \tag{A2}$$

The agreed recovery rates $\bar{\delta}^*(b, k_1^g, \bar{a})$ satisfy the following:

$$\begin{aligned} \bar{\delta}^*(b, k_1^g, \bar{a}) &= argmax V^{PRO}(b, k_1^g, \bar{a}) \\ s.t. \quad V^{PRO}(b, k_1^g, \bar{a}) &\geq V^{PASS}(b, k_1^g, \bar{a}) \\ V^{*ACT}(b, k_1^g, \bar{a}) &\geq V^{*REJ}(b, k_1^g, \bar{a}) \end{aligned} \tag{A3}$$

This implies $\bar{a} \in R^B(b, k_1^g)$ which contracts with $\bar{a} \notin R^B(b, k_1^g)$.

Second, for the case that the lender is the proposer, we can prove it by the identical logic above. Therefore, theorem 1 holds.

□

Appendix E Computation Algorithm

The procedure to compute the equilibrium distribution of the model is the following:

1. First, we set finite grids on the space of asset/debt holdings, pubic capital and productivity as by $B = [b_{min}, b_{max}]$, $K^g = [k^g_{min}, k^g_{max}]$, and $A = [a_{min}, a_{max}]$. Limits of productivity are large enough to include large deviations from mean value of shocks. We approximate the stochastic productivity process of the sovereign shown by equation (41) using a discrete Markov chain of 21 equally spaced grids as in Tauchen (1986). Moreover, we compute the transition matrix based on the probability distribution $\mu(a_{t+1}|a_t)$.

2. Second, we set finite grids on the space of recovery rates (δ_t). Limits of recovery rates are to ensure that they do not bind in equilibrium.

3. Third, we set the initial values for equilibrium sovereign bond price, payoffs of debt renegotiations for the sovereign and the creditors, and the sovereign's value function. We use the risk-free bond price ($q^0 = (1 + r^*)^{-1}$) for the baseline equilibrium bond price. We set payoffs for debt renegotiations for the sovereign and the creditors as $\Delta_t^{B,0} = \Delta_t^{L,0} = 0$, and the initial value functions for the sovereign as $V^0 = V^{R,0} = V^{D,0} = 0$.

4. Fourth, given the baseline equilibrium bond price, debt renegotiation payoffs and the sovereign's value functions, we solve for the household's and the firm's maximization problems to obtain private consumption, labor supply, and labor demand.

5. Fifth, given the baseline equilibrium sovereign bond price, debt renegotiation payoffs, and the private sector's equilibrium policy functions, we solve for the sovereign's optimization problem for both good and bad credit records ($h_t = 0, 1$). This procedure finds the value functions for the sovereign ($V^1, V^{R,1}, V^{D,1}$), the optimal asset/debt functions ($b^1, b^{R,1}, b^{D,1}$), and public capital functions ($k^{g,1}, k^{g,R,1}, k^{g,D,1}$). Furthermore, we obtain the default choice, which requires a comparison of the value functions of repayment and default. By comparing these two value functions, we derive the corresponding default set. Based on the default set, we also evaluate the default probability using the transition matrix.

6. Sixth, using the default set in step (5), and the zero profit condition for the foreign creditors, we compute the new price of sovereign bonds (q^1).

7. Seventh, given the value functions for the sovereign, we solve the bargaining problem and compute the new payoffs for two cases either the sovereign or the creditors is the proposer ($\Delta_t^{B,1}, \Delta_t^{L,1}$).

8. We iterate steps (4), (5), (6) and (7) to have fixed optimal value functions for the sovereign, debt renegotiation payoffs, bond price and the private sector's policy functions.

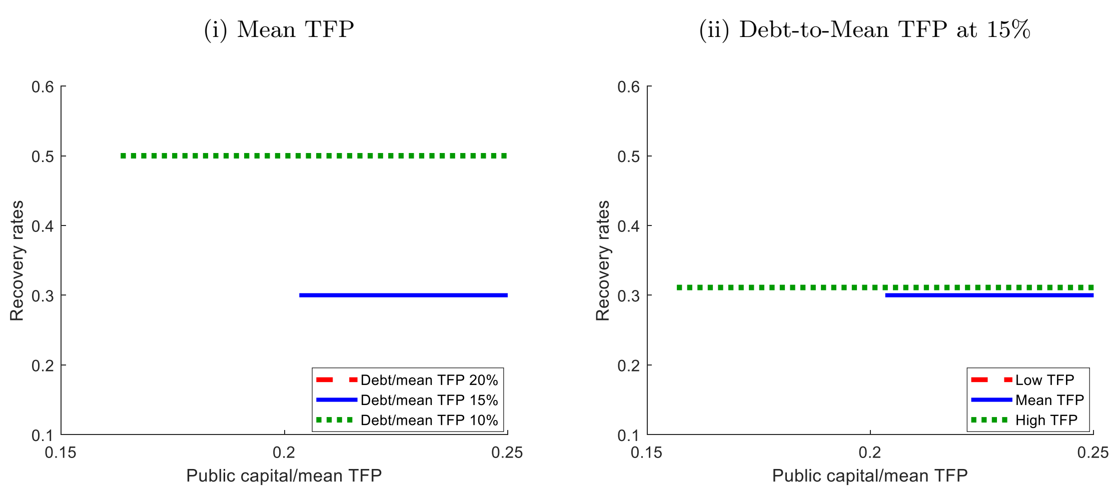
Appendix F Further Equilibrium Properties

F.1 Equilibrium Properties in the Case the Debtor Proposes

Figure F1 reports agreed recovery rates when the sovereign proposes. In both panels (i) and (ii), the horizontal axis is public capital-to-mean TFP ratio and the vertical axis is recovery rate. Two panel charts are classified as follows: panel (i): TFP at the mean level, and panel (ii): debt-to-mean TFP ratio of 15 percent, respectively. Both panels (i) and (ii) show that agreed recovery rates are independent of the level of public capital—for instance, agreed recovery rates stay constant at 30 percent when debt-to-TFP ratio is 15 percent (panel i). What generates this result is the multi-round stochastic bargaining game where settlement is reached only when the proposer—in this case, the debtor—proposes and the counterpart—in this case, the creditors—accepts the proposal. That is, the agreed recovery rates satisfy participation constraints of both the sovereign and the creditors shown in equation (22). Otherwise, there is no agreement reached by the two parties. To maximize its value of proposing, the proposer (the sovereign) chooses the lowest level of recovery rates among possible recovery rates which do not violate the participation constraints of the sovereign and the creditors. The agreed recovery rates are determined by both fixed outside options for the sovereign and the creditors, i.e., values of passing and rejecting (equations 20 and 21). While the sovereign's value of passing increases as public capital increases, the creditors' value of rejecting is independent of the level of public capital. Therefore, the agreed recovery rates are independent of the level of public capital.

On the contrary, both panels (i) and (ii) show that the agreed recovery rates are higher (lower) when debt is lower (higher) and the TFP is higher (lower). These are general patterns of recovery rates as in previous work on debt restructurings (Yue 2010; Bi 2008; Asonuma and Trebesch 2016); recovery rates are increasing with respect to the debtor's assets and repayment capacity, i.e., income.

Figure F1: Agreed Recovery Rates



F.2 Equilibrium Properties in the Case the Creditors Propose

We show the sovereign's choice between repayment and default, and between settlement and delay when the creditors propose in Figure F2. We follow the same presentation approach as in Figure 6 in terms of axis, panel classifications and regions. The sovereign's choice when the creditors propose is exactly identical to that when the sovereign proposes (Figure 6). This is the finding in the literature of multi-round renegotiations (Bi 2008); whether settlement can be reached in the current period does not depend on the identity of the proposer. Intuitively, if one party proposes recovery rates that make both parties at least weakly better off by settling than postponing, this offer of recovery rates could identically be proposed by the counterpart and accepted by the original party.

Figure F2: Debtor's Choice between Repayment and Default, and between Settlement and Delay when the Creditors Propose

A: Mean TFP

(i) Good Credit Record

(ii) Bad Credit Record

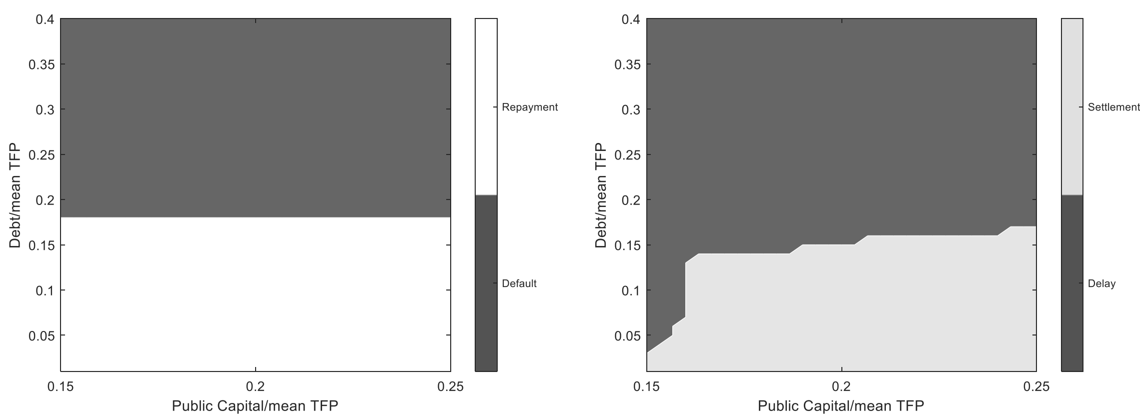
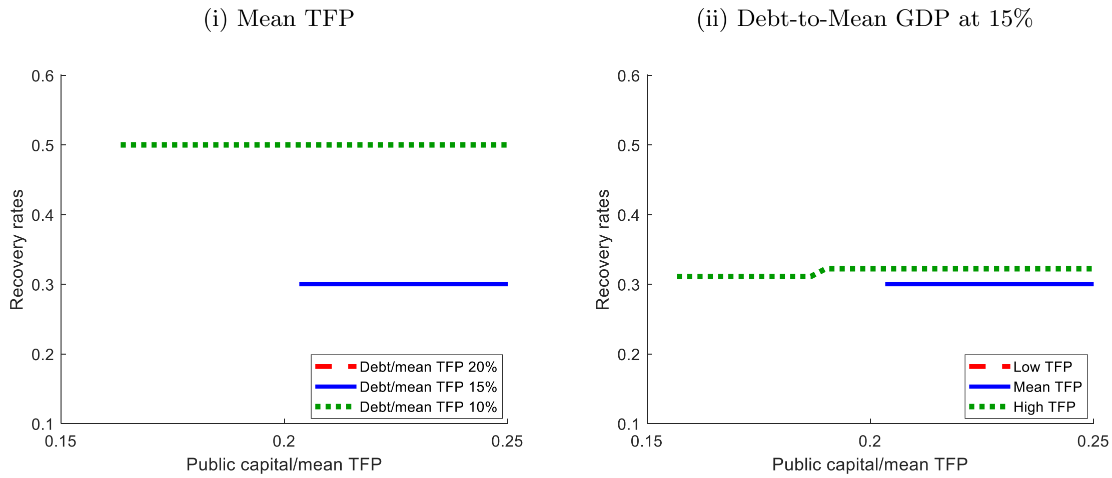


Figure F3 reports agreed recovery rates when the creditors propose. We follow the same presentation approach as in Figure F1 in terms of axes and panel classifications. Our model also shows that in the case where the creditors propose, agreed recovery rates are independent of the level of public capital—for instance, agreed recovery rates stay constant at 30 percent when debt-to-TFP ratio is 15 percent (panel i). The same logic applies as in the case where the debtor proposes: the creditors propose the highest level of recovery rates among possible recovery rates which do not violate the participation constraints of the sovereign and the creditors. The agreed recovery rates are determined by both fixed outside options for the sovereign and the creditors, i.e., values of rejecting and passing (equations 28 and 29). While the sovereign's value of rejecting increases as public capital increases, the creditors' value of passing is independent of the level of public capital. Therefore, the agreed recovery rates are independent of the level of public capital.

Agreed recovery rates when the creditors propose are slightly higher than those when the debtor proposes (Figure F1) as in previous studies on multi-round renegotiations (Bi 2008; Asonuma and Joo 2020). This is due to the "advantage of the first mover"; the party who proposes, i.e., the proposer, can choose the best term of offer from a wide range of recovery rates which the counterpart would accept, while the counterpart can only choose to accept or reject the offer. Therefore, the proposer is willing to offer more favorable term for him than the term of the offer he receives from the counterpart.

Figure F3: Agreed Recovery Rates when the Creditors Propose



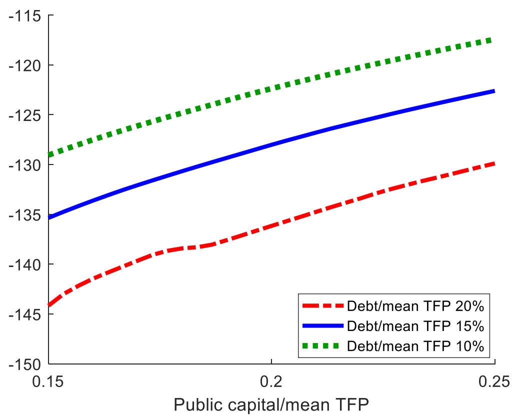
We explore the role of public capital influencing the sovereign's choice between repayment and default, and between settlement and delay when the creditors propose reported in Figure F4. We follow the same presentation approach as in Figure 9 in terms of axis, panel classifications and labels. First, we start from the role of public capital on the sovereign's choice between repayment and default. The sovereign's value functions of repayment and default together with a difference between the two when the creditors propose (panel A in Figure F4) are identical to those when the sovereign proposes (panel A in Figure 9). Default costs, i.e., length of financial exclusion—when both parties settle on debt renegotiations—do not depend on the identity of the proposers. The value function of default when the creditors propose is the same with that when the sovereign proposes. A combination of the autarky channel and the renegotiation channel dominates the smoothing channel at the high level of public capital, while is dominated by the smoothing channel at the low and mean levels of public capital. The sovereign's willingness to default weakly increases as public capital increases (panel A-i in Figure F4).

Second, we move on to the role of public capital on the sovereign's choice of accepting and rejecting. Panel B-(i) reports the value function of accepting conditional on debt settlement. When debt settlement is not achieved, the value function of accepting is truncated or does not exist (i.e., the truncated blue solid lines and non-existing red dashed lines). It shows that as public capital increases, the settlement is more likely to be reached and the value function of accepting exists (renegotiation channel). The sovereign's value function of accepting when the creditors propose is lower than that of proposing when the sovereign proposes (panel B-i in Figure

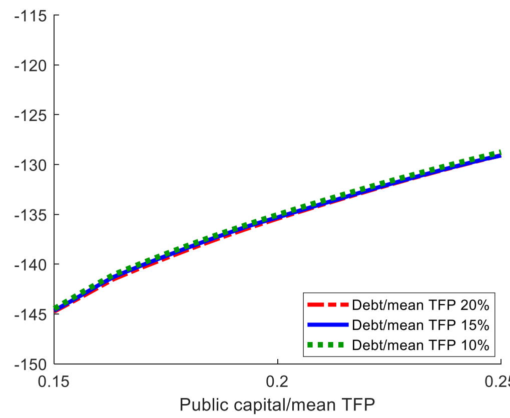
Figure F4: Value Functions at the Mean TFP when the Creditors Propose

A: Value Functions of Repayment and Default

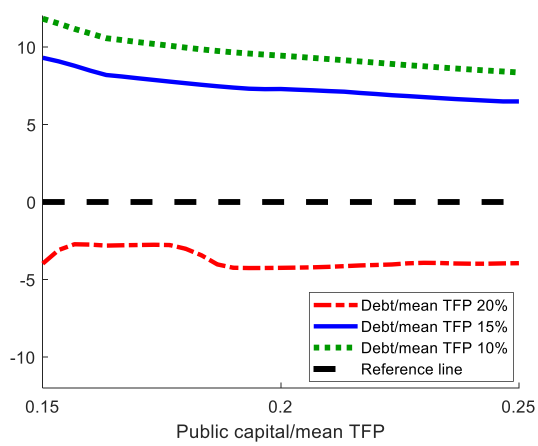
(i) Value Function of Repayment V^R



(ii) Value Function of Default V^D



(iii) Difference between Two Value Functions $V^R - V^D$

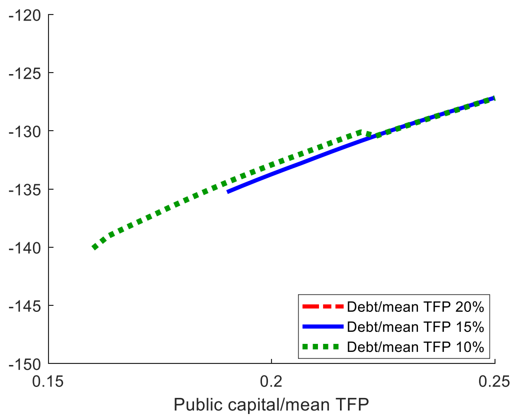


9). As explained above, this is due to the "advantage of the first mover"; the proposer can choose the best term of offer from a wide range of recovery rates which the counterpart would accept, while the counterpart can only choose to accept or reject the offer. Panel B-(ii) shows that the value function of rejecting also increases as public capital increases (autarky channel). The sovereign's value function of rejecting when the creditors propose is identical to that of passing when the sovereign proposes (panel B-ii in Figure 9) because both parties do not reach settlement in the current period and continue renegotiations in the next period. Panel B-(iii) shows that when debt is at 15 percent of the mean TFP, as public capital increases, the settlement is more likely to be reached and the difference between the value functions of accepting and rejecting increases and is above zero value (blue solid line). That is, the renegotiation channel of public capital dominates the autarky channel when public capital is high.

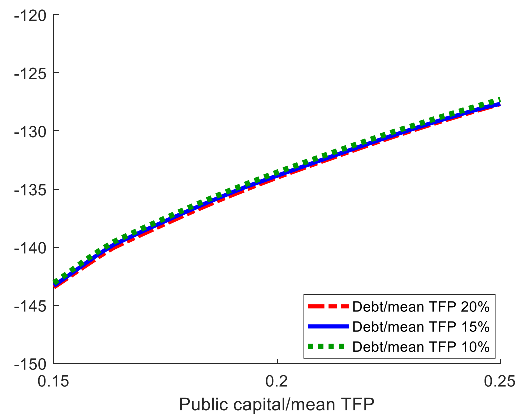
Figure F4: Value Functions at the Mean TFP when the Creditors Propose (Cont.)

B: Value Functions of Accepting and Rejecting

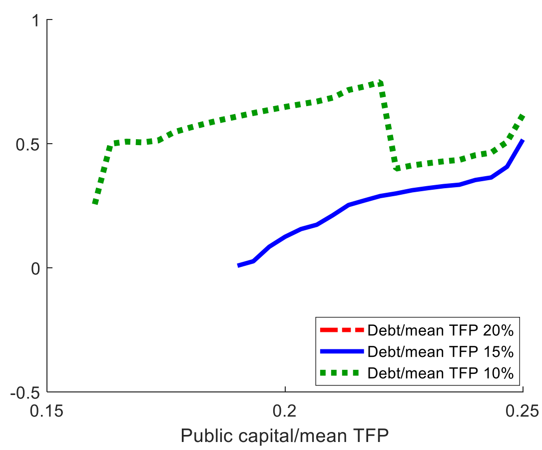
(i) Value Function of Accepting by Borrower V^{ACT}



(ii) Value Function of Rejecting by Borrower V^{REJ}



(iii) Difference between Two Value Functions $V^{ACT} - V^{REJ}$



F.3 Equilibrium Properties in Comparison with Models of Sovereign Default

We contrast equilibrium properties in our baseline model with those in previous models of sovereign default. We consider two cases: (i) a model with exogenous reentry and zero recovery rates (Arellano 2008; Gordon and Guerron-Quintana 2018) and (ii) a model with a one-round negotiation (Yue 2010; Arellano and Bai 2017). To generate model features comparable to ours, we embed assumptions of exogenous reentry and zero recovery rates for the case (i), and an assumption of one-round Nash bargaining for the case (ii) in our model, respectively, leaving all other parameters unchanged.

Figure F5 contrasts the sovereign's choice between repayment and default at the mean TFP in our baseline model (panel i) with that in these two models of sovereign default (panels ii and iii). We follow the same presentation approach as in panel A-(i) in Figure 6 in terms of axis and regions. There are two features in these two models of sovereign default different from those in our baseline model. First, the sovereign is more willing to repay debt as public capital increases. This is shown in the enlarged (shrunk) "Repayment region" when public capital is high (low) in panels (ii) and (iii). Second, the sovereign is more willing to default at low level of debt due to low default costs—fixed (i.e., exogenously determined) or short periods of financial autarky over which the sovereign suffers productivity loss—than our baseline model. We do not contrast the sovereign's choice of settlement and delay in our baseline model with that in the model with a one-round negotiation. This is because the choice in our model does not correspond one-to-one with the choice in the model with a one-round negotiation due to the difference in the two bargaining frameworks.

Figure F6 contrasts the difference in the sovereign's value functions of repayment and default (at the mean TFP) in our model (panel i) with that in two models of sovereign default (panels ii and iii). We follow the same presentation approach as in panel A-(iii) in Figure 9 in terms of axis, lines and labels. In these two models of sovereign default, the difference between value functions of repayment and default (shown in blue solid lines in panels ii and iii) is above the reference line of zero value when public capital is high, while below the reference line when public capital is low. That is, given that the renegotiation channel is missing, effects from the smoothing channel dominate those from the autarky channel when public capital is high, while are dominated by those from the autarky channel when public capital is low (Gordon and Guerron-Quintana 2018). This is consistent with the aforementioned fact that the sovereign is more willing to repay debt as public capital increases (panels ii and iii in Figure F5).

Figure F5: Debtor's Choice of Repayment and Default at the Mean TFP

(i) Baseline Model

(ii) Exogenous Reentry with Zero Recovery Rates

(iii) One-round Negotiation

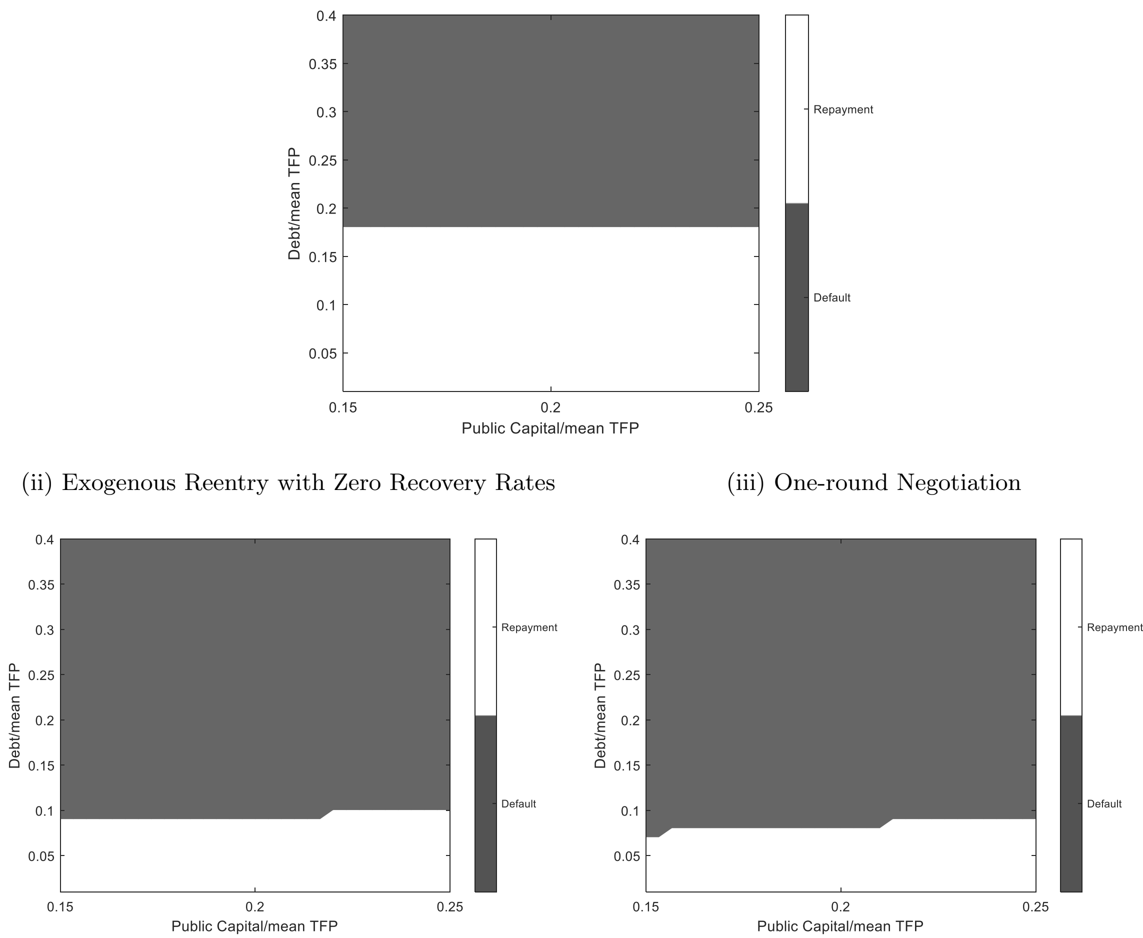
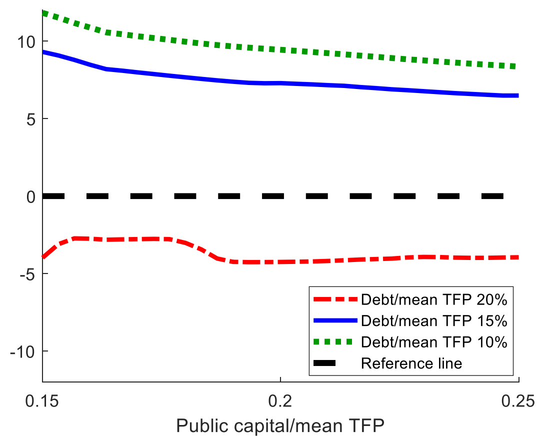
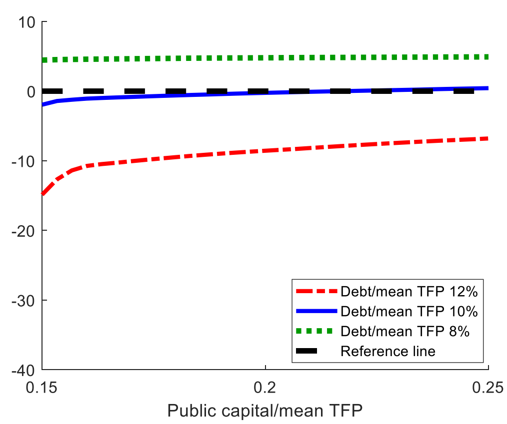


Figure F6: Difference in Value Functions of Repayment and Default at the Mean TFP

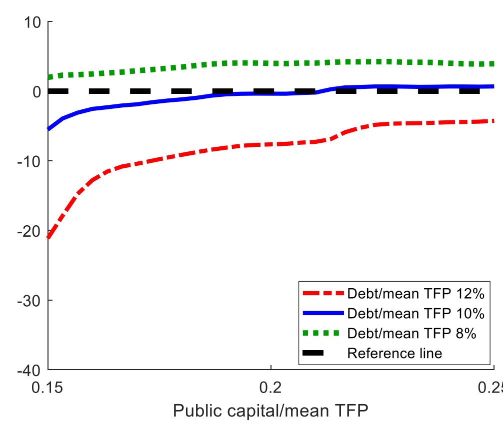
(i) Baseline Model



(ii) Exogenous Reentry with Zero Recovery Rates



(iii) One-round Negotiation



Appendix G Further Quantitative Analysis

G.1 Comparison with Models in Previous Studies

Table G1 shows that business cycle statistics for private sector in our model match with those in the data. Similar to previous studies (Arellano 2008; Yue 2010), our baseline model replicates both volatile consumption and trade balance-to-GDP ratio.

Table G2 compares non-target statistics in our baseline mode with those in previous studies in two streams of literature; sovereign debt and fiscal policy (Cuadra et al. 2010; Hatchondo et al. 2017; Arellano and Bai 2017) and debt renegotiations (Benjamin and Wright 2013; Bi 2008; Yue 2010; Arellano 2008). For the literature on sovereign debt and fiscal policy, we consider two cases; (a) a model with fixed or no public capital and exogenous reentry and zero recovery rates (columns 5 and 8 in panels i and ii)—corresponding to Cuadra et al. (2010) and Hatchondo et al. (2017)—; (b) a model with fixed or no public capital and a one-round negotiation (columns 4 and 7 in panels i and ii)—corresponding to Arellano and Bai (2017). For the literature on debt renegotiations, we consider three cases; (c) a model with fixed or no public capital and multi-round renegotiations (columns 3 and 6 in panels i and ii)—Benjamin and Wright (2013) and Bi (2008) with our parameters—; (d) a model with fixed or no public capital and a one-round negotiation (columns 4 and 7 in panels i and ii)—corresponding to Yue (2010); (e) a model with fixed or no public capital and exogenous reentry and zero recovery rates (columns 5 and 8 in panels i and ii)—Arellano (2008). To generate moments comparable to ours, we embed key assumptions in our model for each case, leaving all other parameters unchanged. Since none of the previous studies introduces public capital, we consider both cases of fixed and no public capital.

For business cycle statistics reported in panel i in Table G2, our baseline calibration results (column 2) outperform calibration results of the previous studies. Most importantly, our model is the only one which successfully replicates moment statistics of public investment in both the pre-default and restructuring periods which match closely with the data: lower public investment-to-GDP ratio and public investment-to-expenditure ratio in the restructuring periods than those in the pre-default periods. This is because our model embeds endogenous public capital accumulation, whereas none of Cuadra et al., (2010), Hatchondo et al., (2017) or Arellano and Bai (2017) has public capital in their models. Introducing fixed public capital in their model is not enough to account for the moment statistics of public investment because both public investment is kept at a fixed level exogenously.

For non-business cycle statistics reported in panel ii in Table G2, our baseline calibration results (column 2) continue to outperform calibration results of the previous studies. First, most importantly, our model successfully replicates both a negative correlation between declines in public investment and duration and a positive correlation between recoveries of public investment and duration. None of the previous studies on sovereign debt and fiscal policy (Cuadra et al. 2010; Hatchondo et al. 2017; Arellano and Bai 2017) does. As explained above, what drives this difference is endogenous public capital accumulation which is only present in our model, but not in the previous models. Second, our model replicates longer duration of renegotiations (11.2 quarters) which is close to the data than that in models of multi-round renegotiations (Benjamin and Wright 2013; Bi 2008; 6.8 quarters), one-round negotiation (Yue 2010; 2.0 quarters). As explained in Section 5.4, what generates long duration of restructurings in our model are both endogenous public capital accumulation and (full) tight fiscal constraint. Both of these are absent in the previous models of multi-round renegotiations (Benjamin and Wright 2013; Bi 2008).

Table G3 compares non-target statistics in our baseline model with those in models with net issuance and different taxation methods. For net issuance, we incorporate net issuance at settlement in our baseline model with all parameters unchanged. For taxation methods, we consider three cases; (a) distortionary taxation (baseline); (b) distortionary taxation and lump-sum taxation; (c) no distortionary taxation. Previous studies on sovereign debt and fiscal policy (Cuadra et al. 2010; Hatchondo et al. 2017; Arellano and Bai 2017) assume distortional tax to explore the role of fiscal policy. To generate moments comparable to ours, we replace our baseline assumption of distortional tax with a different taxation assumption for each case, leaving all other parameters unchanged. Since none of the previous studies embeds public capital, we consider both cases of fixed and no public capital.

For business cycle statistics reported in panel i in Table G3, moment statistics in models with net issuance and different taxation methods are identical to those in our baseline model.

For non-business cycle statistics reported in panel ii in Table G3, for net issuance, duration of restructurings is shorter in the model with net issuance than that in our baseline model (5.0 quarters in column 3). As explained in Figure C3 in Appendix C, the sovereign is more willing to settle quickly since the net lending reduces the costs of debt settlement. As a result, debt-to-GDP ratio in the pre-restructuring period is lower than that in our baseline model. For taxation methods, in both cases of fixed and no public capital, duration of restructurings is shorter in models with distortionary taxation and lump-sum taxation (columns 5 and 8) and without distortionary tax (columns 6 and 9) than that in our baseline model. When we allow the sovereign to have an additional method of taxation, i.e., lump-sum tax (columns 5 and 8), the impact of distortional taxation on resource allocation is partially reduced (i.e., "partial fiscal constraint"). Moreover, when we remove distortionary tax (columns 6 and 9), the impact of distortional taxation on resource allocation is fully eliminated (i.e., "no fiscal constraint").

Lastly, Table G4 compares non-target statistics in our baseline model with those obtained from recalibration exercises of the following previous studies: (i) Gordon and Guerron-Quintana (2018) with one-period bonds, (ii) Arellano and Bai (2017), (iii) Cuadra et al. (2010), and (iv) Benjamin and Wright (2013) with constant bargaining power. To have moment statistics comparable to our baseline model, the recalibration of Benjamin and Wright (2013) assumes both constant bargaining power and our Argentine income process. This differs slightly with Benjamin and Wright (2013) which assume both stochastic process of bargaining power, and income process—estimated from 27 emerging market countries and close to that of Thailand. We also include the reported moment statistics in Benjamin and Wright (2013) in column (7).

In a similar vein, the recalibration of Gordon and Guerron-Quintana (2018) assumes one-period bonds, not long-duration bonds. Only a few moment statistics in the recalibration differ from those in Gordon and Geurron-Quintana (2018): average and standard deviation of bond spreads and average debt-to-GDP ratio.

Our baseline calibration results reported in column (2) continue to outperform the recalibration results of the previous studies. First, our model is the only one which successfully replicates two key features of public investment: lower average public investment and investment share in public expenditure in the restructuring periods than those in the pre-default periods. Second, average restructuring duration in our model (11.2 quarters) is remarkably longer than that in the replication results of Benjamin and Wright (2013) (8.7 quarters). Average duration reported in Benjamin and Wright (2013) (33 quarters) might be largely due to both stochastic process of bargaining power and its correlation with income process—neither of which are explicitly specified in their paper. Third, together with the recalibration of Benjamin and Wright (2013), our model accounts for higher level of debt in both pre-default and restructuring periods due to larger default costs associated with longer duration of renegotiations. Gordon and Guerron-Quintana (2018) assume long-duration bonds and account for high level of debt, while the recalibration of Gordon and Guerron-Quintana (2018) assumes one-period bonds.

Table G1: Simulation Results of Models

(i) Business Cycle Statistics

	Data	Baseline Model	Model with Fixed Public Capital[1/]	Model with No Fiscal Constraint[2/]	Cuadra et al. (2010) Recalibration
Pre-default periods					
Private sector					
Private consumption (std. dev.)/output (std. dev.)	1.11	1.03	1.02	1.02	1.01
Trade balance/output: std. dev. (%)	1.28	0.91	0.48	1.03	0.50
Corr.(trade balance, output)	-0.87	-0.19	-0.07	-0.21	-0.41
Renegotiation periods					
Private sector					
Private consumption (std. dev.)/output (std. dev.)	1.17	1.05	1.00	0.99	1.00
Trade balance/output: std. dev. (%)	0.45	0.00	0.00	0.00	0.00
Corr.(trade balance, output)	-0.97	0.00	0.00	0.00	0.00

(ii) Non-business Cycle Statistics

	Data	Baseline Model	Model with Fixed Public Capital[1/]	Model with No Fiscal Constraint[2/]	Cuadra et al. (2010) Recalibration
Pre-default periods					
Corr.(spreads, output)	-0.88	-0.10	-0.31	-0.14	-0.41
Corr.(debt/GDP, output)	-0.97	-0.70	-0.70	-0.62	-0.28
Renegotiation periods					
Corr.(debt/GDP, output)	-0.95	-0.99	-0.99	-0.99	-0.99

Sources: Datastream, IMF WEO, MECON.

Notes: [1/]Model with fixed public capital corresponds to our model (with the same parameter values) with fixed public capital (Arellano and Bai 2017; Cuadra et al. 2010; Hatchondo et al. 2017).

[2/]Model with no fiscal constraint corresponds to our model (with the same parameter values) with no distortionary consumption taxation and lump-sum taxation (Arellano 2008; Gordon and Guerron-Quintana 2018).

Table G2: Simulation Results of Models of Sovereign Debt and Fiscal Policy

(i) Business Cycle Statistics

	Data	Baseline	Model with Fixed Public capital			Model with No Public Capital		
		Model	Multi-round renegotiations[1/]	One-round negotiation[2/]	Exogenous reentry and zero recovery rates[3/]	Multi-round renegotiations[1/]	One-round negotiation[2/]	Exogenous reentry and zero recovery rates[3/]
Target statistics								
Pre-default periods								
Average public consumption & transfers/GDP ratio (%)	20.0	22.9	22.5	22.7	22.7	24.5	24.7	24.8
Public investment (std. dev.)/output (std. dev.)	5.1	5.9	-	-	-	-	-	-
Renegotiation periods								
Average output deviation during debt renegotiations (%)	-4.45	-3.47	-4.43	-	-	-3.79	-	-
Non-target statistics								
Pre-default periods								
Public sector								
Public consumption & transfers (std. dev.)/output (std. dev.)	1.26	1.23	1.22	1.40	1.11	1.16	1.19	1.20
Corr.(public consumption & transfers, output)	0.52	0.85	0.94	0.93	0.98	0.93	0.94	0.93
Average public investment/GDP ratio (%)	1.31	1.60	2.01	1.92	2.02	-	-	-
Average public investment/public expenditure ratio (%)	6.2	6.4	8.0	7.7	8.1	-	-	-
Corr.(public investment, output)	0.51	0.63	-	-	-	-	-	-
Renegotiation periods								
Public sector								
Public consumption & transfers (std. dev.)/output (std. dev.)	0.99	2.36	1.07	-	-	1.00	-	-
Corr.(public consumption & transfers, output)	0.99	0.77	0.68	-	-	0.80	-	-
Average public investment/GDP ratio (%)	1.19	1.47	2.36	-	-	-	-	-
Average public investment/public expenditure ratio (%)	5.7	5.9	9.5	-	-	-	-	-
Corr.(public investment, output)	0.99	0.82	-	-	-	-	-	-
Public capital (percent change from the trough to the end, %)	2.31	2.00	-	-	-	-	-	-

(ii) Non-business Cycle Statistics

	Data	Baseline	Model with Fixed Public Capital			Model with No Public Capital		
		Model	Multi-round renegotiations[1/]	One-round negotiation[2/]	Exogenous reentry and zero recovery rates[3/]	Multi-round renegotiations[1/]	One-round negotiation[2/]	Exogenous reentry and zero recovery rates[3/]
Target statistics								
Default probability (%)	3.26	3.05	2.71	2.77	3.36	3.47	2.82	2.93
Average recovery rate (%)	25.0	27.1	22.4	38.8	-	22.7	56.4	-
Pre-default periods								
Average debt/GDP ratio (%)	45.4	44.7	45.6	4.79	4.01	51.9	5.1	5.3
Bond spreads: average (%)	9.4	1.65	1.20	3.04	1.14	0.20	2.85	1.68
Bond spreads: std. dev. (%)	7.6	2.25	1.60	5.0	2.42	0.20	3.66	2.41
Corr.(debt/GDP, spreads)	0.92	0.18	0.37	0.10	0.37	0.34	0.44	0.36
Renegotiation periods								
Average debt/GDP ratio (%)	130.5	50.7	53.7	4.80	4.50	60.1	5.3	5.5
Duration of renegotiations/ exclusion (quarters)	14.0	11.2	8.7	2.00	-	10.0	2.00	-
Corr.(decline in public investment, duration)[4/]	-0.25	-0.11	-	-	-	-	-	-
Corr.(recovery in public investment, duration)[5/]	0.22	0.56	-	-	-	-	-	-

Sources: Datastream, IMF WEO, MECON.

Notes: [1/]Model with fixed or no public capital and multi-round renegotiations corresponds to our model (with the same parameter values) with fixed or no public capital and multi-round debt renegotiations as in Benjamin and Wright (2013) and Bi (2008).

[2/]Model with fixed or no public capital and a one-round negotiation (Nash bargaining) corresponds to our model (with the same parameter values) with fixed or no public capital and a one-round debt negotiation as in Arellano and Bai (2017) and Yue (2010).

[3/]Model with fixed or no public capital, and exogenous reentry and zero recovery rates corresponds to our model (with the same parameter values) with fixed or no public capital and without debt renegotiations (e.g., exogenous reentry) as in Cuadra et al. (2010), Hatchondo et al. (2017) and Arellano (2008)

[4/]Decline in public investment is measured in percentage change of public investment from level in t-4 (quarter) to the lowest level, i.e., the level at end of declining trend.

[5/]Recovery in public investment is measured in periods (years) from the time which public investment is at the lowest level to the time which it recovers to the pre-default average.

Table G3: Simulation Results of Models of Multi-round Renegotiations

(i) Business Cycle Statistics

	Data	Baseline Model	Net Issuance	Model with Fixed Public Capital: Full fiscal constraint[1/]	Model with Fixed Public Capital: Partial fiscal constraint (lump-sum tax)[2/]	Model with Fixed Public Capital: No fiscal constraint[3/]	Model with No Public Capital: Full fiscal constraint[1/]	Model with No Public Capital: Partial fiscal constraint (lump-sum tax)[2/]	Model with No Public Capital: No fiscal constraint[3/]
Target statistics									
Pre-default periods									
Average public consumption & transfers/GDP ratio (%)	20.0	22.9	23.3	22.5	22.4	-	25.2	24.5	-
Public investment (std. dev.)/output (std. dev.)	5.1	5.9	7.6	-	-	-	-	-	-
Renegotiation periods									
Average output deviation during debt renegotiations (%)	-4.45	-3.47	-2.65	-4.50	-4.60	-5.41	-4.35	-4.74	-4.61
Non-target statistics									
Pre-default periods									
Public sector									
Public consumption & transfers (std. dev.)/output (std. dev.)	1.26	1.23	1.77	1.43	1.40	-	1.10	1.12	-
Corr.(public consumption & transfers, output)	0.52	0.85	0.77	0.94	0.85	-	0.95	0.74	-
Average public investment/GDP ratio (%)	1.31	1.46	1.53	1.12	1.12	-	-	-	-
Average public investment/public expenditure ratio (%)	6.2	6.4	7.3	8.0	8.4	-	-	-	-
Corr.(public investment, output)	0.51	0.63	0.51	-	-	-	-	-	-
Renegotiation periods									
Public sector									
Public consumption & transfers (std. dev.)/output (std. dev.)	0.99	2.36	2.25	1.07	1.06	-	1.00	1.00	-
Corr.(public consumption & transfers, output)	0.99	0.77	0.40	0.67	0.74	-	0.59	0.74	-
Average public investment/GDP ratio (%)	1.19	1.47	1.21	2.36	2.38	-	-	-	-
Average public investment/public expenditure ratio (%)	5.7	5.9	4.50	9.5	9.6	-	-	-	-
Corr.(public investment, output)	0.99	0.82	0.44	-	-	-	-	-	-
Public capital (percent change from the trough to the end, %)	2.31	2.00	0.40	-	-	-	-	-	-

(ii) Non-business Cycle Statistics

	Data	Baseline Model	Net Issuance	Model with Fixed Public Capital: Full fiscal constraint[1/]	Model with Fixed Public Capital: Partial fiscal constraint (lump-sum tax)[2/]	Model with Fixed Public Capital: No fiscal constraint[3/]	Model with No Public Capital: Full fiscal constraint[1/]	Model with No Public Capital: Partial fiscal constraint (lump-sum tax)[2/]	Model with No Public Capital: No fiscal constraint[3/]
Target statistics									
Default probability (%)	3.26	3.05	2.71	2.71	3.20	2.29	2.10	3.01	3.24
Average recovery rate (%)	25.0	27.1	93.5	22.4	33.2	32.0	20.5	21.1	32.7
Pre-default periods									
Average debt/GDP ratio (%)	45.4	44.7	13.5	45.6	62.5	52.5	66.1	56.6	53.6
Bond spreads: average (%)	9.4	1.65	3.50	0.20	0.10	0.15	0.20	0.20	0.20
Bond spreads: std. dev. (%)	7.6	2.25	2.90	0.34	0.18	0.20	0.20	0.30	0.30
Corr.(debt/GDP, spreads)	0.92	0.18	0.32	0.37	0.29	0.39	0.12	0.35	0.36
Renegotiation periods									
Average debt/GDP ratio (%)	130.5	50.7	15.0	53.7	73.5	63.7	77.1	67.7	62.9
Duration of renegotiations/ exclusion (quarters)	14.0	11.2	5.0	8.3	7.8	6.8	9.3	8.9	7.7
Corr.(decline in public investment, duration)[4/]	-0.25	-0.11	-0.14	-	-	-	-	-	-
Corr.(recovery in public investment, duration)[5/]	0.22	0.56	0.60	-	-	-	-	-	-

Sources: Datastream, IMF WEO, MECON.

Notes: [1/] Model with fixed/no public capital and full fiscal constraint corresponds to our model (with the same parameter values) with fixed/no public capital, distortionary tax, and no lump-sum tax.

[2/] Model with fixed/no public capital and partial fiscal constraint (with lump-sum tax) corresponds to our model (with the same parameter values) with fixed/no public capital, distortionary tax and lump-sum taxation.

[3/] Model with fixed/no public capital and no fiscal constraint corresponds to our model (with the same parameter values) with fixed/no public capital, no distortionary tax and lump-sum taxation as Gordon and Guerron-Quintana (2018).

[4/] Decline in public investment is measured in percentage change of public investment from level in t-4 (quarter) to the lowest level, i.e., the level at end of declining trend.

[5/] Recovery in public investment is measured in periods (years) from the time which public investment is at the lowest level to the time which it recovers to the pre-crisis average.

Table G4: Simulation Results of Models—Recalibration

(i) Business Cycle Statistics

	Data	Baseline Model	Gordon and Guerron-Quintana (2018) recalibration[1/]	Arellano and Bai (2017) recalibration[2/]	Cuadra et al. (2010) recalibration[3/]	Benjamin and Wright (2013) recalibration[4/]	Benjamin and Wright (2013) statistics[5/]
Target statistics							
Pre-default periods							
Private consumption (std. dev.)/output (std. dev.)	1.11	-	1.14	-	-	-	-
Average public consumption & transfers/GDP ratio (%)	20.0	22.9	-	-		-	-
Average public consumption & transfers/private consumption ratio (%)	29.0	-	-	-	32.9	-	-
Public consumption & transfers (std. dev.)/output (std. dev.)	1.26	-	-	-	1.16	-	-
Public investment (std. dev.)/output (std. dev.)	5.1	5.9	5.1	-	-	-	-
Renegotiation periods							
Average output deviation during renegotiations (%)	-4.45	-3.47	-	-	-	-4.13	-
Non-target statistics							
Pre-default periods							
Private sector							
Private consumption (std. dev.)/output (std. dev.)	1.11	1.03	-	1.06	1.01	1.07	1.02
Trade balance/output: std. dev. (%)	1.28	0.91	1.58	1.11	0.50	1.27	-
Corr.(trade balance, output)	-0.87	-0.19	-0.49	-0.52	-0.41	-0.40	-0.10
Public sector							
Public consumption & transfers (std. dev.)/output (std. dev.)	1.26	1.23	-	1.80	-	-	-
Corr.(public consumption & transfers, output)	0.52	0.85	-	0.83	0.94	-	-
Average public consumption & transfers/GDP ratio (%)	20.0	-	-	24.6	-	-	-
Average public investment/GDP ratio (%)	1.31	1.60	1.78	-	-	-	-
Average public investment/public expenditure ratio (%)	6.2	6.4	-	-	-	-	-
Corr.(public investment, output)	0.51	0.63	0.59	-	-	-	-
Renegotiation periods							
Private sector							
Private consumption (std. dev.)/output (std. dev.)	1.17	1.05	-	-	-	1.00	-
Trade balance/output: std. dev. (%)	0.45	0.00	-	-	-	0.00	-
Corr.(trade balance, output)	-0.97	0.00	-	-	-	0.00	-
Public sector							
Public consumption & transfers (std. dev.)/output (std. dev.)	0.99	2.36	-	-	-	-	-
Corr.(public consumption & transfers, output)	0.99	0.77	-	-	-	-	-
Average public investment/GDP ratio (%)	1.19	1.47	-	-	-	-	-
Average public investment/public expenditure ratio (%)	5.7	5.9	-	-	-	-	-
Corr.(public investment, output)	0.99	0.82	-	-	-	-	-
Public capital (percent change from the trough to the end, %)	2.31	2.00	-	-	-	-	-

(ii) Non-business Cycle Statistics

	Data	Baseline Model	Gordon and Guerron-Quintana (2018) recalibration[1/]	Arellano and Bai (2017) recalibration[2/]	Cuadra et al. (2010) recalibration[3/]	Benjamin and Wright (2013) recalibration[4/]	Benjamin and Wright (2013) statistics[5/]
Target statistics							
Default probability (%)	3.26	3.05	-	-	-	3.01	5.2
Average recovery rate (%)	25.0	27.1	-	23.8	-	25.6	50.0
Average debt service/GDP ratio (%)	8.0	-	-	8.7	7.0	-	-
Bond spreads: average (%)	9.4	-	7.5	8.2	-	-	-
Bond spreads: std. dev. (%)	7.6	-	7.2	-	-	-	-
Pre-default periods							
Default probability (%)	3.26	-	3.70	3.71	3.03	-	-
Average debt/GDP ratio (%)	45.4	44.7	9.6	-	-	37.2	76.0
Bond spreads: average (%)	9.4	1.65	-	-	1.17	1.17	-
Bond spreads: std. dev. (%)	7.6	2.25	-	7.5	1.85	1.42	-
Corr.(spreads, output)	-0.88	-0.10	-0.56	-0.61	-0.41	-0.24	-0.12
Corr.(debt/GDP, spreads)	0.92	0.27	0.18	0.05	0.29	0.37	-
Corr.(debt/GDP, output)	-0.97	-0.70	-0.06	-0.13	-0.28	-0.41	-
Renegotiation periods							
Average debt/GDP ratio (%)	130.5	50.7		-	-	43.2	84.0
Corr.(debt/GDP, output)	-0.95	-0.99	-	-	-	-0.99	-
Duration of renegotiations/ exclusion (quarters)	14.0	11.2	-	2.00	-	8.7	33.2
Corr.(decline in public investment, duration)	-0.25	-0.11	-	-	-	-	-
Corr.(recovery in public investment, duration)	0.22	0.16	0.56	-	-	-	-

Sources: Datastream, IMF WEO, MECON.

[1/] Gordon and Guerron-Quintana (2018) recalibration corresponds to calibration results with one-period bonds and four target statistics (i) average bond spreads, (ii) standard deviation of bond spreads, (iii) ratio between standard deviation of total investment and standard deviation of output, and (iv) excess consumption volatility.

[2/] Arellano and Bai (2017) recalibration corresponds to calibration results with three target statistics (i) average bond spreads, (ii) debt service-to-GDP ratio, and (iii) average recovery rate.

[3/] Cuadra et al. (2010) recalibration corresponds to calibration results with three target statistics (i) debt service-to-GDP ratio, (ii) ratio between public consumption and transfers and private consumption, and (iii) ratio between standard deviation of public consumption and standard deviation of output.

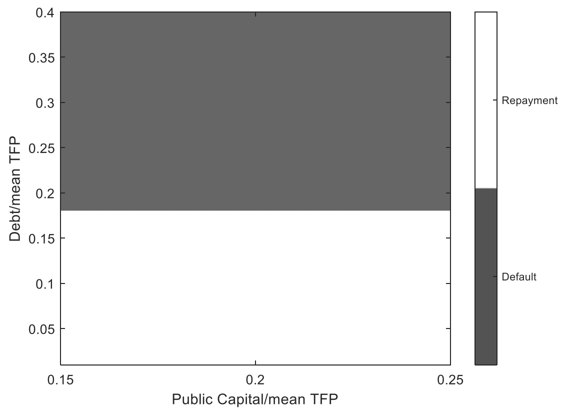
[4/] Benjamin and Wright (2013) recalibration corresponds to calibration results with three target statistics (i) default frequency, (ii) average recovery rate, and (iii) average debtor output deviation during renegotiations.

[5/] Benjamin and Wright (2013) statistics correspond to their moment statistics in calibration results using average emerging market income process and stochastic bargaining power.

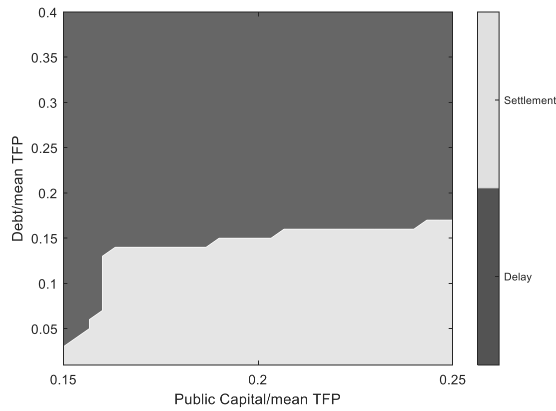
Figure G1: Robustness Check

A: Baseline Model

(i) Good Credit Record

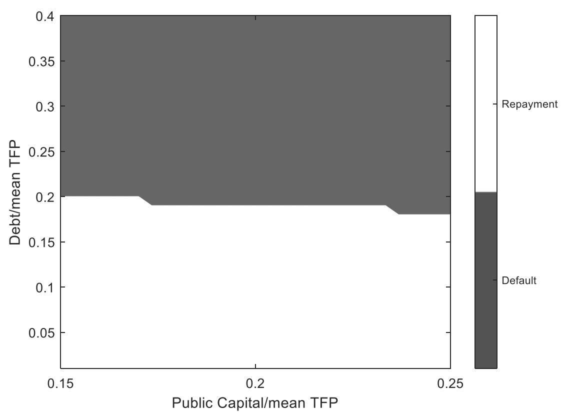


(ii) Bad Credit Record

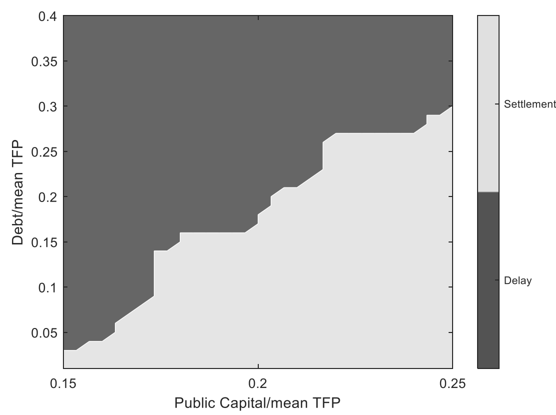


B: Low Capital Adjustment Costs - $\Omega = 5$

(i) Good Credit Record

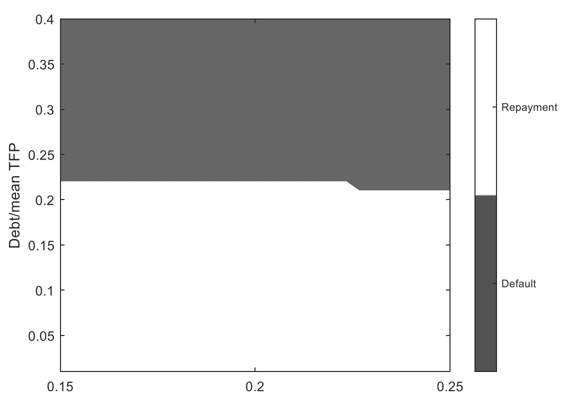


(ii) Bad Credit Record

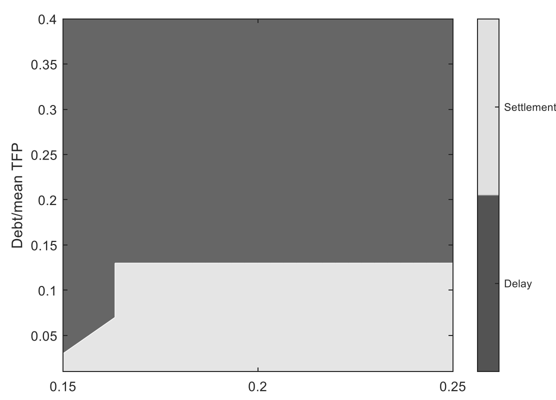


C: High Capital Depreciation Rate - $\delta^k = 0.075$

(i) Good Credit Record



(ii) Bad Credit Record



G.2 Comparison with Models of Multi-round Renegotiations: Decomposition of Delays

Table G5: Simulation Results of Models of Multi-round Renegotiations

	Data	Baseline Model	Fixed Public Capital (case i)1/	Endogenous Public Capital (case ii)2/			Total (Private) Capital and No Fiscal Constraint (case iii)3/	Fixed Public Capital and No Fiscal Constraint (case iv)4/
				No fiscal constraint (case ii-a)	Partial fiscal constraint (lump-sum tax) (case ii-b)	Partial fiscal constraint (no transfers) (case ii-c)		
Target statistics								
Default probability (%)	3.26	3.05	2.71	3.32	3.50	2.15	2.25	2.30
Average recovery rate (%)	25.0	27.1	22.4	36.8	54.8	30.4	41.9	32.0
Average output deviation during debt renegotiation (%)	-4.45	-3.47	-4.43	-4.23	-4.42	-4.62	-5.2	-5.5
Pre-default periods								
Average debt/GDP ratio (%)	45.4	44.7	45.6	48.3	24.5	34.4	46.6	52.5
Bond spreads: average (%)	9.4	1.65	1.20	1.55	1.47	1.10	1.00	1.20
Bond spreads: std. dev. (%)	7.6	2.25	1.60	2.20	1.90	1.15	0.90	1.26
Corr.(spreads, output)	-0.88	-0.10	-0.18	-0.31	-0.05	-0.10	-0.23	-0.31
Corr.(debt/GDP, spreads)	0.92	0.18	0.37	0.26	0.78	0.29	0.31	0.39
Corr.(debt/GDP, output)	-0.97	-0.70	-0.70	-0.62	-0.10	-0.73	-0.69	-0.70
Renegotiation periods								
Average debt/GDP ratio (%)	130.5	50.7	53.7	57.0	30.0	40.9	55.4	63.7
Corr.(debt/GDP, output)	-0.95	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99
Duration of renegotiations/ exclusion (quarters)	14.0	11.2	8.7	8.9	9.0	9.4	7.4	6.8
Public capital (percent change from the trough to the end)	2.31	2.01	-	-	0.05	1.19	-	-
Corr.(decline in public investment, duration)	-0.25	-0.10	-	-	-0.17	-0.10	-	-
Corr.(recovery in public investment, duration)	0.22	0.16	-	-	0.28	0.84	-	-

Sources: Datastream, IMF WEO, MECON.
Notes: 1/ Model with fixed public capital corresponds to our model (with the same parameter values) with public capital fixed at the average (under the baseline model).
2/ Model with endogenous public capital corresponds to our model (with the same parameter values) with no fiscal constraint (case ii-a), partial fiscal constraint (lump-sum tax) (case ii-b) and partial fiscal constraint (no transfers) (case ii-c).
3/ Model with total (private) capital and no fiscal constraint corresponds to our model (with the same parameter values) with the total (private) capital income share and no fiscal constraint.
4/ Model with fixed public capital and no fiscal constraint corresponds to our model (with the same parameter values) with public capital fixed at the average (under the baseline model) and no fiscal constraint.
5/ Decline in public investment is measured in percentage change of public investment from level in t-4 (quarter) to the lowest level, i.e., the level at end of declining trend.
6/ Recovery in public investment is measured in periods (years) from the time which public investment is at the lowest level to the time which it recovers to the pre-crisis average.

Table G5 contrasts non-business cycle statistics in our baseline model with those in models of multi-round renegotiations. We consider four cases: (i) a model with fixed public capital, (ii) a model with endogenous public capital, (iii) a model with total (private) capital and no fiscal constraint, and (iv) a model with fixed public capital and no fiscal constraint. For (ii), we consider three cases; (ii-a) no fiscal constraint; (ii-b) partial fiscal constraint (lump-sum tax); (ii-c) partial fiscal constraint (no transfers). To generate moments comparable to ours, we fix public capital at the constant level for case (i), remove full fiscal constraint for case (ii-a), replace full fiscal constraint with partial fiscal constraint for cases (ii-b, ii-c), replace the public capital income share with the total (private) capital income share and remove full fiscal constraint for case (iii), and fix public capital at the constant level and remove full fiscal constraint for case (iv), respectively, leaving all other parameters unchanged.

First, we compare our baseline model and cases (ii-a) and (iv). Average duration of renegotiations is 11.2 quarters in our baseline model, 8.9 quarters in case (ii-a) and 6.8 quarters in case (iv), respectively. A difference in average duration of renegotiations between our baseline model and case (ii-a) (11.2 vs. 8.9 quarters) corresponds to delays due to (full) tight fiscal constraint, i.e., "fiscal delays" (the red segments in panel ii in Figure 11). A difference in average duration of renegotiation between our baseline model and case (iv) (8.9 vs. 6.8 quarters) corresponds to delays due to public capital accumulation, i.e., "capital accumulation delays" (the blue segments in panel ii in Figure 11).

Second, we compare our baseline model and cases (ii-b) and (ii-c). Average duration of renegotiations is 11.2 quarters in our baseline model, 9.0 quarters in case (ii-b) and 9.4 quarters in case (ii-c), respectively. A difference in average duration of renegotiations between our baseline model and cases (ii-b, ii-c) (11.2 vs. 9.0 or 9.4 quarters) corresponds to delays due to (full) tight or partial fiscal constraint (the red segment in panel i in Figure 11).

Third, we compare cases (ii-a), (iii) and (iv). Average duration of renegotiations is 8.9 quarters in case (ii-a), 7.4 quarters in case (iii), and 6.8 quarters in case (iv), respectively. A difference in average duration of renegotiations between case (ii-a) and case (iii) (8.9 vs. 7.4 quarters) corresponds to the difference in capital accumulation delays. In case (ii-a), slightly longer capital accumulation delays are due to the marginal product of public capital with small public capital income share, while in case (iii), slightly shorter capital accumulation delays are due to the marginal product of total capital with large total capital income share.