Growth in the Shadow of Debt

Jamus Jerome Lim*

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Abstract

This paper revisits the relationship between debt and growth from a vantage point that considers the totality of private and public debt. We exploit quarter-long timing lags inherent in the response of borrowing to innovations in output to identify the effects of debt on growth in a panel vector autoregressive model. We verify that debt accumulation is negatively related to output growth, with a one standard deviation innovation in the former leading to a 0.2 percentage-point contraction in the latter. This result is robust to the inclusion of exogenous variables in the system, alternative measures of the endogenous variables, and varying temporal treatments. We also find variations depending on the type of debt accumulated, the specific subset of countries considered, and the channels along which debt expansion operates.

KEYWORDS: Economic growth, total debt, panel VAR
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*ESSEC Business School and Center for Analytical Finance. Contact: Jamus Lim, Economics Department, ESSEC Business School Asia-Pacific, 5 Nepal Park, Singapore 139408. Email: jamus@essec.edu. The author thanks Musa Iftekhar for assistance with data collection, Michael Abrigo and Inessa Love for making available their `pvar` and related packages (used extensively for the empirical analyses in this paper), and Paul O'Brien for useful feedback. As a sole-authored paper, its impossible to even blame the coauthor for remaining errors and omissions, so I'll grudgingly accept any as my own.

He that goes a-borrowing, goes a-sorrowing.

Benjamin Franklin (1706–1790)

1 Introduction

The assumption of debt, from an economic perspective, can be both a blessing and a curse. Leverage is often necessary for financing profitable investment opportunities, and rapid economic growth is often accompanied by deepening financial markets that render the debt burden sustainable. Yet rapid borrowing can result in misallocated resources and heightened inefficiencies, and an excessive debt overhang can be corrosive to economic confidence and growth prospects. This fundamental tension—the question of whether debt accumulation leads to or follows from aggregate growth—underlies all studies that seek to understand the relationship between debt burdens and economic performance.

Given this essential tradeoff, it is natural to couch any relationship between debt and economic outcomes in terms of the full extent to which leverage is deployed; that is, *total* economywide debt—rather than debt of either a public or private nature—is what should be relevant. Even setting aside arguments about Ricardian equivalence (Barro 1974)—where, at the limit, higher public debt financed by more taxation would simply be offset by greater private saving or, equivalently, reduction in private debt—it is straightforward to recognize that any marginal gain or loss to economic growth as a result of credit extension should depend only on increments in the total debt stock, regardless of source. Yet most of the literature has focused on either private or public debt independently, leaving the macroeconomic effects of total debt underexplored.

The objective of this paper is to contribute to the understanding of the linkages between total debt and economic outcomes, especially output growth. In particular, we seek to establish a causal link from debt to growth, which we do by exploiting the temporal lag between shocks to output and the rational responses by public and private borrowers, within a panel vector autoregressive (VAR) framework. Our identification assumption is premised on the fact that neither private action nor public policy responds contemporaneously to innovations in aggregate economic activity, but do so after a quarter. This is plausible for movements in slower-adjusting real variables—such as changes in debt—since reacting to growth shocks typically requires redesigning policies, restructuring plans, renegotiating terms, and amending contracts, all of which require time. Moreover, our panel VAR setting offers several additional advantages. VARs permit insight into short-run dynamics—by accounting for interdependencies between debt and growth—while the panel setting allows abstraction from (time-invariant) unobserved heterogeneity that is secondary to the question at hand. At the same time, panel VARs accommodate general inferences that may not be available to causal analyses reliant on country-level natural experiments, due to external validity concerns.

Existing studies of debt and growth rely, virtually unanimously, on data gathered at the annual frequency. While this is not generally problematic for empirical analyses whose central objective is to simply document the coevolution of the two variables of interest, annual data typically disqualifies the use of standard Blanchard & Perotti (2002)-type timing assumptions necessary for causal identification. Such arguments are generally only plausible when working with quarterly data, since it is much harder to argue the case that innovations to macroeconomic variables do not fully propagate within the economy—and hence garner behavioral responses from agents—over the course of a full year.

Using this timing-based identification strategy, we verify that debt accumulation leads to a contraction in output growth: a one standard deviation innovation results in a decline in GDP of around 0.2 percentage points. This relatively modest cumulative effect is mostly realized by the first year following the shock, although in a more fully-specified model, changes in the current account and real exchange rate serve to largely offset this drag, nullifying any relationship in the long run.

In addition to these baseline results obtained, our analysis also reveals additional nuances. A decomposition of debt indicates that, on average, public debt expansions are responsible for growth contractions; to the extent that private debt accumulation matters, it operates more along corporate, rather than household, leverage. We also find evidence of variations in outcomes based on different subsamples of the data. In particular, interdependencies between the issuance of public and bank debt appear to be more a Euro Area-concern, with such linkages absent from broader samples of either developed economies or all countries. Finally, we establish that the effects of debt accumulation after the global crisis appear to operate along both real and financial channels.

There is a small cottage industry of empirical papers exploring the relationship between debt and growth. However, much of this work is focused on the debt burden of the public sector alone. Eberhardt & Presbitero (2015), for example, rely on a suite of heterogeneous panel models to identify a negative relationship between the two. Lof & Malinen (2014) and Panizza & Presbitero (2014) find similar results, although the former claim *reverse* causality (from growth to debt), while the latter finds that the debt-growth linkage disappears once they account for endogeneity. De Vita, Trachanas & Luo (2018) even argue, using linear and nonlinear panel test, for bidirectionality in causation. Although interesting in their own right, the focus of these papers on public debt leads us to regard these results as an incomplete representation of the full effects of debt on the macroeconomy.

A number of papers narrow the concern to the existence of threshold effects of debt. Reinhart & Rogoff (2010)[1] and Cecchetti, Mohanty & Zampolli (2011), for instance, argue in favor of a hard threshold. But most other papers have struggled to verify the existence of such a tipping point. Chudik, Mohaddes, Pesaran & Raissi (2017), for example, find a negative relationship between public

[1] The work of Reinhart & Rogoff (2010) was famously called into question by Herndon, Ash & Pollin (2014), who claim that a number of data and methodological irregularities invalidate the claim of a 90 percent debt/GDP threshold. However, subsequent work (Reinhart, Reinhart & Rogoff 2012), not subject to the original critique, has offered continued (albeit weaker) support for the threshold effect.

debt and growth, but no evidence of thresholds. Similarly, Pescatori, Sandri & Simon (2014) and Arčabić, Tica, Lee & Sonora (2018) both fail to identify diminished growth prospects across a range of candidate threshold debt values. These negative results are further echoed by Koursaros, Michail & Savva (2016), who consider the tipping-point question from a purely private debt perspective. Compared to these papers, our work here offers some insight into the effects of long-run debt levels, but the question of threshold effects is secondary to our primary concern regarding the causal nature of debt on growth.

Several papers have touched on a broader conception of debt. The voluminous literature on financial development and growth (Arcand, Berkes & Panizza 2015; Levine 2005; Levine, Loayza & Beck 2000; Rajan & Zingales 1998; Xu 2007) has typically relied on domestic credit provided to the private sector as a proxy for the maturity of the financial sector. Yet even when we set aside definitional distinctions,[2] it is still the case that this branch of the literature is generally more interested with the longer-term relationship between private credit availability, rather than the total debt burden. Perhaps more crucially, such findings are often due to between-country variations in financial depth (along with other structural factors), rather than the sort of within-country debt and growth dynamics that give rise to our results. And while several other papers—such as Drehmann & Juselius (2014) and Schularick (2014)—are also concerned with total debt, their studies focus specifically on financial stability and crisis likelihood, rather than broader macroeconomic performance. By a similar token, papers that study the choice between types of public and private debt instruments at the firm level (Denis & Mihov 2003) tend to abstract from implications for economywide growth.

The papers that are closest in spirit to our own are Bernardini & Forni (2017), Jordà, Schularick & Taylor (2013), and Mian, Sufi & Verner (2017). The first two rely primarily on local projections methods to examine how changes in total debt can affect macroeconomic outcomes, such as growth or the probability of a financial crisis. Both find that debt buildups are indeed associated with longer-lasting and more severe recessions, and the latter paper further demonstrates that this effect is even more pronounced when the intensity of credit growth during the expansion period is greater. However, the reliance of these papers on local projection methods imposes distinct identification assumptions that abstract from causal interpretation, in contrast our timing approach. Like us, the final paper details the distinct effects of household, corporate, and public debt, and how these may differentially affect macroeconomic outcomes of interest. But unlike us, the emphasis is on distinguishing between the growth effects of household and corporate debt (in particular the former); we instead stress the importance of total debt, and remain agnostic with regard to the contribution of any given subcomponent that comprises this aggregate. Finally, it is worth noting that all these papers rely on data gathered annually, which can obscure important shorter-term dynamics in favor of long-run equilibrium relationships.

[2] Domestic credit generally refers to financial resources that may include financing items, such as trade credit, which are generally excluded from "core" definitions of debt.

The rest of the paper is organized as follows. In the following section, we review the relevant theory on the relationship between debt and growth, together with the case for treating public and private debt in tandem. Section 3 describes our empirical approach and identification strategy, while Section 4 documents our main results, including robustness. A penultimate section discusses a number of secondary findings, applied to specific cases. A final section concludes with some brief remarks on future research directions.

2 Theoretical Background

2.1 Debt accumulation and economic growth

In theory, the relationship between debt and growth is indeterminate. The transfer of risk between savers and investors necessarily requires the extension of credit. As an economy develops, therefore, it is natural for debt to increase, especially as domestic financial markets become more efficient in their intermediation of capital. To the extent that such leverage raises the intensity of efficient capital usage, the economy will grow faster than otherwise; this increased growth will then serve to reduce the ratio of total debt to output, even in the absence of fiscal consolidation/deleveraging, excess inflation/monetization, or default. In this instance, both the growth of debt and output move in tandem.

However, if borrowing becomes excessive, there is a risk that financial resources are misallocated. This will result in inefficiencies that lower the performance of the economy below potential. The debt burden then becomes increasingly unsustainable: the overhang of debt erodes economic confidence, lowering investment; this in turn heightens uncertainly over future prospects, which further reduces investment in a negative feedback loop. Such an outcome would then imply a negative relationship between debt accumulation and growth outcomes.

One natural question, then, is whether there is an optimal level of debt that serves as a sweet spot between finance-supported economic growth and irresponsible leverage. This is the subject of a large literature on public sector debt sustainability (Bi 2012; Denes, Eggertsson & Gilbukh 2013; Ley 2009; Turnovsky 1996), although the focus of this body of work has been on clarifying the sorts of fiscal policies that heighten default risks, and identifying critical debt-to-output ratios that give rise to explosive debt dynamics. An analogous literature exists in corporate finance, although here many papers have concerned themselves with firms' debt capacity and establishing conditions where their optimal capital structure deviates from Modigliani & Miller (1958) irrelevance (Barclay, Smith & Morellec 2006; Barges 1968; Jensen & Meckling 1976; Leland 1998).

While there is undoubtedly value in establishing whether such optimal debt thresholds exist, the more fundamental issue is whether taking on more debt stimulates growth or retards it. Given the indeterminacy of the debt-growth relationship—especially the heterogeneity of conditions under which accelerated debt buildup may alter the growth trajectory—a deeper understanding of the phenomenon ultimately calls for an empirical resolution, which is the objective of this paper.

2.2 Total debt and growth dynamics

Economic theory has long implied that properly accounting for the effects of debt on growth entails working with changes in the aggregate debt stock, rather than either the public or private debt burden alone. At the most basic level, Ricardian equivalence-type arguments (Barro 1974) would imply substitutability between public debt and the future tax burden, which detracts from saving available for allocation into private assets. If such government debt financing is subsequently directed toward expenditure, one would expect a concomitant reduction in capital formation, and hence growth (Modigliani 1961).[3]

More articulated models make analogous points. While canonical Ramsey-Cass-Koopman-style models typically introduce debt as a single state variable, relatively straightforward extensions that explicitly model government reconcile the distinct public and private components under a single intertemporal national resource constraint (see Blanchard & Fischer 1989, chap. 2)). Both forms of debt enter into the first-order conditions that define optimal growth, and in cases where taxation is distortionary, the balanced growth path as well. But the corrosive effects of debt need not operate only on the supply side: if agents face debt constraints, debt can give rise to changes in aggregate demand as well, whether in overlapping-generations settings (Blanchard 1985; Diamond 1965) or New-Keynesian models (Eggertsson & Krugman 2012).[4]

The conditioning effects of debt are not limited to first-generation models of growth. Second-generation endogenous growth models that incorporate leverage elements generally identify a negative growth drag due to debt (Saint-Paul 1992). In contrast to exogenous growth settings, however, an enlarged debt stock in such models may diminish real growth through mechanisms beyond the interest rate;[5] such factors include the nonneutral effects of monetary expansions (van der Ploeg & Alogoskoufis 1994) or congestion in the provision of public goods (Turnovsky 1996).

Another theoretical argument in favor of a complete treatment of debt stems from more recent work on government-bank debt interdependence (Brunnermeier *et al.* 2016; Cheng, Dai & Dufourt 2017; Farhi & Tirole 2018; Gennaiola, Martin & Rossi 2014).[6] This literature traces the manner by which bank

[3]At the extreme, Pritchett (2000) goes as far as to argue that government investment results in little useful productive capital, in which case inefficient public borrowing would fully crowd out private debt.

[4]In the appendix, we develop a sketch of a number of these theoretical arguments in formal detail.

[5]Indeed, Lin (2000) demonstrates that in an endogenous growth model with overlapping generations, changes to debt may have an ambiguous effect on the real interest rate and, in turn, growth.

[6]This concurrent occurrence of different types of financial distress has long been recognized in the empirical twin-crises literature, of course. Hutchison & Noy (2005) is an early exam-

indebtedness—which in turn reflects borrowing from the nonfinancial private sector—can amplify credit stresses experienced by the sovereign, in a mutually-reinforcing "doom loops." On the other side of the coin, banks—due to either risk-shifting (Crosignani 2017) or credit discrimination (Broner, Erce, Martin & Ventura 2014) motivations—may persist in holding (and may even expand) government debt even in bad times, effectively supporting the sovereign. Because such feedback loops effectively link public and private debt, buildups in either class will have implications for the overall quality of the country's aggregate debt portfolio, as well as for the nation's financial stability and economic performance.

3 Empirical Approach

3.1 Data sources and definitions

The baseline sample is an unbalanced panel beginning in 1952Q1 and ending 2016Q3, with coverage of up to 41 advanced and emerging economies. The debt data are from the Bank for International Settlements' (BIS) *Total Credit Statistics*. For our baseline, these are matched with standardized national accounts data for real GDP from Datastream—which in turn relies on national statistical organizations—and supplemented with real effective exchange rate (REER) data from the *Effective Exchange Rate Indices* of the BIS, and balance-of-payments data from the International Monetary Fund's (IMF) *International Financial Statistics*. Beyond our baseline, we draw further on a variety of sources, including (but not limited to) national accounts data from the Organisation for Economic Cooperation's (OECD) *Main Economic Indicators*, effective exchange rate estimates from J.P. Morgan, and political risk data from the Political Risk Services' *International Country Risk Guide*.

Since the debt data are central to our study, it is worth describing the series in some additional detail. The database includes coverage of both bank and nonbank credit extended to either the private nonfinancial sector and government sector. Private nonfinancial credit can be further subdivided into corporate and household borrowing, via either loans or debt securities. Government credit comprises only core debt instruments (currency & deposits, loans, and debt securities), and all liabilities are consolidated across different levels of government (central, state, and local), such that cross-holdings between different public entities are netted out. For all the analyses to follow, total debt (or its subcomponent) is always measured as a share of GDP.

The overall trend of increases in the global debt stock, especially from the 1990s onward, is well-recognized. This fact is captured in Figure 1, which charts the decomposition of total debt for our unbalanced panel, by developmental

ple that links currency with banking crises; while Reinhart & Rogoff (2011) document the relationship for debt and banking crises empirically, and Bindseil & Winkler (2013) propose a theoretical explanation based on a closed system of financial accounts.

aggregate.[7] Although the pattern of rising total debt is evident in both groups, the increase appears to be greater for public debt among developed market (DM) economies, while the rise in private debt is more pronounced among emerging market (EM) economies.

All variables were deseasonalized (where necessary), and the baseline computes either quarter-on-quarter (QoQ) first differences or deviations from the linear-quadratic trend of natural logarithms of the variables (except when ratios are involved).[8] The full list of data sources, and their accompanying definitions, is provided in the appendix.

3.2 Econometric methodology

Our baseline model is an m-variate homogeneous panel VAR, of order k and comprised of $i = 1, \ldots, N$ economies over $t = 1, \ldots, T$ periods. This is represented as

$$\mathbf{X}_{it} = \sum_{j=1}^{k} \mathbf{X}'_{i,t-j}\boldsymbol{\beta}_j + \mathbf{Z}'_{it}\boldsymbol{\zeta} + \boldsymbol{\alpha}_i + \boldsymbol{\epsilon}_{it}, \tag{1}$$

where $\mathbf{X}$ is a $(1 \times m)$ vector of interdependent system variables, $\mathbf{Z}$ is a $(1 \times l)$ vector of exogenous covariates, and $\boldsymbol{\alpha}$ is a $(1 \times m)$ vector of time-invariant fixed effects specific to each system variable. $\boldsymbol{\epsilon} \sim \text{IID}\,(\mathbf{0}, \boldsymbol{\Sigma})$ is the vector of idiosyncratic innovations, and the $(m \times m)$ matrices $\boldsymbol{\beta}_1, \ldots, \boldsymbol{\beta}_k$ and $(l \times m)$ matrix $\boldsymbol{\zeta}$ are the coefficients to be estimated.

To reduce dimensionality, our solution approach follows Holtz-Eakin, Newey & Rosen (1988) in assuming that every ith cross-sectional unit shares the same data-generating process, and hence the reduced-form coefficient estimates $\boldsymbol{\beta}_1, \ldots, \boldsymbol{\beta}_k$, and $\boldsymbol{\zeta}$ are common among all N economies.[9]

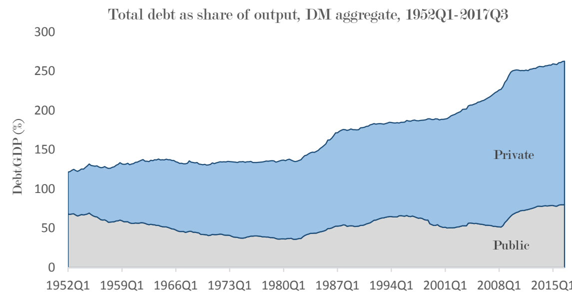
For what follows, we let the two-variable vector of debt (D) and output (Y), represented by $\mathbf{X}^p = [D \;\; Y]$, be our *parsimonious* specification. We populate our *comprehensive* version with the addition of the balance of payments (B) and real exchange rate (Q), so that $\mathbf{X}^c = [D \;\; Y \;\; B \;\; Q]$.[10]

[7] Note that, in constructing the charts, we have chosen to introduce countries into the sample as data become available, which may account for discrete jumps in the aggregate representations shown. Such anomalies do not affect our formal analyses, however, since we allow for country-specific fixed effects.

[8] Taking QoQ changes is most consistent with the timing assumptions implied by our Cholesky-type identification strategy. In robustness checks, we also consider transformations of the data by taking year-on-year (YoY) or deviations from trend.

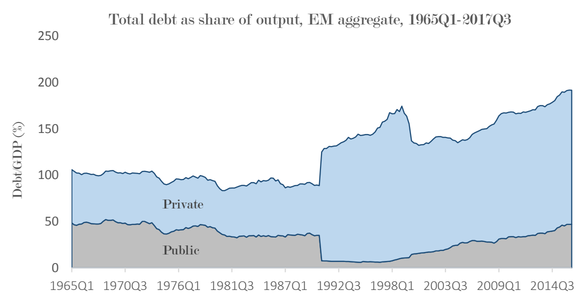
[9] This stands in contrast to the random-coefficient approach, the other commonly-applied estimation methodology for panel VARs, which estimates slope parameters using either classical or Bayesian distributions.

[10] As we discuss in Section 4.1, these variables are subsequently transformed to ensure stationarity. Thus debt and output actually enter in first-differenced form, while the current account and exchange rate enter as trend deviations.



Source: Author's calculations, using BIS (2017).
Notes: Public debt is credit by general government (series Q:...:G:A:N:XDC:A) and private debt is credit to nonfinancial sector from all sectors (series Q:...:P:B:M:770:A), computed at nominal and market value, respectively, adjusted for breaks. Sanple excludes Japan, which is included in the analysis but distorts the visual representation due limited to data availability.

(a) Developed markets



Source: Author's calculations, using BIS (2017).
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(b) Emerging markets

Figure 1: Total debt as share of output, decomposed into public and private shares, for developed (left panel) and emerging (right panel) market economies. Growth in the debt stock, especially for private sector debt, has been steadily rising since the 1990s, with increases among EMs around financial crisis-led recessions in Asia and Latin America, and among DMs around the subprime- and Euro Area-crises. The discrete jumps in the DM and EM charts at 1997Q4, 1990Q4, and 2010Q1 are artifacts of the data, representing the inclusion of Japan, Russia, and Indonesia into the respective aggregates.

3.3 Estimation and identification strategy

Our empirical analysis begins with a number of preliminaries, which we summarize in Section 4.1. These involve assessing variable transformations and checks to ensure stationarity, and absence of longer-run cointegrating or cross-sectionally dependent relationships between the variables. We then proceed with the estimation of the panel VAR using generalized method of moments (GMM), which yields consistent estimates of (1) in the presence of Nickell (1981) bias, so long as $\frac{T}{N} \to c,\ \forall c \leq 2$ (as is the case in our application).[11] To minimize data loss given the unbalanced nature of our panel, panel-specific fixed effects α_i are removed using forward orthogonal deviations rather than first differences. All standard errors are computed such that they are robust to misspecification due to heteroskedasticity.

Our identification of the relationship between output and public debt is an expanded version of the argument first forwarded by Blanchard & Perotti (2002). Discretionary adjustments made to fiscal policy in response to unexpected events require at least a quarter or more before policymakers are able to learn about, decide on fiscal responses, pass relevant legislature, and implement measures, which only then become reflected in aggregate output. Government expenditure or tax revenue (or more simply, the primary balance) is then directly reflected as changes in debt, net of interest payments on past debt—which we assume to be orthogonal to unexpected changes in debt, and hence exogenous.[12] Consequently, unexpected changes in output do not prompt any *immediate* feedback response from the stock of outstanding public debt.

The identification of private sector debt responses follow a similar logic of delayed response. Unanticipated economic activity does not affect contemporaneous accrual of private debt. Here, we appeal to financing frictions faced by firms endured during capital raising (Gilchrist, Sim & Zakrajšek 2014; Gomes 2001), along with standard time-to-build delays incurred when implementin new production plans (Kydland & Prescott 1982; Salomon & Martin 2008). Consequently, changes to a firm's debt liabilities require at least a quarter before it is captured in aggregate output fluctuations.[13] Thus, analogously to public debt, unanticipated output shocks yield no systematic responses from private debt.

Taken together, output is effectively more endogenous than total debt, and treated as such in the innovation variance-covariance matrix $\mathbf{\Sigma}$ used for our estimation of the orthogonalized impulse response functions (IRFs). More formally, innovations in our parsimonious setup follow the structure

$$D_{it} = \psi Y_{it} + \varepsilon^{D}_{it}, \tag{2a}$$

[11]Since differencing introduces serial correlation into the model, our internal instrument list comprises lags of at least one or deeper (for trend deviations), and two or deeper (for first differences), through to four periods.

[12]Importantly, this assumption does *not* imply that interest rates are therefore exogenous; rather, the schedule of interest payments on debt *already incurred* is exogenous.

[13]This serves as a pure private sector-induced delay in responding to changes in macroeconomic conditions, and is a related (but distinct) mechanism from the assumption that the private sector does not respond to monetary policy changes contemporaneously, à la Bernanke & Mihov (1998).

$$Y_{it} = \delta D_{it} + \varepsilon_{it}^{Y}, \tag{2b}$$

where ε^D and ε^Y are mutually uncorrelated structural shocks to be recovered. Given the identification assumptions discussed above, $\psi = 0$, but $\delta \neq 0$; equivalently, this implies that we adopt a recursive identification scheme with a lower-triangular impact matrix. As stressed by Blanchard & Perotti (2002), our identification strategy depends crucially on the fact that the higher-frequency quarterly data effectively eliminates the channel where agents, whether public or private, are able to respond to unanticipated movements in output within the period.

Identification for the remaining two variables in the comprehensive specification is straightforward. We rely on the conventional Cholesky ordering common in the open-economy literature—such as that employed in Ilzetzki, Mendoza & Végh (2013)—that treats the external account as less endogenous than the real exchange rate. Thus, whereas the current account (along with debt and output) affect the exchange rate both contemporaneously as well as with a lag, the exchange rate only affects these variables with a lag. In our robustness checks, we also investigate alternative orderings of these secondary variables.

4 Results

4.1 Preliminaries

We begin by examining a number of temporally-relevant panel properties of the data. In particular, we wish to ascertain that the form of the variables we include in the panel VAR are not only stationary, but also do not exhibit any cointegrating or spatially-dependent relationship among themselves, since imposing a VAR structure in that case would amount to misspecification. In the interest of space, we relegate the details of these preliminary tests to the appendix. Here, we summarize the main findings.

Insofar as stationarity is concerned, the panel unit root tests we run suggest that stationarity tends to be an issue for total debt and real output when entered as either levels or trend deviations. Accordingly, these take on a first-differenced form in our baseline.[14] However, since the current account and exchange rate are stationary in trend deviation form, we adopt this alternative transformation for these latter two variables instead.[15]

In terms of cointegration, while test statistics from a small handful of panel cointegration checks do reject the null of no cointegration, the likelihood of cointegrating relationships is rejected in the large majority of tests. Tests for cross-sectional dependence likewise indicate the absence of (potentially unobservable) spatial interdependencies between countries. We therefore proceed on

[14] Incidentally, this treatment of debt and output as changes, instead of levels, is entirely consistent with their representation in the transition dynamics of standard growth models.

[15] Our decision to consider trend deviations is to minimize the effects of overdifferencing for the purposes of attaining stationarity, since doing so can degrade the quality of the forward projections.

the notion that neither cointegration nor spatial dependency are of sufficient concern for our application.

Our optimal model and moment selection tests used for lag length selection do not yield a perfectly unambiguous result. However, most information criteria support the selection of the first-order panel VAR. Accordingly, we treat this as our baseline, and consider deeper-order panel VARs in our robustness checks.

4.2 Baseline results

Table 1 reports the baseline results for both the parsimonious (top panel) and comprehensive (bottom panel) specifications of the model. As is convention, in the absence of imposing additional structure, we refrain from excess interpretation of the coefficients. However, we do note that the coefficient of the response of growth to (lagged) debt accumulation is negative, although statistically insignificant in the comprehensive model.

Table 1: Baseline estimates for panel VAR, parsimonious and comprehensive models, 1970Q1–2016Q3 (unbalanced)[†]

Response of	*Response to*			
	D_{t-1}	Y_{t-1}	B_{t-1}	Q_{t-1}
	Parsimonious			
D_t	0.304	-0.230		
	(0.04)***	(0.05)***		
Y_t	-0.030	0.259		
	(0.01)**	(0.03)***		
Obs	3,174			
Ctry (Periods)	41 (77)			
	Comprehensive			
D_t	0.286	-0.147	-0.070	0.029
	(0.04)***	(0.06)***	(0.02)***	(0.01)***
Y_t	-0.015	0.339	0.010	-0.006
	(0.02)	(0.04)***	(0.02)	(0.00)*
B_t	-0.044	-0.185	0.779	-0.009
	(0.02)**	(0.04)***	(0.02)***	(0.00)***
Q_t	-0.258	-0.031	0.077	0.934
	(0.05)***	(0.06)	(0.03)**	(0.01)***
Obs	2,559			
Ctry (Periods)	41 (62)			

[†] Panel VAR estimated via GMM, with fixed effects removed via forward orthogonal deviations. Coefficients correspond to the regression of variables in each row on the lagged variables in each column. Reported periods are averages, since the panel is unbalanced. Heteroskedasticity-robust standard errors are given in parentheses, where * indicates significance at the 10 percent level, ** significance at the 5 percent level, and *** significance at the 1 percent level.

We now turn to examining the impulse response functions.[16] These are provided in Figure 2, for a unit standard deviation innovation of D_t on Y_t, and *vice versa* (responses of the variable to its own impulse are omitted).

Our results indicate that the effect of debt on growth is negative: an increase in debt is followed on impact by a decline in growth, which attains a maximum after a quarter, before gradually fading over the course of around a year.[17] This effect is less precisely estimated for the comprehensive model—the error bands larger—and the magnitude of effects smaller. The converse effect of growth on debt, which is also negative, lends further nuance to this result. Clearly, there are two-way effects: more rapid GDP growth also decelerates the buildup of debt. In a sense, this result is less surprising, given its somewhat mechanical nature: *ceteris paribus*, rapid growth tends to lower growth in the debt/GDP ratio, by dint of changes to the denominator. But the result underscores the importance of modeling these mutual feedback effects via a VAR structure.

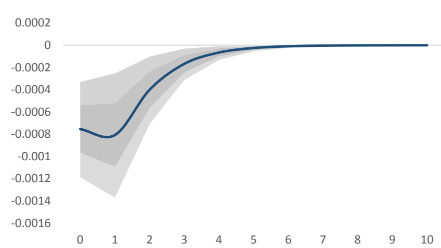
To place this results in context, consider a one-standard deviation positive innovation to debt accumulation in our parsimonious model. In this case, a country that sees a one-off increase in debt accumulation—of 2.2 percentage points faster than the average quarterly growth rate of 0.4 percent—is also liable to see an accompanying decline in its GDP growth rate, amounting to a total of around 0.2 percent, most of which will be realized within a year. Since the mean annualized real growth rate of our sample is 2.9 percent, this amounts to a growth deceleration of around 7 percent. These findings are broadly consistent with the existing literature, which finds that increases in the debt stock give rise to a growth slowdown (Chudik *et al.* 2017; Eberhardt & Presbitero 2015; Jordà *et al.* 2013; Mian *et al.* 2017), although these papers typically focus on the effects of either public or private debt alone.

Since the total effect of any given shock is best understood in terms of its full impact, Figure 3 shows the cumulative orthogonalized impulse responses for each model. What is most striking here is how, once we allow for the additional feedback effects from the current account and exchange rate, the cumulative effects eventually fade away; this results from the incrementally *positive* effects of debt on growth in the comprehensive model, which are evident on closer inspection of Figure 2(b) (the net cumulative effect remains negative, however, even after 20 quarters).

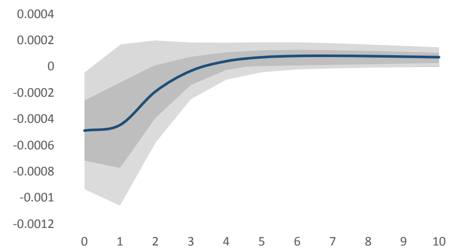
We interpret this diminished effect of debt on growth in the comprehensive model as reflective of the importance of open-economy factors in conditioning the ultimate persistence of any given debt shock. More specifically, an economy that undergoes an acceleration in its total debt burden will experience a persistent effect on its growth performance only if it is not mitigated by adjustments in its external account. This can be verified by examining the response

[16] The moduli of eigenvalues of both fitted models are strictly less than unity, thereby satisfying the stability condition for the invertibility of the respective characteristic polynomials; IRFs therefore admit their standard interpretations. These results are available on request.

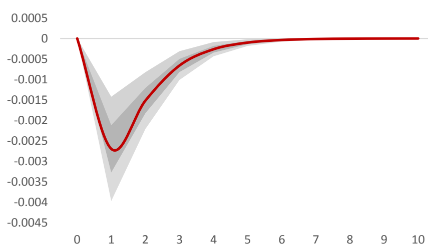
[17] This reversion is also consistent with standard theoretical predictions that imply no steady-state relationship between changes in debt and output along the balanced growth path.



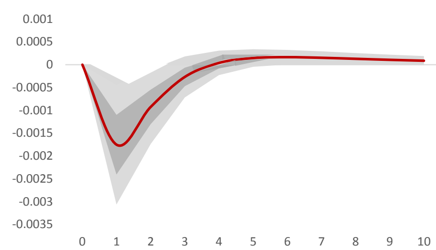
(a) Debt on growth, parsimonious



(b) Debt on growth, comprehensive



(c) Growth on debt, parsimonious



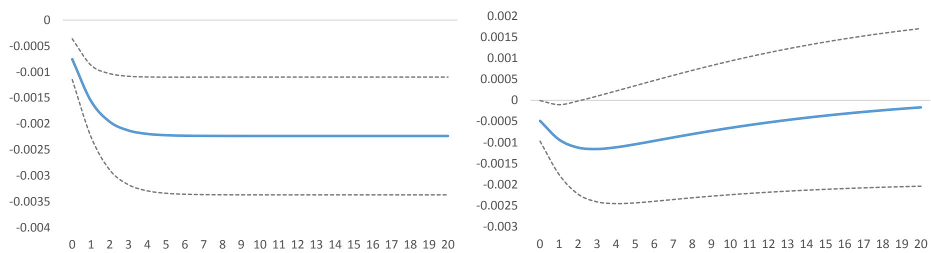
(d) Growth on debt, comprehensive

Figure 2: Orthogonalized impulse response functions for debt on growth (top panel) and growth on debt (bottom panel), for a one standard-deviation innovation in debt and growth, respectively, for 10 quarters after the shock. The dark (light) gray areas indicate the 68 (95) percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. It is evident that in both cases, increases in either debt or growth give rise to a negative response from the other. In both instances, the effect fades after around a year, with peaks in the first quarter after impact.

of the exchange rate and current account in the full impulse response matrix (included in the appendix). After impact, the exchange rate gradually depreciates, reaching a peak after 2 quarters. In the short run, the current account also deteriorates—in line with the J-curve effect—but this reverses as the effects of depreciation begin to operate, and this positive contribution of a balance of payments surplus, which follows after 7 quarters, offsets the growth drag that results from the debt increase.[18]

But taking into account the conditioning effect of the balance of payments goes beyond expressing the effects of a trade-related adjustment mechanism in an open economy. The flip side of the current account is the financial account, and so an alternative interpretation of this result is that the cumulative detri-

[18]This diminishing effect of debt and growth in the longer run may explain why authors working with annual data, such as Panizza & Presbitero (2014), find that the growth effects of debt disappear after accounting for endogeneity.



(a) Debt on growth (cumulative), parsimonious (b) Debt on growth (cumulative), comprehensive

Figure 3: Cumulative orthogonalized impulse response functions for debt on growth for the parsimonious (left panel) and comprehensive (right panel) models, for a one standard-deviation innovation in debt, for 20 quarters after the shock. The gray dark dashed lines indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The cumulative effects appear to fade away for the full model, in contrast to the parsimonious specification.

mental effect of debt accumulation on growth can be offset if an economy runs a substantial excess of national saving over investment. This is essentially the story of high-surplus export-oriented economies, as exemplified by the newly-industrialized economies in East Asia (and most recently, China).

The modest effects of debt on growth is further corroborated by variance decompositions, which are shown in Table 2. The 10-period-ahead response of growth to innovations in debt is just shy of 1 percent (in the parsimonious model) and as low as 0.3 percent (in the comprehensive one). By and large, the significant majority of the dynamics displayed by each macro variable continues to be explained by its own autoregressive contribution. In addition, the meaningful amount of variation in debt explained by changes in the exchange rate—around 2 percent—likewise points to the moderating effects of the external sector, as mentioned previously.[19] In sum, the effects of an increase in debt accumulation on output growth are nontrivial, but relatively limited, and tend to be eroded over time.

4.3 Robustness of the baseline

We are now in a position to examine the overall robustness of the baseline result. We focus here on only our main relationship of interest—the effect of a debt accumulation impulse on growth—and mention alternative results only where relevant.[20] Unless not applicable, we include both IRFs from the parsimonious

[19]Variations in the exchange rate attributable to debt are even larger, close to 12 percent.

[20]For completeness (and because they are potentially of independent interest), we include the full matrix of IRFs for higher-order panel VARs in the appendix. The IRF matrices for the remainder of the robustness checks discussed in this subsection are available on request.

Table 2: Variance decompositions for the baseline panel VAR, parsimonious and comprehensive models, 1970Q1–2016Q3 (unbalanced)†

Response of	*Response to*					
	Parsimonious		**Comprehensive**			
	D_t	Y_t	D_t	Y_t	B_t	Q_t
Y_{t+10}	0.009	0.991	0.003	0.993	0.001	0.003
D_{t+10}	0.979	0.021	0.960	0.008	0.011	0.021
B_{t+10}			0.004	0.030	0.959	0.007
Q_{t+10}			0.115	0.004	0.006	0.875

† Share of forecast error variance for predicted variables 10 periods ahead in each row explained by innovations of variables in each column.

and comprehensive models. We proceed with three classes of checks: (a) the inclusion of exogenous variables for the vector **Z** into the baseline models; (b) the use of alternative measures for our endogenous variables; and (c) changes to the temporal treatment of the models.

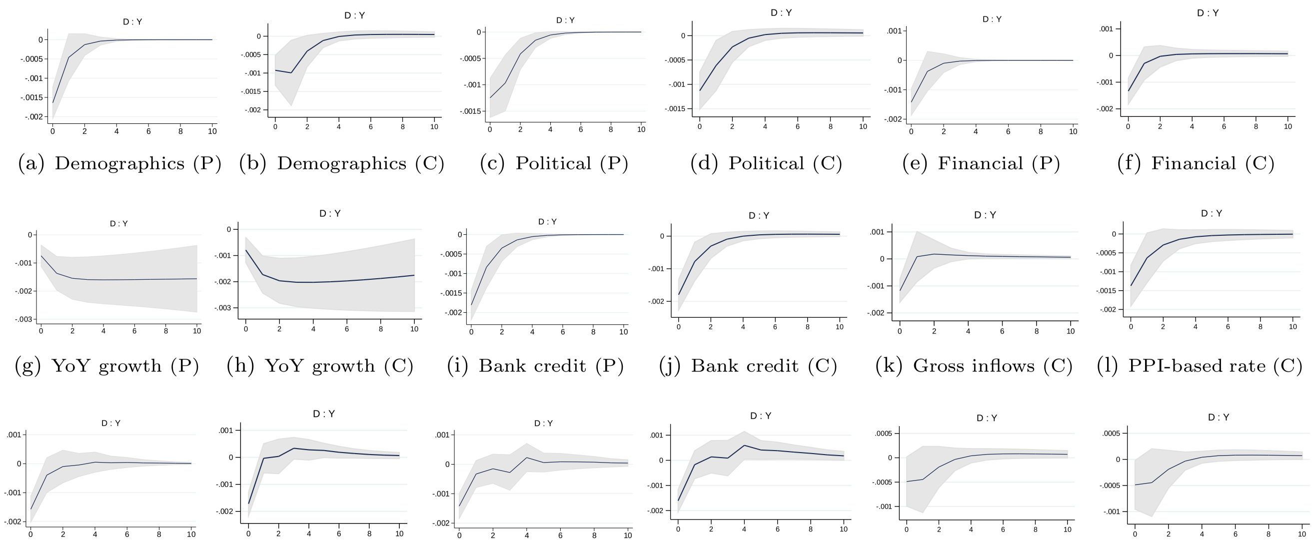
Impulse responses for first set of checks are presented in the top row of Figure 4. These further condition the panel VAR with the exogenous effects of demographics, political risk, and financial development (which we distinguish from debt, *per se*).[21,22] On balance, including exogenous controls does not substantially alter the effects of debt on growth. If anything, even while the overall dynamics of output in response to a debt shock remain very close to the baseline, the magnitudes of the contractions are larger in virtually all cases.

We next consider a range of alternative measures for our endogenous variables. Given the relative importance of debt, we introduce two different variations: debt calculated as the year-on-year change in total debt, and debt with the private component computed as credit extended by banks alone (rather than across all financial sectors).[23] We next substitute the balance of payments with gross financial (portfolio and FDI) inflows, which offers an external account measure that better approximates the effects of capital flows. For the real exchange rate, we replace the baseline REER, which is deflated with the consumer

[21] We capture demographics with the dependency ratio (of young and aged to the working-age population), political risk with a weighted, subjective index of political-economic risk ratings based on factors such as government stability, corruption, ethno-religious tensions, and law and order, and financial development with the equity market capitalization of listed corporations (as a share of output).

[22] Our measure of financial market development does *not* rely on domestic credit to the private sector (a more commonly-employed proxy for financial depth) because of its close relationship to private debt. Our choice of stock market capitalization is motivated by the fact that the correlation between capitalization and either total debt or private debt is very low ($\rho = 0.21$ and 0.26, respectively).

[23] The difference between credit from all sectors and from banks is credit by the nonbank financial sector, commonly referred to as shadow bank lending.



(a) Demographics (P) (b) Demographics (C) (c) Political (P) (d) Political (C) (e) Financial (P) (f) Financial (C)

(g) YoY growth (P) (h) YoY growth (C) (i) Bank credit (P) (j) Bank credit (C) (k) Gross inflows (C) (l) PPI-based rate (C)

(m) VAR(2) (P) (n) VAR(2) (C) (o) VAR(4) (P) (p) VAR(4) (C) (q) Switched order (C) (r) Between order (C)

Figure 4: Orthogonalized impulse response functions for debt on growth for the parsimonious (P) and comprehensive (C) models with the inclusion of exogenous variables (top row), alternative variable choices (middle row), and different temporal assumptions (bottom row), for a one standard-deviation innovation in debt, for 10 quarters after the shock. The light gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The overall dynamics of growth in response to a debt shock are similar to those in the baseline, although the dynamics in a few instances differ.

price index (CPI), with a version deflated by the producer price index (PPI).[24] Finally, we impose different transformations: trend deviations for GDP and total debt, and first differences for the balance of payments and real exchange rate.[25] The results are summarized in second row of Figure 4.

The main takeaway from these changes is that changes in debt retain their negative relationship with growth. In all instances, positive debt impulses are followed by declines in output. In most cases, the decline is greatest on impact or within the first quarter, as it was in the baseline, with the effects fading within the year. Notably, however, this effect does *not* dissipate when debt is measured in a YoY fashion, nor in the case when debt and growth are measured as trend deviations. For technical reasons alluded to earlier,[26] however, we are cautious about overinterpreting this result, and simply note that the overall negative relationship remains robust to this suite of alternative measures.

The first of our final set of tests increases the lag count to higher-order VAR(2) and VAR(4) systems.[27] Next, we alter the ordering of the secondary variables, but in a manner that does not affect the timing inherent in our identification strategy: we either switch the real exchange rate and allow it to be more exogenous than the current account, or we place the real exchange rate between debt and growth.

We summarize the responses of these temporal sensitivity tests in the bottom row of Figure 4. While our main qualitative results are unchanged, we offer two additional remarks concerning the effects of a different VAR order. First, the *cumulative* effects of debt on growth tend to weaken as the number of lags increases; this is especially the case for the comprehensive model, as evidenced by Figure 4(p), which shows the growth response remaining positive for a substantial time from the fourth quarter onward. Second, the corresponding dynamics in a panel VAR(4) specification are also less smooth; indeed, there is a sharp kink in either model in the third quarter following the shock, which actually goes some way toward offseting the initial negative impulse.

Lastly, we consider a number of alternative estimators that allow us to relax the assumptions of no cointegration or spatial dependency.[28] In particular, we

[24]Arguably, a PPI-based REER measure is more sensitive to changes in the exchange rate, since the CPI basket is more likely to include less-tradable goods and services, such as owners' equivalent rent.

[25]For economy, we report the IRFs corresponding to these final two modifications in the appendix.

[26]In particular, the YoY measure is not well-suited to our identification strategy premised on quarter-to-quarter changes in debt in response to output. The ambiguous stationarity properties of the trend deviations for debt and output are also potentially problematic for a VAR setting, although if the objective is to understand interrelationships between variables rather than obtain parameter estimates, variable nonstationarity may be less of a concern than overdifferencing (Sims, Stock & Watson 1990).

[27]Other than the majority of the tests—which favor the VAR(1)—the other lag specifications identified are the VAR(2) and VAR(4) for the parsimonious model (by R^2 and AIC, respectively) and VAR(3) for the comprehensive model (by AIC). We chose to report the VAR(2) because the IRFs for the VAR(3) appear to be averages of the VAR(2) and VAR(4) outcomes; the greater contrast offered by the VAR(2) therefore favors its inclusion here.

[28]Recall, our baseline is premised on the fact that tests for both cointegration and cross-sectional dependence indicate that these are statistically inconsequential. The models esti-

estimate a number of dynamic heterogeneous panel models that cater for the possibility of such relationships, which we summarize in Table 3.

More specifically, we accommodate the possibility of a long-run cointegrating relationship between debt and growth by considering panel error-correction models (ECMs) of the form

$$\Delta Y_{it} = \sum_{j=1}^{k} \delta_{ij} \Delta Y_{i,t-j} + \sum_{j=1}^{k} \Delta \mathbf{X}'_{i,t-j} \boldsymbol{\beta}_j + \phi_i \left(Y_{i,t-1} - \tilde{\mathbf{X}}'_{it} \boldsymbol{\theta}_i \right) + \alpha_i + \epsilon_{it}, \quad (3)$$

where Y is output, and $\tilde{\mathbf{X}}$ is the $(1 \times (n-1))$ vector of endogenous variables *excluding* output. $\phi \geq 0$, commonly known as the error-correction parameter, captures the speed of adjustment to the long-run relationship, α is a country fixed effect, and δ, $\boldsymbol{\beta}$, and $\boldsymbol{\theta}$ are additional coefficients to be estimated. ϵ is an error term that, in the first instance, we assume to be spatially independent. $\tilde{\mathbf{X}}^p = [D]$ then mimics our parsimonious specification, and $\tilde{\mathbf{X}}^c = [D \;\; B \;\; Q]$ is analogous to the comprehensive specification. For consistency with our baseline, we maintain just one lag, $k = 1$.

We report two alternative panel ECM specifications: a dynamic fixed effect model with Nickell (1981) bias-corrected estimators—which imposes the most restrictions on parameters—and a mean group model (Pesaran & Smith 1995), which imposes the least.[29] In each case, we consider both parsimonious and comprehensive versions; the results are given in the first four columns of the table.

The next two sets of specifications relaxes the spatial independence assumption for the error term by allowing $\operatorname{cov}(\epsilon_{it}, \epsilon_{jt}) \neq 0$ for some $i \neq j$ and t. We first impose an error-correction structure on fixed-effect estimates corrected for spatial correlation (Driscoll & Kraay 1998),[30] before running models with dynamic common correlated effects (Chudik & Pesaran 2015), which addresses spatial dependency within a very heterogeneous error structure (and is the most general among the estimators we consider here). These results constitute the final four columns.

A few takeaways are in order. Across all the specifications considered, the shorter-run effects of debt are systematically negative, albeit not always statistically significant (they are in half the specifications). The longer-run effects of debt are also mixed; although by and large, the coefficients—while sometimes much larger in magnitude—are insignificant. Overall, even after accounting for

mated here are therefore potentially misspecified, although they are still potentially useful robustness checks.

[29]Specifically, the former pools all time-series data for each country, allowing only the intercepts to differ, while the latter allows intercepts, slope coefficients, and error variances to vary. We also obtained intermediate pooled mean group (Pesaran, Shin & Smith 1999) estimates, which yielded very similar results; these are available on request.

[30]By including the lagged dependent variable into the specification, we introduce the possibility that the estimated coefficients suffer from Nickell (1981) bias. That said, any such bias is likely to be limited since our temporal dimension is relatively long, and the estimator is consistent as $T \to \infty$.

Table 3: Robustness results for dynamic heterogeneous panels, parsimonious and comprehensive models, 1970Q1–2016Q3 (unbalanced)†

	Potential cointegration				*Potential spatial dependency*			
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
				Short-run				
ΔY_{t-1}	0.171	0.172	-0.020	-0.038	0.163	0.160		
	(0.02)***	(0.02)***	(0.01)***	(0.01)***	(0.06)***	(0.07)**		
ΔD_t	-0.049	-0.024	-0.121	-0.100	-0.049	-0.026	-0.044	-0.038
	(0.08)	(0.07)	(0.02)***	(0.02)***	(0.04)	(0.04)	(0.01)***	(0.02)**
ΔB_t		0.022		-0.055		-0.022		0.001
		(0.08)		(0.04)		(0.05)		(0.03)
ΔQ_t		0.029		-0.027		0.028		-0.024
		(0.04)		(0.02)		(0.01)		(0.02)
				Long-run				
Y_{t-1}	0.000	-0.004		-0.038	-0.003	-0.008	-0.006	-0.015
	(0.01)	(0.01)		(0.01)***	(0.00)*	(0.00)**	(0.00)	(0.01)**
D_t	-0.004	-0.005	4.660	4.188	-0.004	-0.005	0.522	2.469
	(0.01)	(0.01)	(5.44)	(2.11)**	(0.00)	(0.00)	(1.79)	(3.68)
B_t		0.024		-0.890		0.025		-26.706
		(0.04)		(7.13)		(0.01)**		(28.66)
Q_t		0.003		9.751		0.003		-86.580
		(0.01)		(7.55)		(0.01)***		(83.11)
Estimator	DFE-C	DFE-C	MG	MG	SCC	SCC	DCCE	DCCE
Model	Pars.	Comp.	Pars.	Comp.	Pars.	Comp.	Pars.	Comp.
R^2	0.03	0.04			0.03	0.06	0.25	0.33
Obs	3,244	2,618	3,256	2,625	3,244	2,618	3,256	2,625
Ctry (Periods)	41 (79)	41 (63)	41 (79)	41 (64)	41 (79)	41 (63)	41 (79)	41 (64)

† The dependent variable is the GDP growth rate. Dynamic heterogeneous panel methods reported in the first row of the lower panel, corresponding to biased-corrected dynamic fixed effects (DFE-C), mean group (MG), spatial correlation-consistent (SCC), and dynamic common correlated (DCCE) estimators. DFE-C estimates are initialized with the Anderson-Hsiao estimator and corrected to order $O(1/NT)$. Within goodness of fit (adjusted R^2) reported where available. Reported periods are averages, since the panel is unbalanced. A homogeneous constant was included in all specifications, but not reported. Standard errors are given in parentheses, and are bootstrapped over 200 simulations (DFE-C), Driscoll-Kraay spatial dependency, heteroskedasticity, and autocorrelation-corrected standard errors (SCC). * indicates significance at the 10 percent level, ** significance at the 5 percent level, and *** significance at the 1 percent level.

the possibility of cointegrating relationships and spatial dependency, the message of a negative effect of debt accumulation on output growth remains, along with the tendency for these effects to dissipate in the longer run.

4.4 Identification concerns

To gain additional perspective into the (temporally) causal nature of our results, we report panel Granger (non)causality tests for each model for growth on debt, and *vice versa*, in Table 4. The top and middle panels report standard Granger tests for panel VARs with variables in the first differenced and trend deviation forms, respectively. The bottom panel reports tests for variables in levels, following the Toda & Yamamoto (1995) procedure, which yields results robust to the presence of nonstationarity.

Table 4: Panel Granger causality tests, parsimonious and comprehensive models†

	$Y_{t-1} \to D_t$	$\tilde{\mathbf{X}}_{t-1} \to D_t$	$D_{t-1} \to Y_t$	$\tilde{\mathbf{X}}_{t-1} \to Y_t$
		First differences		
Parsimonious	16.107^{***}		3.944^{**}	
Complete	7.595^{***}	20.744^{***}	0.855	4.663
		Trend deviations		
Parsimonious	25.953^{***}		1.827	
Complete	27.545^{***}	32.739^{***}	3.627^{*}	5.469
		Log levels		
Parsimonious	26.610^{***}		0.600	
Complete	5.190		2.990	

† The null hypothesis is that the excluded variable(s) (on the left) does not Granger-cause the dependent variable (on the right). $\tilde{\mathbf{X}}_t$ represents all other endogenous variables in the complete specification. The Granger causality test reports the Wald χ^2 statistic for the coefficients of all lags of non-excluded variables jointly being zero, with the exception of the log levels, where only the first 3 lags are considered. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

As can be seen, the results almost uniformly indicate that lagged effects of growth (Granger)-causes debt accumulation in either model, while the lagged effects of changes in debt—as well as the totality of the other endogenous variables in the comprehensive model—has no Granger-causal effect on growth, with the exception of the parsimonious model in first-differenced form.[31] This implies that growth shocks induce contemporaneous shifts in debt stocks, whereas changes in debt will only affect future changes in output: a result that indirectly

[31] This ambiguity in a two-equation setting could be the reason behind why others, such as Lof & Malinen (2014), have struggled to establish any robust effects of debt on growth.

supports the error structure we impose on (2), and our implied causal ordering that places output before debt.

While the presence of a (Granger) influence of debt on output (in the parsimonious model) may lead one to question the credibility of our identification strategy, it is useful to keep in mind two mitigating factors. Most importantly, Granger causality from debt changes to growth fails to hold in all other specifications, at least at conventional levels of significance. Furthermore, it is useful to recall that the simple presence of a lagged effect is neither necessary nor sufficient to claim genuine causality. This is because our identification argument relies on responses to *unplanned* innovations in output; in contrast, the Granger (non)causality tests only establish whether lagged changes in the debt stock—which includes both anticipated (interest payments, planned spending) and unanticipated (true fiscal and investment innovations) components—help predict growth outcomes (beyond lagged growth alone). Overall, however, the results essentially corroborate the theoretical arguments made concerning the exclusion restriction.

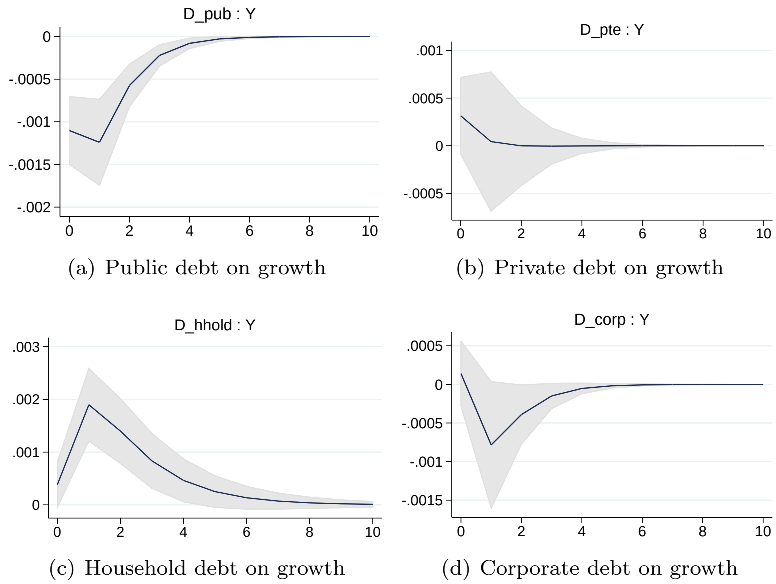
5 Discussion

5.1 China's debt experience

It is instructive to consider our findings in the context of China. In the two decades between 1996 and 2016, the total debt stock in the economy more than doubled, rising from around 107 percent of GDP to in excess of 250 percent. Perhaps more alarming, the rate of debt accumulation also doubled, from an average rate of 0.6 to 1.5 percent (QoQ). The rapid growth of Chinese debt has evoked much consternation among observers, who rightly note that such a debt burden is unprecedented in the country's modern history.

In light of our baseline results, such rapid debt buildup certainly invites caution. However, it is also worthwhile probing into whether the *nature* of debt matters, especially given the focus of many observers on private debt in particular (see, for example, Coulton, Fennell & Darmet (2018) and International Monetary Fund (2017)). To this effect, the top row of Figure 5 produces the IRFs for each type of debt on growth, while the bottom row further decomposes private debt into household and corporate components. On the basis of this set of IRFs, it is clear that the negative effect of debt on growth is driven by public debt accumulation. Private debt impulses actually generate a positive—albeit insignificant—growth outcome. This positive growth effect of private debt is attributable to household debt, however, while corporate debt accumulation remains detrimental.

Does this contradict the claim by authors, such as Jordà *et al.* (2013) and Schularick & Taylor (2012), that private debt overhang induces slower growth? Not necessarily. The slower post-recession growth demonstrated in these papers are *relative* to a no-crisis counterfactual; this could well hold in our data as well. Instead, our claim here is simply that *absolute* output growth is little



(a) Public debt on growth

(b) Private debt on growth

(c) Household debt on growth

(d) Corporate debt on growth

Figure 5: Orthogonalized impulse response functions for various subcomponents of debt on growth for the parsimonious model, for a one standard-deviation innovation in debt, for 10 quarters after the shock. The light gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The negative effect of debt on growth is driven by public debt accumulation, whereas private debt impulses generate a positive (but insignificant) growth outcome. The positive effect of private debt on growth is attributable to household debt, with corporate debt accumulation remaining detrimental.

threatened by private debt accumulation. More importantly, Jordà *et al.* (2013) also find that when treated in tandem, public debt conditions the post-recession path of output, and economies with large holdings of public debt do grow more slowly.[32] In this regard, their results underscore important conditioning role of public debt growth, just as we do.

In China's case, much of recent debt growth has been private-sector buildup, with public debt remaining significantly below shares routinely observed in developed markets (the public-to-private debt ratio for China in 2016 was 82—versus 18 percent across all DMs—and public debt only amounted to 46 percent of GDP in 2016). If it is public and not private debt booms that give rise to growth slowdowns, defenders of China's recent debt trajectory may point to this fact as a mitigating factor. But this claim appears premature. In contrast

[32] Jordà *et al.* (2013) also find that the counterfactuals they find are mostly applicable to post-financial crisis recessions, and their various output paths for regular contractions are largely indistinguishable.

to other economies, the pattern of total debt growth in China has historically been much more reflective of private credit growth (Figure 6); to the extent that it is total debt that matters, China's rapid private debt expansion may well still prejudice its growth prospects. Furthermore, it is corporate debt that underlies China's private debt expansion, and since the growth of firm debt is unambiguously negative for growth, continued expansion in this component of the private debt will further subtract from GDP performance.[33] Finally, it is worth keeping in mind that Japanese government debt, up till the eve of its crisis in 1991, remained very manageable (around 68 percent of GDP), and only increased to its current levels following a lost decade of economic growth.

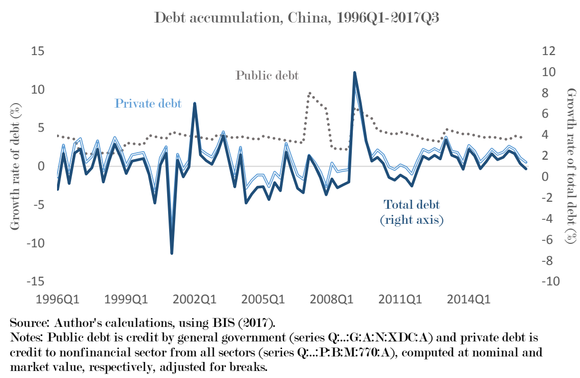


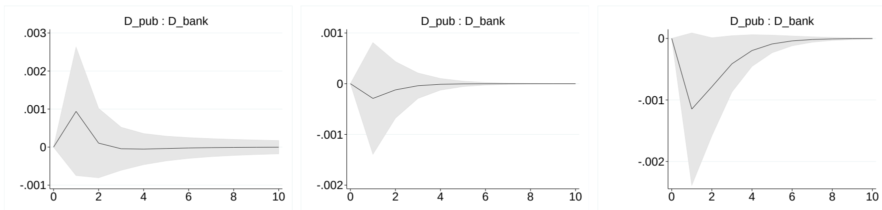
Figure 6: Chinese debt accumulation dynamics, decomposed into public and private rates. The growth rate of total debt for the period 1996Q1–2006Q4 averaged 0.6% QoQ, compared to 1.5% between 2007Q1–2016Q3. In contrast to other economies, total debt growth in the economy has historically reflected changes in private rather than public sector debt.

5.2 Europe's toxic bank-sovereign debt loop

The tight relationship between public and private debt is by no means limited to China. Indeed, analysts following the European debt crisis of 2009 have remarked on how debt interdependence between banks and their sovereigns played a central role in perpetuating the crisis (Brunnermeier *et al.* 2016; Farhi & Tirole 2018; Lane 2012). While empirical papers examining this phenomenon are beginning to emerge (Acharya & Steffen 2015; Altavilla, Pagano & Simonelli 2017; Bocola 2016; Gennaiola *et al.* 2014; Popov & Van Horen 2015), the overall evidence base remains small. We offer some additional insight into this issue by taking advantage of our VAR setup, which inherently captures the effects of cross-variable feedback. Our analysis begins by separating out the total debt

[33] In the appendix, we apply our model to explore, via simulations, how different debt accumulation paths may potentially affect China's future growth rate.

stock into public and private bank-financed components, followed by examining the IRFs for a public debt impulse on private debt issued by banks. The results are shown in Figure 7.[34]



(a) Euro Area (b) All DMs (c) All countries

Figure 7: Orthogonalized impulse response functions for public debt on private bank debt for the parsimonious model, for a one standard-deviation innovation in debt, for 10 quarters after the shock. The light gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. An increase in the rate of public debt issuance gives rise to faster accumulation of bank debt in the Euro Area, a result that does not hold either in the broader subsample of all DMs, or the full sample of all countries (where the effects tend in the opposite direction).

For the Euro Area, we find evidence in favor of the doom loop hypothesis. Figure 7(a) shows that an increase in public debt issuance is, among Euro Area economies, accompanied by a concomitant increase in private bank debt (although this shock is not statistically significant at 95 percent confidence, it is at the 68 percent level). Akin to our other debt shocks, this effect is short-lived, and fades within the year. What is remarkable about this result is that it neither holds for the broader sample of all DMs (Figure 7(b)), nor for the full sample of all countries (Figure 7(c)); in fact, the evidence for the latter is that the effects of public debt expansion tend to give rise to the *opposite* outcome (a crowding out of bank debt). This suggests that the sovereign-bank doom loops are essentially a European phenomenon, which are probably best understood in the context of the region's unique institutional features, such as the Fiscal Compact and TARGET2 settlement system.[35]

5.3 Debt transmission channels after the global crisis

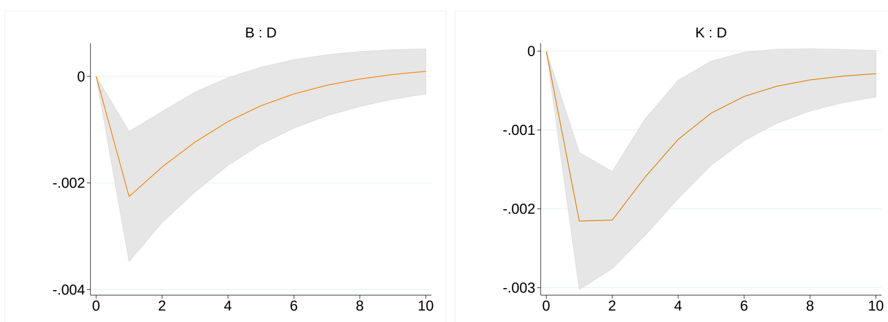
One important feature of the post-2008 global financial landscape has been the persistence of leverage, even in the wake of a massive leverage-driven crisis

[34] We report the parsimonious model with bank debt ordered before public debt. Alternative specifications, either with the comprehensive model or with the alternative ordering of the debt variables, do not generate very different results, and are detailed in the annex.

[35] The role of these institutional elements in driving bank-sovereign diabolical loops has been discussed elsewhere at length; see, *inter alia*, Campos & Sturm (2018).

(Dobbs, Lund, Woetzel & Mutafchieva 2015). This is evident in Figure 1: after 2008, total debt continues to accumulate, with an acceleration in public (private) debt growth among DMs (EMs). The specific transmission channels by which debt has expanded, however, remain unclear; while some have suggested that capital flows into emerging markets—led by the adoption of unconventional monetary policies by G4 central banks—may be responsible (Ahmed & Zlate 2014; Lim & Mohapatra 2016), others have sought to pose debt uptake as a function of responses to the post-crisis collapse in international trade (Aizenman & Jinjarak 2012; Baldwin & Evenett 2009). Which transmission channel came to be more relevant, however, remains uncertain.

We dig a little deeper into this issue by comparing the IRFs for the comprehensive model when we utilize different proxies for the external account. As discussed in Section 4.2, the external account plays an important role in mitigating the permanence of a debt shock on growth. By substituting gross capital inflows—which we regard as more consistent with a financial-side transmission channel—for the trade balance (which instead primarily captures real-side effects due to trade flows), we can examine how total debt responds to impulses in either of these measures, and determine whether one channel might be more operative (or not). To ensure relevance for the post-crisis period, we restrict the sample to data from 2008 onward.



(a) Real (trade balance)

(b) Financial (gross inflows)

Figure 8: Orthogonalized impulse response functions for the external account on debt for the comprehensive model when using the trade balance (left) or financial inflows (right) during 2008Q1–2016Q3, for a one standard-deviation innovation in debt, for 10 quarters after the shock. The light gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

The outcome of this exercise is given in Figure 8. In both cases, either a positive real (a trade surplus) or financial (increased capital inflows) shock leads to a reduction in total debt growth. The magnitudes of the declines are also comparable, consistent with the fact that both a constrained according to the balance of payments identity. However, the effects of changes in capital flows appears to be more persistent. After attaining troughs over two quarters, it never fully dissipates, unlike the case of trade flows. This result is not exactly replicated in our full sample (reported in the appendix); instead, the magnitudes of both the responses are smaller (by about half), and the response of debt to the financial channel is also more volatile and less persistent. Taken together, this set of results suggests that capital flows played a more important role in debt accumulation after the crisis, as might be expected from a major financial shock.

6 Conclusion

In this paper, we establish a negative relationship between the rate of total debt accumulation and economic growth. In particular, we find that debt impulses generate a small but negative growth effect, which tends to dissipate over time, especially in an open-economy setting. Beyond academic interest, our findings are also relevant to current debates over China's debt trajectory, the Euro Area sovereign-bank doom loop, and the absence of deleveraging in the post-crisis period.

As is standard for VAR analyses, the results we obtain may be sensitive to misspecification concerns. We have shown in Section 4.3 that our results survive a very rich set of perturbations, but one aspect in particular may warrant further attention: the need to examine the stability of long-run effects of leverage extension on economic performance. While we have taken a meaningful stab at the question in the results reported in Table 3, we believe that a dedicated analysis—which carefully distinguishes between sustainable financial development and unsustainable debt buildups—would be valuable. So would studies that better differentiate between domestic and external creditors. We leave such an endeavors to future research.

References

Acharya, Viral V. & Sascha Steffen (2015). "The 'Greatest' Carry Trade Ever? Understanding Eurozone Bank Risks". *Journal of Financial Economics* 115(2) (February): 215–236

Ahmed, Shaghil & Andrei Zlate (2014). "Capital Flows to Emerging Market Economies: A Brave New World?" *Journal of International Money and Finance* 48(B) (November): 221–248

Aizenman, Joshua & Yothin Jinjarak (2012). "The Fiscal Stimulus of 2009–10: Trade Openness, Fiscal Space and Exchange Rate Adjustment". In Jeffrey A. Frankel & Christopher A. Pissarides (editors), *NBER International Seminar on Macroeconomics*, pp. 301–342. Chicago, IL: University of Chicago Press

Altavilla, Carlo, Marco Pagano & Saverio Simonelli (2017). "Bank Exposures and Sovereign Stress Transmission". *Review of Finance* 21(6) (October): 2103–2139

Andrews, Donald W.K. & Biao Lu (2001). "Consistent Model and Moment Selection Procedures for GMM Estimation with Application to Dynamic Panel Data Models". *Journal of Econometrics* 101(1) (March): 123–164

Arcand, Jean Louis, Enrico Berkes & Ugo G. Panizza (2015). "Too Much Finance?" *Journal of Economic Growth* 20(2) (June): 105–148

Arčabić, Vladimir, Josip Tica, Junsoo Lee & Robert J. Sonora (2018). "Public Debt and Economic Growth Conundrum: Nonlinearity and Inter-temporal Relationship". *Studies in Nonlinear Dynamics & Econometrics* 22(1) (February): 1–20

Baldwin, Richard E. & Simon J. Evenett (editors) (2009). *The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20.* London, England: Centre for Economic Policy Research Press

Barclay, MichaelJ., CliffordW. Smith, Jr. & Erwan Morellec (2006). "On the Debt Capacity of Growth Options". *Journal of Business* 79(1) (January): 37–60

Barges, Alexander (1968). "Growth Rates and Debt Capacity". *Financial Analysts Journal* 24(1) (Jan–Feb): 100–104

Barro, Robert J. (1974). "Are Government Bonds Net Wealth?" *Journal of Political Economy* 82(6) (November): 1095–1117

Bernanke, Ben S. & Ilian Mihov (1998). "Measuring Monetary Policy". *Quarterly Journal of Economics* 113(3) (August): 869–902

Bernardini, Marco & Lorenzo Forni (2017). "Public and Private Debt: Are Emerging Markets at Risk?" *IMF Working Paper* WP/17/61, Washington, DC: International Monetary Fund

Bi, Huixin (2012). "Sovereign Default Risk Premia, Fiscal Limits, and Fiscal Policy". *European Economic Review* 56(3) (April): 389–410

Bindseil, Ulrich & Adalbert Winkler (2013). "Dual Liquidity Crises—A Financial Accounts Framework". *Review of International Economics* 21(1) (February): 151–163

Blanchard, Olivier J. (1985). "Debt, Deficits, and Finite Horizons". *Journal of Political Economy* 93(2) (April): 223–247

Blanchard, Olivier J. & Stanley Fischer (1989). *Lectures on Macroeconomics.* Cambridge, MA: MIT Press

Blanchard, Olivier J. & Roberto Perotti (2002). "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output". *Quarterly Journal of Economics* 117(4) (November): 1329–1368

Bocola, Luigi (2016). "The Pass-Through of Sovereign Risk". *Journal of Political Economy* 124(4) (August): 879–926

Broner, Fernando A., J. Aitor Erce, Alberto Martin & Jaume Ventura (2014). "Sovereign Debt Markets in Turbulent Times: Creditor Discrimination and Crowding-Out Effects". *Journal of Monetary Economics* 61(1) (January): 114–142

Brunnermeier, Markus K., Luis Garicano, Philip R. Lane, Marco Pagano, Ricardo A.M.R. Reis, Tano Santos, David Thesmar, Stijn G. Van Nieuwerburgh & Dimitri Vayanos (2016). "The Sovereign-Bank Diabolic Loop and ESBies". *American Economic Review* 106(5) (May): 508–512

Caballero, Ricardo J., Takeo Hoshi & Anil K. Kashyap (2008). "Zombie Lending and Depressed Restructuring in Japan". *American Economic Review* 98(5) (December): 1943–1977

Campos, Nauro F. & Jan-Egbert Sturm (editors) (2018). *Bretton Woods, Brussels, and Beyond: Redesigning the Institutions of Europe.* London, England: CEPR Press

Cecchetti, Stephen G., Madhusudan S. Mohanty & Fabrizio Zampolli (2011). “Achieving Growth Amid Fiscal Imbalances: The Real Effects of Debt”. In *Proceedings of the Economic Policy Symposium*, pp. 145–196. Jackson Hole, WY: Federal Reserve Bank of Kansas City

Cheng, Jin, Meixing Dai & Frédéric Dufourt (2017). “Banking and Sovereign Debt Crises in a Monetary Union Without Central Bank Intervention”. *Journal of Mathematical Economics* 68(1) (January): 142–151

Choi, In (2001). “Unit Root Tests for Panel Data”. *Journal of International Money and Finance* 20(2) (April): 249–272

Chudik, Alexander, Kamiar Mohaddes, M. Hashem Pesaran & Mehdi Raissi (2017). “Is There a Debt-Threshold Effect on Output Growth?” *Review of Economics and Statistics* 99(1) (March): 135–150

Chudik, Alexander & M. Hashem Pesaran (2015). “Common Correlated Effects Estimation of Heterogeneous Dynamic Panel Data Models with Weakly Exogenous Regressors”. *Journal of Econometrics* 188(2) (October): 393–420

Coulton, Brian, Andrew Fennell & Maxime Darmet (2018). *China: Deleveraging Would Mean Slower Growth*. Hong Kong, China: Fitch Ratings

Crosignani, Matteo (2017). “Why Are Banks Not Recapitalized During Crises?” *Finance and Economics Discussion Paper* 2017–08, Washington, DC: Board of Governors of the Federal Reserve System

De Vita, Glauco, Emmanouil Trachanas & Yun Luo (2018). “Revisiting the Bi-Directional Causality Between Debt and Growth: Evidence from Linear and Nonlinear Tests”. *Journal of International Money and Finance* 83(1) (May): 55–74

Denes, Matthew R., Gauti B. Eggertsson & Sophia Gilbukh (2013). “Deficits, Public Debt Dynamics and Tax and Spending Multipliers”. *Economic Journal* 123(566) (February): F133–F163

Denis, David J. & Vassil T. Mihov (2003). “The Choice Among Bank Debt, Non-Nank Private Debt, and Public Debt: Evidence from New Corporate Borrowings”. *Journal of Financial Economics* 70(1) (October): 3–28

Diamond, Peter A. (1965). “National Debt in a Neoclassical Growth Model”. *American Economic Review* 55(5) (December): 1126–1150

Dobbs, Richard, Susan Lund, Jonathan Woetzel & Mina Mutafchieva (2015). *Debt and (Not Much) Deleveraging*. Washington, DC: McKinsey Global Institute

Drehmann, Mathias & J. Mikael Juselius (2014). “Evaluating Early Warning Indicators of Banking Crises: Satisfying Policy Requirements”. *International Journal of Forecasting* 30(3) (July–September): 759–780

Driscoll, John C. & Aart C. Kraay (1998). “Consistent Covariance Matrix Estimation With Spatially Dependent Panel Data”. *Review of Economics and Statistics* 80(4) (November): 549–560

Eberhardt, Markus & Andrea F. Presbitero (2015). “Public Debt and Growth: Heterogeneity and Non-linearity”. *Journal of International Economics* 97(1) (September): 45–58

Eggertsson, Gauti B. & Paul R. Krugman (2012). “Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach”. *Quarterly Journal of Economics* 127(3) (August): 1469–1513

Farhi, Emmanuel & Jean Tirole (2018). “Deadly Embrace: Sovereign and Financial Balance Sheets Doom Loops”. *Review of Economic Studies* 85(3) (July): 1781–1823

Findley, David F., Brian C. Monsell, William R. Bell, Mark C. Otto & Bor-Chung Chen (1998). "New Capabilities and Methods of the X-12-ARIMA Seasonal Adjustment Program". *Journal of Business & Economic Statistics* 16(2) (April): 127–152

Gennaiola, Nicola, Alberto Martin & Stefano Rossi (2014). "Sovereign Default, Domestic Banks, and Financial Institutions". *Journal of Finance* 69(2) (April): 819–866

Gilchrist, Simon G., Jae W. Sim & Egon Zakrajšek (2014). "Uncertainty, Financial Frictions, and Investment Dynamics". *NBER Working Paper* 20038, Cambridge, MA: National Bureau of Economic Research

Gomes, Joao F. (2001). "Financing Investment". *American Economic Review* 91(5) (December): 1263–1285

Herndon, Thomas, Michael A. Ash & Robert N. Pollin (2014). "Does High Public Debt Consistently Stifle Economic Growth? A Critique of Reinhart and Rogoff". *Cambridge Journal of Economics* 38(2) (March): 257–279

Holtz-Eakin, Douglas J., Whitney K. Newey & Harvey S. Rosen (1988). "Estimating Vector Autoregressions with Panel Data". *Econometrica* 56(6) (November): 1371–1395

Hutchison, Michael M. & Ilan Noy (2005). "How Bad Are Twins? Output Costs of Currency and Banking Crises". *Journal of Money, Credit, and Banking* 37(4) (August): 725–752

Ilzetzki, Ethan O., Enrique G. Mendoza & Carlos A. Végh (2013). "How Big (Small?) Are Fiscal Multipliers?" *Journal of Monetary Economics* 60(2) (March): 239–254

Im, Kyung So, M. Hashem Pesaran & Yongcheol Shin (2003). "Testing for Unit Roots in Heterogeneous Panels". *Journal of Econometrics* 115(1) (July): 53–74

International Monetary Fund (2017). "Staff Report for the 2017 Article IV Consultation for the People's Republic of China". *IMF Country Report* 17/247, Washington, DC: International Monetary Fund

Jensen, Michael C. & William H. Meckling (1976). "Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure". *Journal of FInancial Economics* 3(4) (October): 305–360

Jordà, Òscar, Moritz H.P. Schularick & Alan M. Taylor (2013). "When Credit Bites Back". *Journal of Money, Credit and Banking* 45(S2) (December): 3–28

Koursaros, Demetris, Nektarios A. Michail & Christos S. Savva (2016). "Bank Lending to the Private Sector and GDP Growth: Thresholds and Returns". *CBC Working Paper* 2016-2, Nicosia, Cyprus: Central Bank of Cyprus

Kydland, Finn E. & Edward C. Prescott (1982). "Time to Build and Aggregate Fluctuations". *Econometrica* 50(6) (November): 1345–1370

Lane, Philip R. (2012). "The European Sovereign Debt Crisis". *Journal of Economic Perspectives* 26(3) (Summer): 49–68

Leland, Hayne E. (1998). "Agency Costs, Risk Management, and Capital Structure". *Journal of Finance* 53(4) (August): 1213–1243

Levine, Ross (2005). "Finance and Growth: Theory and Evidence". In Philippe M. Aghion & Steven N. Durlauf (editors), *Handbook of Economic Growth*, volume 1A, pp. 865–934. Amsterdam, the Netherlands: Elsevier

Levine, Ross, Norman V. Loayza & Thorsten Beck (2000). "Financial Intermediation and Growth: Causality and Causes". *Journal of Monetary Economics* 46(1) (August): 31–77

Ley, Eduardo (2009). "Fiscal (and External) Sustainability". Washington, DC: The World Bank

Lim, Jamus Jerome & Sanket Mohapatra (2016). "Quantitative Easing and the Post-Crisis Surge in Financial Flows to Developing Countries". *Journal of International Money and Finance* 68(1) (November): 331–357

Lin, Shuanglin (2000). "Government Debt and Economic Growth in an Overlapping Generations Model". *Southern Economic Journal* 66(3) (January): 754–763

Lof, Matthijs & Tuomas Malinen (2014). "Does Sovereign Debt Weaken Economic Growth? A Panel VAR Analysis". *Economics Letters* 122(3) (March): 403–407

Maliszewski, Wojciech S., Serkan Arslanalp, John Caparusso, José Garrido, Si Guo, Joong Shik Kang, W. Raphael Lam, T. Daniel Law, Wei Liao, Nadia Rendak, Philippe Wingender, Jiangyan Yu & Longmei Zhang (2016). "Resolving Chinas Corporate Debt Problem". *IMF Working Paper* WP/16/203, Washington, DC: International Monetary Fund

Mian, Atif R., Amir Sufi & Emil Verner (2017). "Household Debt and Business Cycles Worldwide". *Quarterly Journal of Economics* 132(4) (November): 1755–1817

Modigliani, Franco (1961). "Long-Run Implications of Alternative Fiscal Policies and the Burden of the National Debt". *Economic Journal* 71(284) (December): 730–755

Modigliani, Franco & Merton H. Miller (1958). "The Cost of Capital, Corporation Finance and the Theory of Investment". *American Economic Review* 48(3) (June): 261–297

Nickell, Stephen J. (1981). "Biases in Dynamic Models with Fixed Effects". *Econometrica* 49(6) (November): 1417–1426

Panizza, Ugo G. & Andrea F. Presbitero (2014). "Public Debt and Economic Growth: Is There a Causal Effect?" *Journal of Macroeconomics* 41(1) (September): 21 –41

Pedroni, Peter L. (1999). "Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors". *Oxford Bulletin of Economics and Statistics* 61(S1) (November): 653–670

Pedroni, Peter L. (2004). "Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Applicaton to the PPP Hypothesis". *Econometric Theory* 20(3) (June): 597–625

Pesaran, M. Hashem (2007). "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence". *Journal of Applied Econometrics* 22(2) (March): 265–312

Pesaran, M. Hashem (2015). "Testing Weak Cross-Sectional Dependence in Large Panels". *Econometric Reviews* 34(6–10) (August): 1089–1117

Pesaran, M. Hashem, Yongcheol Shin & Ron P. Smith (1999). "Pooled Mean Group Estimation of Dynamic Heterogeneous Panels". *Journal of the American Statistical Association* 94(446) (June): 621–634

Pesaran, M. Hashem & Ron P. Smith (1995). "Estimating Long-Run Relationships from Dynamic Heterogeneous Panels". *Journal of Econometrics* 68(1) (July): 79–113

Pescatori, Andrea, Damiano Sandri & John Simon (2014). "Debt and Growth: Is There a Magic Threshold?" *IMF Working Paper* WP/14/34, Washington, DC: International Monetary Fund

Popov, Alexander A. & Neeltje Van Horen (2015). "Exporting Sovereign Stress: Evidence from Syndicated Bank Lending during the Euro Area Sovereign Debt Crisis". *Review of Finance* 19(5) (August): 1825–1866

Pritchett, Lant H. (2000). "The Tynanny of Concepts: CUDIE (Cumulated, Depreciated, Investment Effort) Is Not Capital". *Journal of Economic Growth* 5(4) (December): 361–84

Rajan, Raghuram G. & Luigi G. Zingales (1998). "Financial Dependence and Growth". *American Economic Review* 88(3) (June): 559–586

Reinhart, Carmen M., Vincent R. Reinhart & Kenneth S. Rogoff (2012). "Public Debt Overhangs: Advanced-Economy Episodes Since 1800". *Journal of Economic Perspectives* 26(3) (Summer): 69–86

Reinhart, Carmen M. & Kenneth S. Rogoff (2010). "Growth in a Time of Debt". *American Economic Review* 100(2) (May): 573–578

Reinhart, Carmen M. & Kenneth S. Rogoff (2011). "From Financial Crash to Debt Crisis". *American Economic Review* 101(5) (September): 1676–1706

Saint-Paul, Gilles (1992). "Fiscal Policy in an Endogenous Growth Model". *Quarterly Journal of Economics* 107(4) (November): 1243–1259

Salomon, Robert M. & Xavier Martin (2008). "Learning, Knowledge Transfer, and Technology Implementation Performance: A Study of Time-to-Build in the Global Semiconductor Industry". *Management Science* 54(7) (July): 1266–1280

Schularick, Moritz H.P. (2014). "Public and Private Debt: The Historical Record (1870–2010)". *German Economic Review* 15(1) (February): 191–207

Schularick, Moritz H.P. & Alan M. Taylor (2012). "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870-2008". *American Economic Review* 102(2) (April): 1029–1061

Sims, Christopher A., James H. Stock & Mark W. Watson (1990). "Inference in Linear Time Series Models with Some Unit Roots". *Econometrica* 58(1) (January): 113–144

Toda, Hiro Y. & Taku Yamamoto (1995). "Statistical inference in vector autoregressions with possibly integrated processes". *Journal of Econometrics* 66(1) (March–April): 225–250

Turnovsky, Stephen J. (1996). "Optimal Tax, Debt, and Expenditure Policies in a Growing Economy". *Journal of Public Economics* 60(1) (April): 21–44

van der Ploeg, Frederick & George S. Alogoskoufis (1994). "Money and Endogenous Growth". *Journal of Money, Credit and Banking* 26(4) (November): 771–791

Westerlund, Joakim (2007). "Testing for Error Correction in Panel Data". *Oxford Bulletin of Economics and Statistics* 69(6) (December): 709–748

Xu, Zhenhui (2007). "Financial Development, Investment, and Economic Growth". *Economic Inquiry* 38(2) (April): 331–344

Appendix

A.1 Theoretical models of total debt and growth

This annex section formally sketches out several channels by which aggregate debt can affect growth dynamics.

First, consider a standard Ramsey-Cass-Koopman setting, with perfect foresight. The decentralized economy is comprised of firms, households, and government.

The production side is populated by identical, perfectly-competitive firms that rely on labor N and capital K as inputs for production, using labor-augmenting technology A, represented in intensive form at a given time s by

$$y_s = f(k_s), \tag{A.1}$$

where $y \equiv Y/AN$ and $k \equiv K/AN$ are output and capital per efficiency unit of labor, respectively, and (A.1) is assumed to be strictly increasing and concave, and satisfy the Inada conditions $f(0) = 0$, $f'(0) = \infty$, and $f'(\infty) = 0$. To ensure interior solutions of interest, we also let $k_t > 0$.

Labor and technology grow at constant rates, according to $\dot{N}/N = \nu$ and $\dot{A}/A = \phi$ (where the dot above a variable indicates its time derivative). Given the competitive environment, firms take wages w and the rental rate r as given, and a representative firm thus solves the program

$$\max_{k_s} f(k_s) - w_s - r_s k_s \quad \forall s.$$

The first order condition for this problem equates the marginal product of capital to the rental rate

$$f'(k_s) = r_s,$$

and with the zero profit condition in equilibrium, Euler's Theorem implies that output is

$$f(k_s) = w_s + r_s k_s.$$

The consumption side is composed of a continuum of homogenous, infinitely-lived households, each endowed with a unit of labor that is supplied inelastically in exchange for wages, and providing capital inelastially as a result of past decisions. Households maximize lifetime utility, which is represented by the discounted sum of instantaneous felicities:

$$\int_{s=t}^{\infty} \exp[-\rho(s-t)]\, u(c_s)\, ds, \tag{A.2}$$

where $c \equiv C/AN$ is per-effective worker consumption, and ρ is the household's subjective discount factor. The felicity function in (A.2) is assumed to be strictly increasing and concave, and satisfy the conditions $u'(0) = \infty$, and $u'(\infty) = 0$. Households face a dynamic budget constraint where assets a are accumulated via

$$\dot{a}_s = (r_s - \nu_s)\, a_s(\tau_s) + w_s + z_s - c_s \quad \forall s, \tag{A.3}$$

where current assets are potentially subject to taxation τ, and households may receive a transfer z_s from the government. Assets (wealth) are equal to capital k and government bond d holdings, net of private debt b:[36]

$$a_s = k_s + d_s - b_s.^{37}$$

The optimization of (A.2) is subject to (A.3) along with a no-Ponzi-game condition

$$\lim_{s\to\infty} a_s \exp\left[-\int_{v=t}^{s} (r_v - n)\, dv\right] \geq 0, \tag{A.4}$$

taking initial capital k_t and private debt b_t as given. It is conventional to impose (A.4) as an equality, and solve, for $k_s, c_s \geq 0\ \forall s$, the current value Hamiltonian

$$\mathcal{H} = \exp(-\rho s)\left\{u(c_s) + \lambda_s\left[w_s + z_s + (r_s - \nu_s)\, a_s(\tau_s) - c_s\right]\right\},$$

where λ is the costate multiplier associated with the state variable k. The necessary and sufficient conditions implied by this maximization are, after some consolidation,

$$\left[\frac{u''(c_s)\, c_s}{u'(c_s)}\right] \cdot \frac{\dot{c}_s}{c_s} = \rho + \nu - r_s, \tag{A.5a}$$

$$\dot{a}_s = (r_s - \nu_s)\, a_s(\tau_s) + w_s + z_s - c_s, \tag{A.5b}$$

$$\lim_{s\to\infty} a_s u'(c_s) \exp\left[-\rho(s-t)\right] = 0. \tag{A.5c}$$

These results are standard; (A.5a) corresponds to the consumption Euler, (A.5b) is the transition equation, and (A.5c) is the transversality condition. Taken together, (A.5) characterizes the optimal growth path. Setting $\dot{c} = \dot{a} = 0$ yields the (steady state) balanced growth path per effective worker.

Finally, the government sector consumes resources at the per-effective labor rate of g (fixed exogenously), funded by both taxes and public debt issuance:

$$\dot{d}_s = (r_s - \nu_s)\, d_s(\tau_s) + g_s - \tau_s \quad \forall s. \tag{A.6}$$

Since $a_s = k_s + d_s - b_s$, (A.5b) implies that both public and private debt are relevant for the optimal growth path, as suggested in the text. Whether the ultimate allocation of resources is affected by the method of finance further depends on the manner of taxation. If taxes are levied in a lump-sum fashion with no corresponding transfer, $z_s = 0$ and (A.3) becomes

$$\dot{a}_s = (r_s - \nu_s)\, a_s - \tau_s^l + w_s - c_s. \tag{A.3$'$}$$

Integrating this constraint and imposing the condition(A.4), the intertemporal household budget constraint is then

$$\int_{s=t}^{\infty} c_s R_s ds = (k_t + d_t - b_t) - \int_{s=t}^{\infty} \tau_s^l R_s ds + \int_{s=t}^{\infty} w_s R_s ds, \tag{A.7}$$

[36]For simplicity, our treatment here restricts private debt to household debt, and treats firm debt as zero.

[37]Note the implicit assumption here that the interest rate across different asset classes are equivalent. Furthermore, in the absence of public debt ($d_s = 0$), private debt among households must exhaust in equilibrium, and so assets are equivalent to capital ($a_s = k_s$).

where $R_s \equiv \exp\left[-\int_{v=t}^{s}(r_v - n)\,dv\right]$ is the present discount factor. Similarly integrating the fiscal balance (A.6) yields

$$\int_{s=t}^{\infty} g_s R_s ds = \int_{s=t}^{\infty} \tau_s^l R_s ds - d_t. \tag{A.8}$$

Substituting (A.8) into (A.7) demonstrates the neutrality of resource allocation to the method of government financing (whether via lump-sum taxation or deficit finance), which is a consequence of Ricardian equivalence in this special case.[38]

However, if taxes are instead applied in a distortionary fashion to capital, this neutrality result no longer holds. In this case, (A.3) is instead

$$\dot{a}_s = (r_s - \nu_s)\left(1 - \tau_s^d\right) a_s + w_s + z_s - c_s. \tag{A.3$''$}$$

In this instance, optimal growth is no longer unaffected by debt. This is evident from the modified consumption Euler, which is now

$$\left[\frac{u''(c_s)\,c_s}{u'(c_s)}\right] \cdot \frac{\dot{c}_s}{c_s} = \rho + \nu - \left(1 - \tau_s^d\right) r_s. \tag{A.5a$'$}$$

Taxation thus affects the allocation of resources (by raising the marginal product of capital) and, indeed, the capital stock in the balanced growth path.[39]

The strong neutrality of debt in the Ramsey-Cass-Koopmans special case is also broken in more sophisticated representations of consumer behavior, as in the baseline two-period Samuelson-Diamond overlapping generations model, or in the Blanchard-Yaari perpetual youth version. Diamond (1965), for instance, proves that changes in the quantity of debt can alter utility relative to the optimal growth path, and Blanchard (1985) shows that both the debt level and its dynamic sequence can alter aggregate demand.

[38] Optimal allocations are still sensitive to the path of government expenditure, of course, which alters the accumulation of capital through private debt. The result is also conditioned by the initial stock of public and private debt.

[39] In the steady state, $\dot{c} = 0$ and the capital stock is now $k^* = f^{-1}\left(\frac{\rho+\nu}{1-\tau^d}\right)$.

A.2 Preliminary tests

This annex section documents preliminary tests for panel data.

A.2.1 Stationarity

Table A.1 reports a set of first- (Choi 2001; Im, Pesaran & Shin 2003) and second- (Pesaran 2007) generation panel unit root tests for total debt/GDP, real GDP, current account, and the REER.[40] These are computed with and without a time trend, for log-levels (top panel), trend deviations (middle panel), and first differences (bottom panel).

For total debt, it is clear that stationarity is an issue whether in level or trend deviation form; as a result, we restrict this series to the (stationary) first-differenced form in all analyses that follow. The results of these tests for real GDP are less clearcut. The series is occasionally stationary when a trend is included, whether in the level or trend-deviation form. However, even in trend-deviation form, the series may be nonstationary in the absence of a trend. Consequently, we adopt the safe route of including in our baseline the first-differenced form of log real GDP as well (therefore effectively utilizing the QoQ growth rate), leaving the trend-deviation form to robustness checks.

When a trend is included, both the current account balance and REER series frequently exhibit stationarity. Since the trend-deviation form of the current account is typically stationary (whether without or without a trend), we adopt this transformation for our baseline. We also rely on the trend deviation form for the REER, since the variable is stationary in levels when a trend is included, and the trend-deviation form remains stationary even when we exclude a trend.

A.2.2 Cointegration

Table A.2 presents two sets of panel cointegration tests, one residual-based (Pedroni 1999), and the other error-correction-based (Westerlund 2007).[41] As before, we consider tests that include and exclude a time trend. TableA.2 reports cointegration test statistics for variables included in the the parsimonious (top panel) and comprehensive (bottom panel) versions of the empirical model.[42]

[40] First-generation tests do not generally account for cross-sectional dependence in the error term, and so the variables were demeaned prior to testing. Second-generation tests allow for the presence of an unobserved common factor with heterogeneous factor loadings; in the tests here, up to 4 lagged differences were considered to account for possible serial correlation, although only the first is reported.

[41] For economy, we report only corresponding group-mean and panel-level ADF and α statistics, respectively, for each of the two sets of tests. These choices were motivated by power considerations. Pedroni (2004, p. 608) makes the case that the ADF statistics tend to exhibit the best power properties when the time series is relatively constrained (as is our case), and Westerlund (2007, p. 722) argues that the α version of his tests may possess higher power is samples where the time dimension is larger than the cross-sectional one (as is our case).

[42] Since the error-correction nature of the Westerlund (2007) test requires a bivariate specification, the comprehensive-model statistics reported correspond just to the cointegrating relationship between D_t and Y_t, but with the sample restricted to the observations available when estimating the comprehensive model. The results for the remaining variables generally

Table A.1: Panel unit root tests for log level, trend deviation, and first difference transformations[†]

	Log levels							
	with constant only				*with constant and trend*			
	D_t	Y_t	B_t	Q_t	D_t	Y_t	B_t	Q_t
Im-Pesaran-Shin	0.926	1.813	-2.630***	-1.900**	0.947	-6.739***	-9.475***	-4.122**
Fisher ADF	-0.269	1.888	-0.068	-1.332*	3.936	-3.989***	-0.507	0.9896
Pesaran CIPS	1.360	2.917	-0.565	-1.896**	7.445	2.421	-1.019	-1.637*
	Trend deviation							
	with constant only				*with constant and trend*			
	$\hat{D}_t$	$\hat{Y}_t$	$\hat{B}_t$	$\hat{Q}_t$	$\hat{D}_t$	$\hat{Y}_t$	$\hat{B}_t$	$\hat{Q}_t$
Im-Pesaran-Shin	-1.0807	1.550	-10.395***	-5.366***	-1.976***	-0.209	-11.093***	-5.745***
Fisher ADF	-4.826***	-0.190	-6.740***	-5.707***	0.271	2.650	-2.117**	-0.697
Pesaran CIPS	-0.121	2.690	-4.586***	-6.193***	3.131	4.047	-1.922**	-3.842***
	First differences							
	with constant only				*with constant and trend*			
	$\dot{D}_t$	$\dot{Y}_t$	$\dot{B}_t$	$\dot{Q}_t$	$\dot{D}_t$	$\dot{Y}_t$	$\dot{B}_t$	$\dot{Q}_t$
Im-Pesaran-Shin	-31.324***	-33.064***	-35.865***	-30.316***	-32.640***	-33.772***	-35.988***	-30.539***
Fisher ADF	-11.963***	-14.492***	-19.863***	-20.215***	-10.675***	-11.568***	-17.217***	-17.217***
Pesaran CIPS	-19.810***	-20.303***	-24.764***	-21.510***	-19.484***	-19.744***	-23.105***	-20.088***

[†] The null hypothesis is the existence of a unit root. For first-generation tests, variables were demeaned in order to minimize cross-sectional dependence; second-generation tests explicitly account for this. Lags for the tests chosen with the Akaike criterion. The Im-Pesaran-Shin test reports the standardized $Z_{\tilde{t}-bar}$, the Fisher-type augmented Dickey-Fuller test reports the inverse normal Z, and the Pesaran CIPS reports the Z_{t-bar} for the first lagged difference. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

The overall takeaway from this set of tests is that it is difficult to reject the null of no cointegration. While the Pedroni statistic for certain specifications—especially when a trend is included—is significant, this is not corroborated by the Westerlund tests, nor by a number of other group- and panel-level Pedroni statistics (not reported). On balance, it appears reasonable to assume that cointegration is not a major concern in our baseline setup, and cointegration possibilities are left as robustness checks.

Table A.2: Panel cointegration tests, parsimonious and comprehensive models†

	Parsimonious			
	with constant only		*with constant and trend*	
	Group	Panel	Group	Panel
Pedroni ADF	1.559*	0.979	3.118***	3.104***
Westerlund α	-4.101	-4.277	-5.870	-7.291
	Comprehensive			
	with constant only		*with constant and trend*	
	Group	Panel	Group	Panel
Pedroni ADF	-0.195	1.040	4.353***	4.443***
Westerlund α	-3.836	-3.629	-5.168	-5.696

† The null hypothesis is of no cointegration. Variables for the Pedroni test were time-demeaned in order to capture common time effects; the Westerlund test explicitly accounts for cross-sectional dependence. The comprehensive-model statistics for the Westerlund are just for D_t and Y_t, with the corresponding comprehensive-model sample. Lags for the tests chosen with the Akaike criterion. The Pedroni test reports the parametric group and panel augmented Dickey-Fuller statistics, and the Westerlund test reports semiparametric group-mean and panel G_α and P_α. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

A.2.3 Cross-sectional dependence

Table A.3 records tests of weak cross-sectional dependence based on the Pesaran (2015) approach, which is well-suited for testing large unbalanced panels with relatively large N and T (as is our case). Similar to the panel unit root tests, we consider each variable in three forms: log-levels (top panel), trend deviations (middle panel), and first differences (bottom panel).

In virtually all cases, cross-sectional dependency in the residuals is not an issue; test statistics for the null of cross-sectional dependency are strongly rejected. In the one instance where the results are only marginally significant—first differences of the current account—the form is not relied on in our (the

point to the absence of a cointegrating relationship between total debt and the other variables (and among themselves), with a very small occurrence of statistically significance test statistics for certain tests. These results are available on request.

variable enters in trend deviation form in our baseline). These results provide confidence that there is not need to explicitly account for the presence of common unobserved temporal shocks, although we nevertheless consider this possibility in our robustness checks.

Table A.3: Panel spatial dependency tests for log level, trend deviation, and first difference transformations†

	Log levels			
	D_t	Y_t	B_t	Q_t
Pesaran CD	221.736***	221.736***	9.109***	272.940***
	Trend deviation			
	$\hat{D}_t$	$\hat{Y}_t$	$\hat{B}_t$	$\hat{Q}_t$
Pesaran CD	35.599***	50.153***	1.958**	34.725***
	First differences			
	$\dot{D}_t$	$\dot{Y}_t$	$\dot{B}_t$	$\dot{Q}_t$
Pesaran CD	37.028***	69.155***	1.819*	13.517***

† The null hypothesis is the existence of weak cross-sectional dependence in the residuals. The Pesaran test reports the CD statistics using all available observations. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

A.2.4 Lag selection

Table A.4 documents the overall model fit (as given by the coefficient of determination), along with the three Hansen's J statistic-based moment criteria proposed by Andrews & Lu (2001), for up to four lags for the parsimonious (left panel) and comprehensive (right panel) models.[43] On balance, the R^2 and information criteria—with the exception of the AIC—support the selection of the first-order panel VAR. Accordingly, we treat this as our baseline, and higher-order panel VARs are left to the robustness checks.

[43] The various specifications were instrumented with lags of one through five, since specifications with four lags would be just identified and yield no moment-based information criteria.

Table A.4: Coefficient of determination and information criteria for lag selection, parsimonious and comprehensive models†

	Parsimonious				**Comprehensive**			
Lag	R^2	AIC	BIC	QIC	R^2	AIC	BIC	QIC
1	0.118	13.360	-81.898	-20.996	0.945	-15.699	-381.152	-149.145
2	0.158	9.238	-62.206	-16.529	0.914	-26.833	-300.923	-126.917
3	-0.835	7.785	-39.845	-9.394	0.607	-29.406	-212.133	-96.129
4	-4.592	2.453	-21.361	-6.136	-0.270	-14.027	-105.390	-47.388

† Test statistics were computed for a maximum lag order of 4 quarters, and instrumented with lags of 1 through 5. The overall fit is given by the coefficient of determination (R^2). The moment and model selection criteria correspond to the Akaike (AIC), Bayesian (BIC), and Hannan-Quinn (QIC) Information Criteria, and are reported for all overidentified specifications.

A.3 Additional data details

This annex section provides additional detail related to the data.

A.3.1 Data cleaning

To obtain real GDP at the quarterly frequency, nominal GDP data were deflated with the GDP deflator. For both instances, deseasonalization was performed using the X-12 algorithm (Findley, Monsell, Bell, Otto & Chen 1998), with multiplicative decomposition. Gaps in the raw data (applicable to Turkey) were replaced with null entries. Because of negative entries in the balance of payments data, current accounts were deseasonalized with an additive decomposition instead. No seasonality was detected for the total debt and real effective exchange rate series, and so these data were not adjusted.

Certain secondary control variables were only available at the annual frequency. In particular, while certain countries make available quarterly demographic and stock market capitalization data, comprehensive, comparable cross-country data are available at only the annual frequency. We take advantage of the relatively persistent—and generally acyclical—nature of these two variables to infer missing quarterly observations via simple linear interpolation.

A.3.2 Data description

This subsection reports basic features related to the data, for the main variables of interest. This includes sources and definitions (Table A.5), countries included in the sample (Table A.6), standard summary statistics (Table A.7), and the corresponding correlation matrix (Table A.8).

Table A.5: Sources and definitions for main variables of interest

Variable	Definition	Source
	Baseline variables	
Total debt	Total credit to public and private sector as share of GDP[†]	BIS TC[‡]
Private debt	Corporate and household debt as share of GDP	BIS TC
Public debt	Government debt as share of GDP	BIS TC
Output	Seasonally-adjusted real gross domestic product[*]	IMF IFS
Real exchange rate	Real effective exchange rate index computed from the CPI	BIS EER
Balance of payments	Seasonally-adjusted current account balance as share of GDP	IMF IFS
	Robustness variables	
Bank credit	Credit to private nonfinancial sector extended by banks	BIS TC
Gross financial inflows	Gross portfolio and FDI inflow, net of disinvestment, as share of GDP	WB GEM
PPI-based real rate	Real effective exchange rate index computed from the PPI	JP Morgan
Political risk	Weighted index of subjective political-economic risk ratings	PRS ICRG
Dependency ratio	Ratio of < 16 and > 64 year-olds to working-age population[§]	WB WDI
Market capitalization	Market capitalization of listed domestic companies as share of GDP[§]	WB WDI
Private investment	Gross fixed capital formation by private sector	OECD MEI
Private investment	Gross fixed capital formation by public sector	OECD MEI

[†] To ensure stationarity, all variables are introduced either as deviations from trend or as first differences. See Section A.2.1 for details.

[‡] BIS TC = Bank for International Settlements Total Credit Statistics, BIS EER = Bank for International Settlements Effective Exchange Rate Indices, OECD MEI = Organisation for Economic Cooperation and Development Main Economic Indicators, PRS ICRG = Political Risk Services International Country Risk Guide, IMF IFS = International Monetary Fund International Financial Statistics, WB GEM = World Bank Global Economic Monitor, WB WDI = World Bank World Development Indicators. ICRG indicators are measured such that higher values indicate lower risk (better outcomes).

[*] Seasonal adjustments (where necessary) performed by author using the X12 ARIMA algorithm.

[§] Source data are at annual frequency, and interpolated to obtain quarterly data.

Table A.6: Country coverage†

Developed markets		
Australia	Greece	Norway
Austria	Hong Kong	Portugal
Belgium	Ireland	Singapore
Canada	Italy	Spain
Denmark	Japan	Sweden
Finland	Luxembourg	United Kingdom
France	Netherlands	United States
Germany	New Zealand	
Emerging markets		
Argentina	Hungary	Russia
Brazil	India	Saudi Arabia
Chile	Indonesia	South Africa
China	Malaysia	South Korea
Colombia	Mexico	Thailand
Czech Republic	Poland	Turkey

† Data availability may mean that some countries drop out of the sample in certain specifications.

Table A.7: Summary statistics for main variables of interest†

Variable	**N**	**Mean**	**Std Dev**	**Min**	**Max**
Total debt	2,666	195.14	81.87	41.50	497.90
Public debt	2,666	56.52	34.55	1.60	201.40
Private debt	2,666	138.63	71.89	17.00	455.30
Output	2,666	371.00	674.22	10.67	4232.84
Balance of payments	2,666	0.03	0.08	-0.12	0.37
Real exchange rate	2,666	97.84	12.61	44.34	149.67

† Balanced sample statistics reported; actual statistics may vary depending on the available sample for a given specification.

Table A.8: Correlation matrix for main variables of interest†

	Tot debt	Pub debt	Pte debt	Output	BOP	REER
Total debt	1.000					
Public debt	0.482	1.000				
Private debt	0.907	0.069	1.000			
Output	0.118	0.234	0.022	1.000		
BOP	0.333	-0.094	0.424	-0.228	1.000	
REER	0.180	-0.075	0.241	0.175	0.071	1.000

† Correlations corresponding to the comprehensive model sample reported.

A.4 Full impulse response matrices

In this annex section we report the full impulse response matrices for both parsimonious (Figure A.1) and comprehensive (Figure A.2) specifications in the baseline, as well as the analogous specifications corresponding to the panel VAR(2) (Figures A.3 and A.4) and VAR(4) (Figures A.5 and A.6) models.

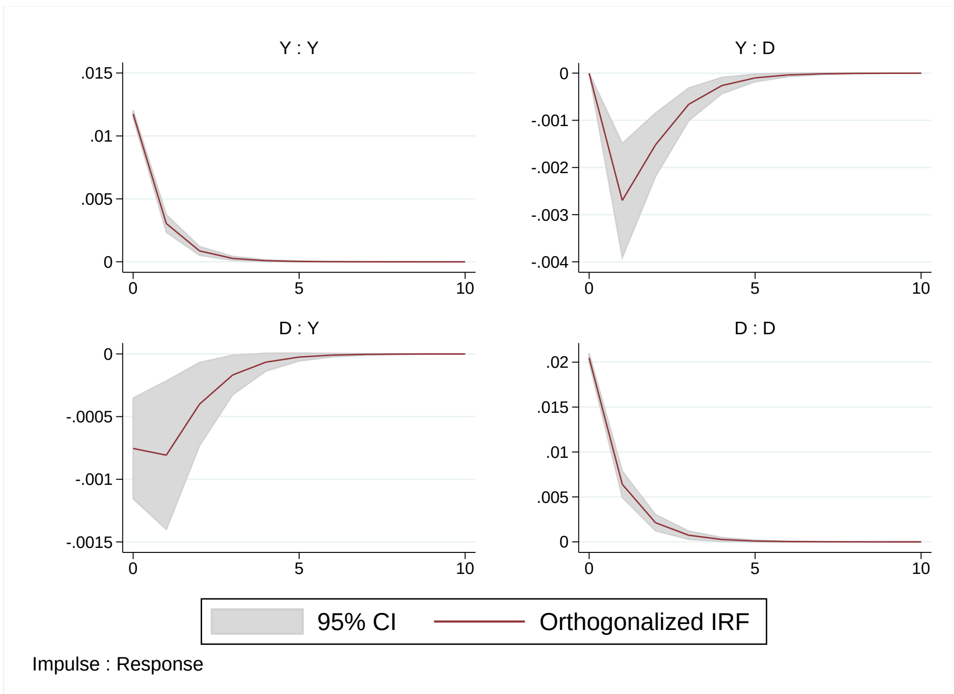


Figure A.1: Full set of orthogonalized impulse response functions for the baseline parsimonious model, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

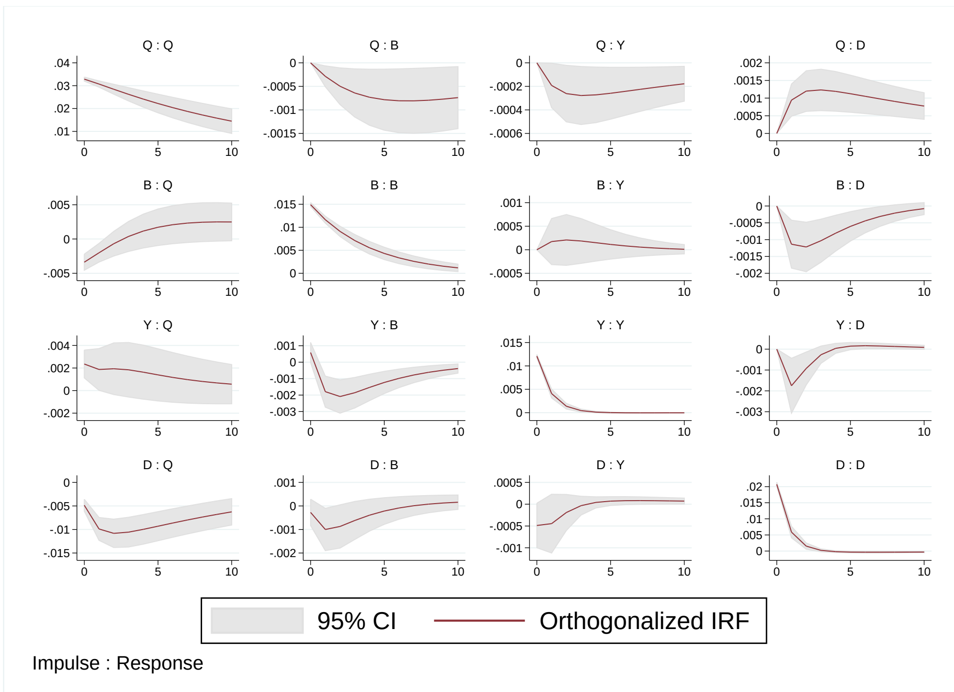


Figure A.2: Full set of orthogonalized impulse response functions for the baseline comprehensive model, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

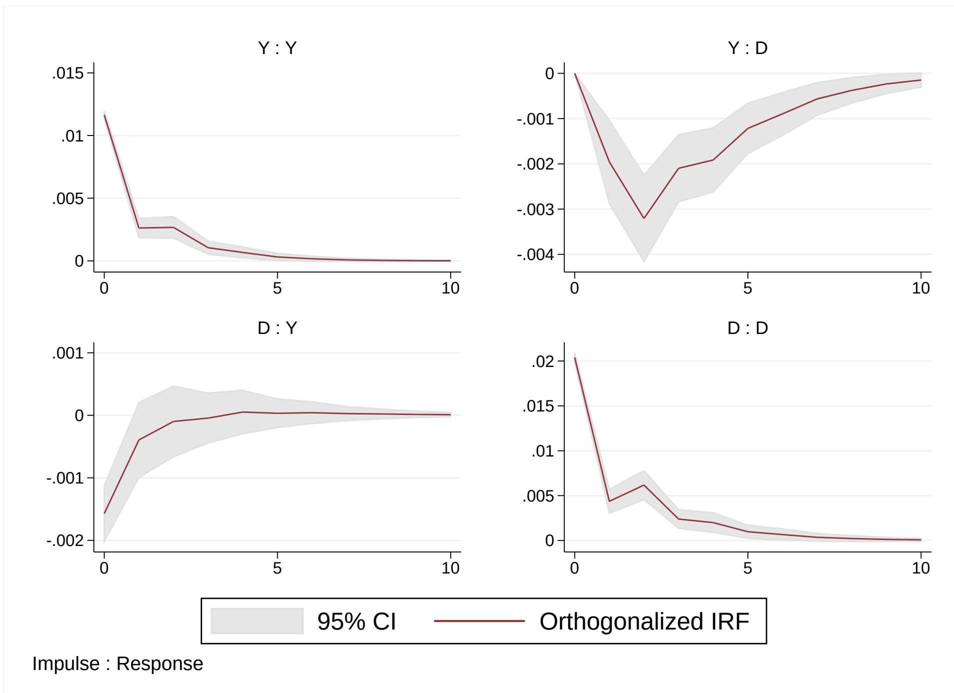


Figure A.3: Full set of orthogonalized impulse response functions for the parsimonious model with two lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

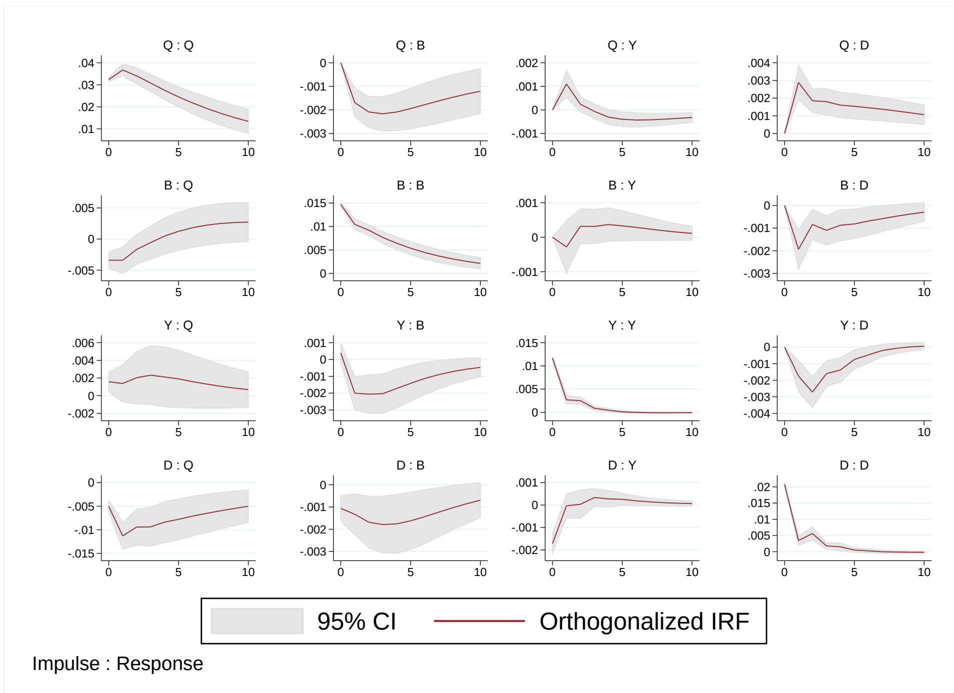


Figure A.4: Full set of orthogonalized impulse response functions for the comprehensive model with two lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

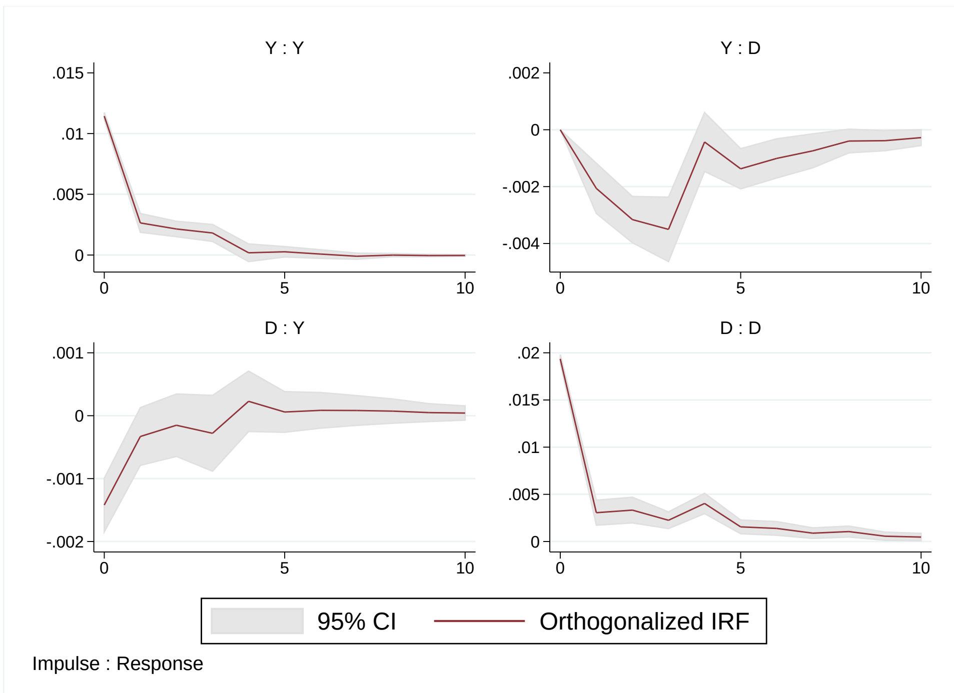


Figure A.5: Full set of orthogonalized impulse response functions for the parsimonious model with four lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

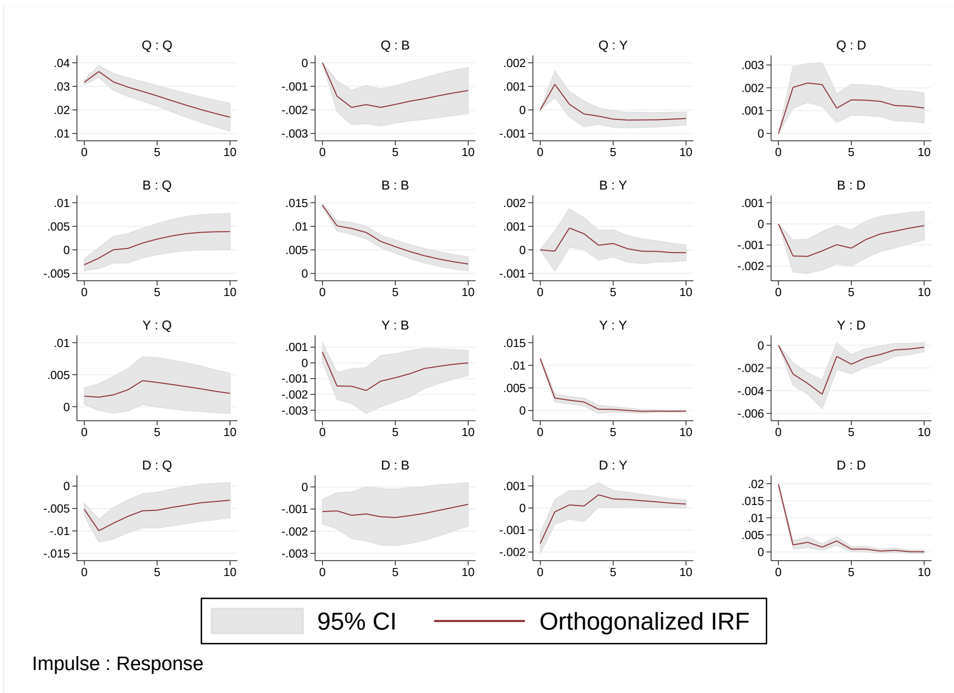
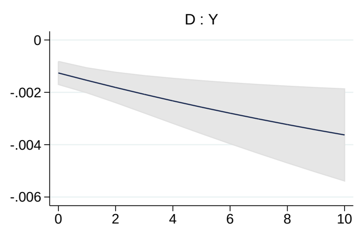


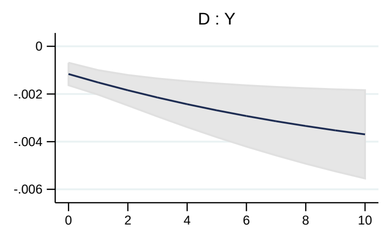
Figure A.6: Full set of orthogonalized impulse response functions for the comprehensive model with four lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR.

A.5 Additional robustness checks

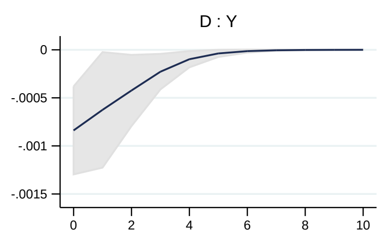
This annex section reports impulse response functions for additional robustness checks that were mentioned in the text, but not shown. These include IRFs when trend-differenced variables are used in place of those in first differences, and *vice versa* (Figure A.7), IRFs for public debt on private bank debt with public debt ordered first (Figure A.8), and for the external account on debt for the full period instead of just post-2008 crisis (Figure A.9).



(a) Parsimonious (trend deviations)

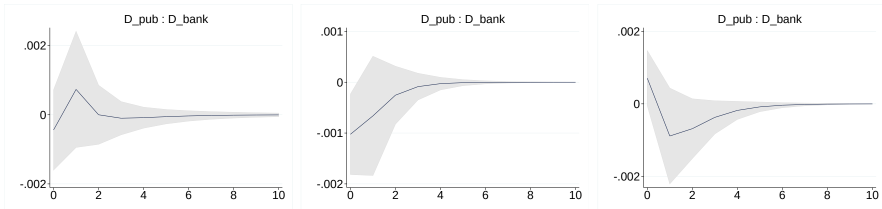


(b) Comprehensive (trend deviations)



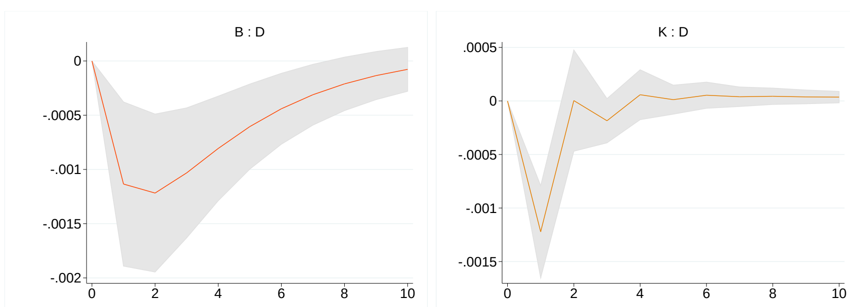
(c) Comprehensive (first differences)

Figure A.7: Orthogonalized impulse response functions for debt on growth for the parsimonious and comprehensive model with trend deviations instead of first differences (top), and the comprehensive model with first differences instead of trend deviations (bottom), for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The major difference in the use of trend-deviation measures, relative to the baseline, is the persistence (and further amplification) of the negative effect over time.



(a) Euro Area (b) All DMs (c) All countries

Figure A.8: Orthogonalized impulse response functions for public debt on private bank debt for the parsimonious model (public debt ordered first), for a one standard-deviation innovation in debt, for 10 quarters after the shock. The light gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The overall patterns are similar to the case where bank debt is ordered first, with the minor exception that the effect in all countries is slightly positive (albeit statistically indistinguishable from zero) on impact, before turning negative by the first quarter.



(a) Financial channel (full period) (b) Real channel (full period)

Figure A.9: Orthogonalized impulse response functions for the external account on debt for the comprehensive model with the current account (left) or financial inflows (right) during 1994Q1–2016Q3, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The magnitudes of the responses are approximately half that in the post-crisis sample, and the response of debt to the financial channel is more volatile and less persistent.

A.6 An application to future of Chinese growth

In this annex section we run a number of simulations for future Chinese growth, based on different possible debt accumulation paths. Our forecast horizon is 10 years (2017Q1–2026Q4). We consider two more optimistic debt resolution paths, and two more pessimistic ones.

The two optimistic ones are: first, a successful restructuring of private sector debt (akin to what occurred in the 1990s), which carries the average debt/GDP growth rate for the most recent year through to the following year (2017), before applying a *negative* growth rate consistent with the pre-crisis historical average (a *de*cumulation rate of -0.7 percent) through the end of the forecast horizon;[44] second, a stabilization of the debt/GDP ratio (a zero debt/GDP growth rate or, equivalently, a growth rate of debt equivalent to GDP growth). This outcome is consistent with a DM-like experience, where total debt loads are higher than EMs on average, and may be justified by the fact that China is a high-saving economy (and so debt is effectively collateralized).

The two pessimistic possibilities are: first, a continuation of debt accumulation, resulting in a Japan-like outcome of zombie-dominated industries with depressed economic vitality (Caballero, Hoshi & Kashyap 2008), which we simulate by reverting to the pre-crisis growth rate of 0.7 percent (from the post-crisis 1.5 percent), but holding this positive rate through till 2026; second, we impose the post-crisis debt growth rate all the way through till 2022, before stabilizing in 2023 till the end of the projection period, which most consistent with a failure of policymakers to control the current debt spiral, and—should current trends continue—appears to be the path that Japan is headed toward at around the end of the decade.

We then compute growth paths corresponding to each of these scenarios. We assume that the benchmark average annual 10-year GDP growth projection is 5.6 percent, which is consistent with the average of the IMF and OECD projections for the economy. For each path, we impose the cumulative annualized growth shock that would result from each scenario, and calculate the final result. The various outcomes, when parameterized by the results of either the parsimonious or comprehensive model, are summarized in the Table A.9, as well as Figure A.11.

These results corroborate the overall message of the paper, which is that the effects of debt growth tend to be statistically significant but modest overall. This is even more so in a fast-growing economy like China, where—with growth effects ranging from $+0.2$ percent to -0.6 percent per annum—is limited for an economy projected to expand at an average rate of 5.6 percent. Furthermore, the moderating effects of the external account in the comprehensive model imply an almost imperceptible growth impact, and nullifies the distinction between debt resolution scenarios. However, in the context of China, the comprehensive outcomes are probably less applicable, given its relatively controlled exchange

[44] Successful resolution along these lines is consistent with the implementation of the "comprehensive and proactive" debt resolution strategy outlined by authors such as Maliszewski *et al.* (2016).

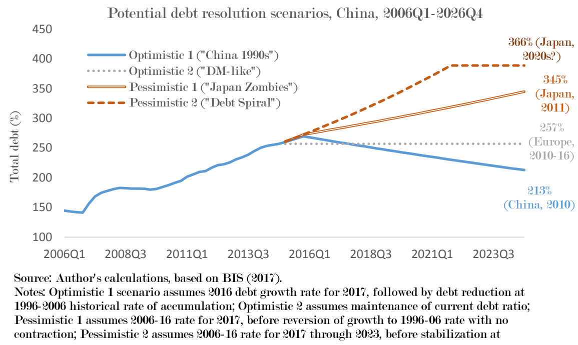


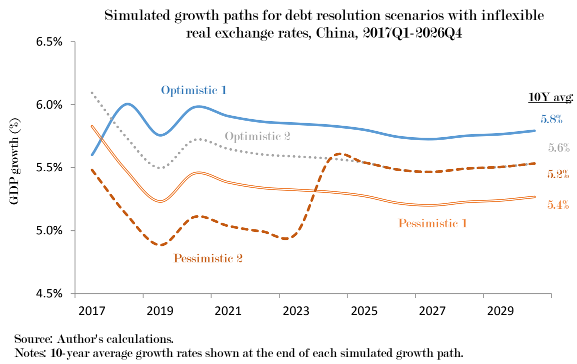
Figure A.10: Historical evolution of total debt and potential debt resolution paths, comprising two optimistic and two pessimistic scenarios for China over the 10-year forecast horizon, 2006Q1–2026Q4. The resultant total debt stock ranges 213% of GDP (similar to China in 2010) to 266% of GDP (the presumed share in Japan for 2020 if current accumulation rates persist).

Table A.9: Simulated growth effects of alternative debt resolution scenarios for China, 2017Q1–2026Q4[†]

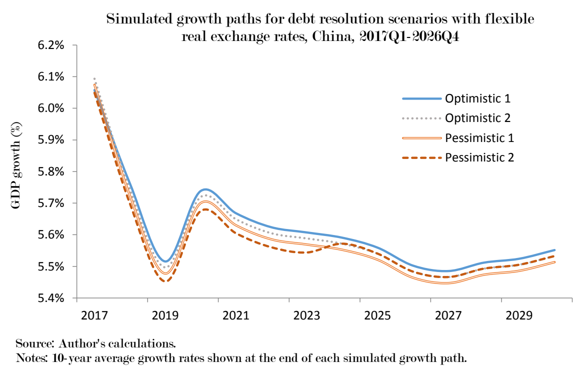
	Parsimonious			
	Optim. 1	*Optim. 2*	*Pessim. 1*	*Pessim. 2*
Average annual shock (%)	-1.84	0	6.09	4.26
Average debt effect (%)	0.18	0	-0.61	-0.43
Total debt effect (%)	1.85	0	-6.11	-4.28
Average GDP growth (%)	5.83	5.65	5.38	5.21
	Comprehensive			
Average annual shock (%)	-1.84	0	6.09	4.26
Average debt effect (%)	0.01	0	-0.04	-0.03
Total debt effect (%)	0.13	0	-0.44	-0.31
Average GDP growth (%)	5.66	5.65	5.63	5.62

[†] Scenarios are as documented in Figure A.10. The neutral benchmark growth rate assumes the average of the OECD and IMF projections for the period of 5.6 percent. Results applying the parsimonious (comprehensive) model implicitly assume an inflexible (flexible) real exchange rate.

rate regime.



(a) Inflexible exchange rate



(b) Flexible exchange rate

Figure A.11: Simulated GDP growth paths for with inflexible (top panel) and flexible (bottom panel) real exchange rates, corresponding to the parsimonious and comprehensive models, for four alternative debt resolution scenarios, China, 2017Q1–2026Q4. As discussed in the text, the moderating effects of the external account in a comprehensive model imply a smaller growth impact, regardless of debt scenario. Even for the parsimonious model, the range of growth effects is relatively limited for a fast-growing economy like China, from +0.2 percent to −0.6 percent per annum.