Online Appendix to Accompany "Growth in the Shadow of Debt" (Not for Publication)

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:

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

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:[43]

$$a_s = k_s + d_s - b_s.^{44}$$

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

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

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

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

[44] 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 ($a_s = k_s$).

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.[45]

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.[46]

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.

[45] 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.

[46] 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 of the time-series properties of the panel data.

A.2.1. Stationarity

Table A.1 reports a set of first- (Choi 2001; Im *et al.* 2003) and second- (Pesaran 2007) generation panel unit root tests for total debt/GDP, real GDP, current account, and the REER.[47] 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 three sets of panel cointegration tests: two residual-based tests (Pedroni 1999; Westerlund 2006), and an error-correction-based one (Westerlund 2007). [48] 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.[49]

[47]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.

[48]Each of these tests address slightly different issues. The Pedroni (1999) test allows for rudimentary cross-sectional dependence (by time-demeaning the data), while the the Westerlund (2007) explicitly accommodates cross-sectional dependence. The Westerlund (2006) test retains the assumption of cross-sectional independence, but allows for endogenous structural breaks (we restrict these to a maximum of five) in either the constant or the trend. For economy, we report only corresponding group-mean and panel-level ADF and α statistics, respectively, for each of the first two sets of tests (the Westerlund (2006) test applies only to the full panel). 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).

[49]Since the error-correction nature of the Westerlund (2007) test requires a bivariate specification, the statistics reported for the comprehensive model 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. For consistency, we retain this strategy for the Westerlund (2006) test; moreover, we further trim the sample to a 35-country, 54-quarter (parsimonious) and 36-country, 42-quarter (comprehensive) strongly balanced panel, which was required to execute the LM test (the specific matrix was chosen to maximize coverage). The results for the excluded variables generally point to the absence of a cointegrating relationship between total debt and the excluded variables (and among themselves), with a very small occurrence of statistically significance test statistics for certain tests. These results are available on request.

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 there is little evidence of cointegration. While the Pedroni statistic for certain specifications—especially when a trend is included—is significant, this is not corroborated by either of 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 complete 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
Westerlund LM		4.306***		12.554***
	Complete			
	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
Westerlund LM		4.366***		20.541***

† The null hypotheses for the first two tests are of no cointegration, while the final is of cointegration. Variables for the Pedroni (1999) test were time-demeaned in order to capture common time effects; the Westerlund (2007) α test explicitly accounts for cross-sectional dependence, while the Westerlund (2006) LM test allows for up to 5 structural breaks in the series. The complete-model statistics for both Westerlund tests are just for D_t and Y_t, with the corresponding complete-model sample. Lags for the tests chosen with the Akaike criterion. The Pedroni (1999) test reports the parametric group and panel augmented Dickey-Fuller statistics, the Westerlund (2007) test reports semiparametric group-mean and panel G_α and P_α, and the Westerlund (2006) test reports the LM statistic, estimated via FMOLS. * 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, the tests indicate the presence of at cross-sectional dependency in the residuals (test statistics for the null of only weak dependency are strongly rejected). These results raise the possibility that the coefficients may be inconsistent, and suggest the need to consider possibility of common unobserved temporal shocks, which we do in our robustness checks.

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

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.

up to four lags for the parsimonious (left panel) and comprehensive (right panel) models.[50] 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.

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.

[50]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.

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 *et al.* 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
Domestic investment	Gross fixed capital formation by private and public sector	OECD MEI/IMF WEO
Government consumption	Government final consumption expenditure	OECD MEI/IMF WEO

† 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.

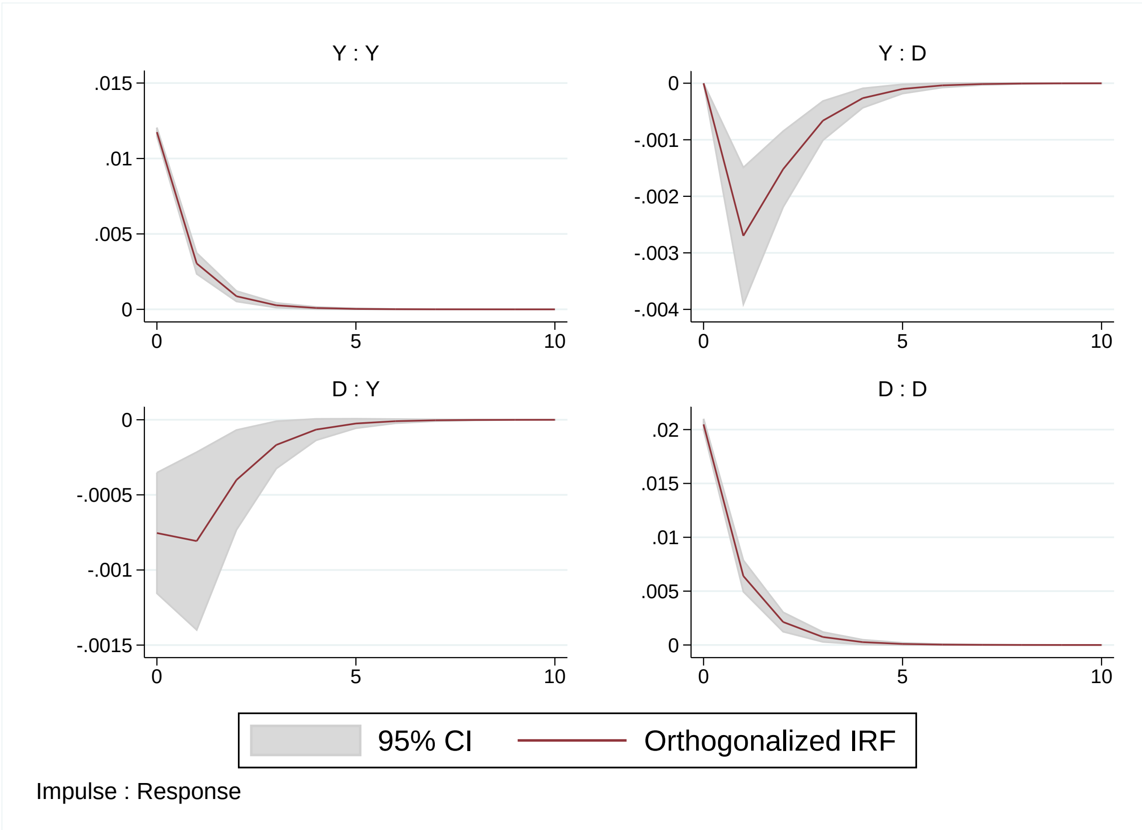


Figure A.1: Full set of orthogonalized impulse response functions for the baseline parsimonious model, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from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

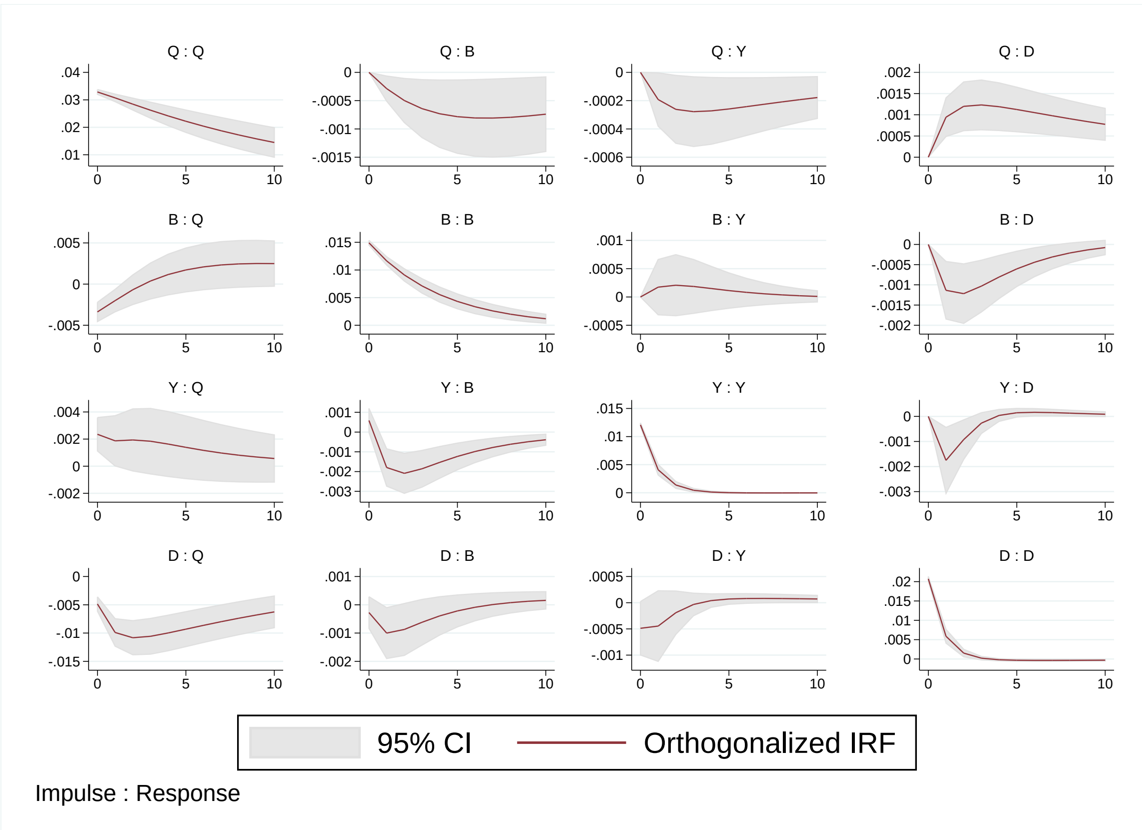


Figure A.2: Full set of orthogonalized impulse response functions for the baseline comprehensive model, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from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

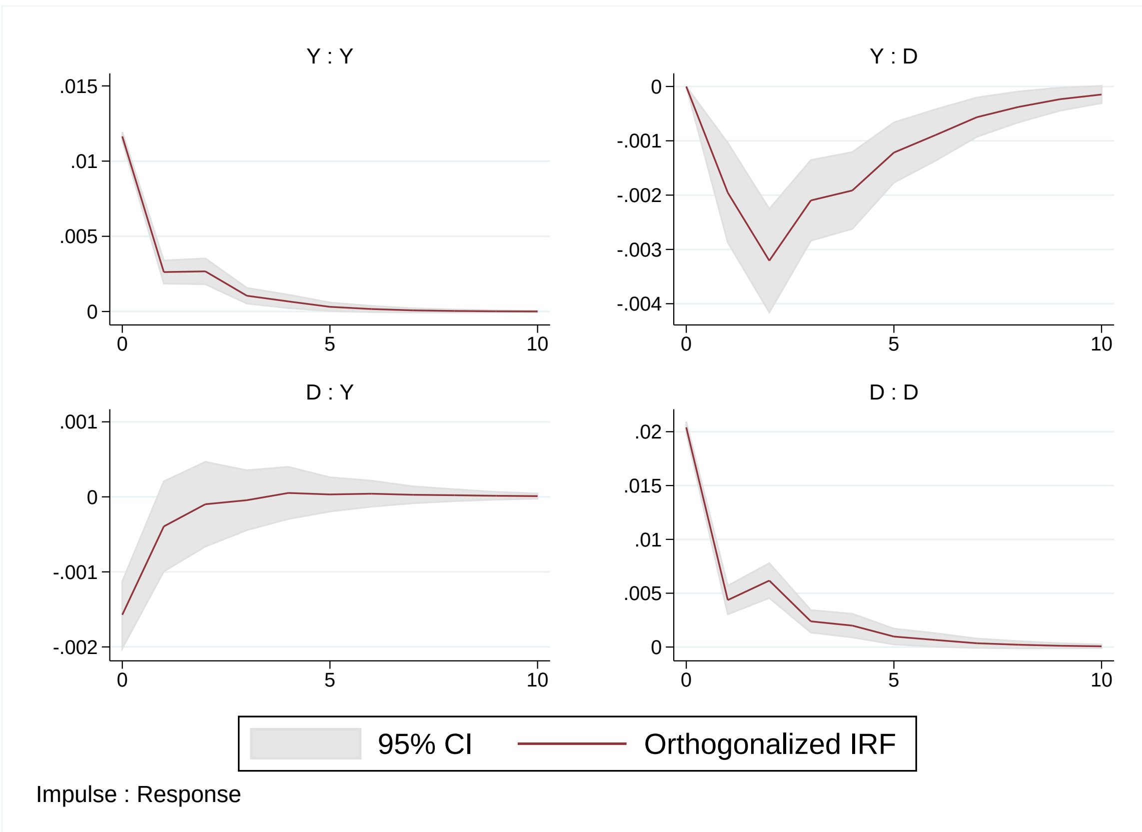


Figure A.3: Full set of orthogonalized impulse response functions for the parsimonious model with two lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws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

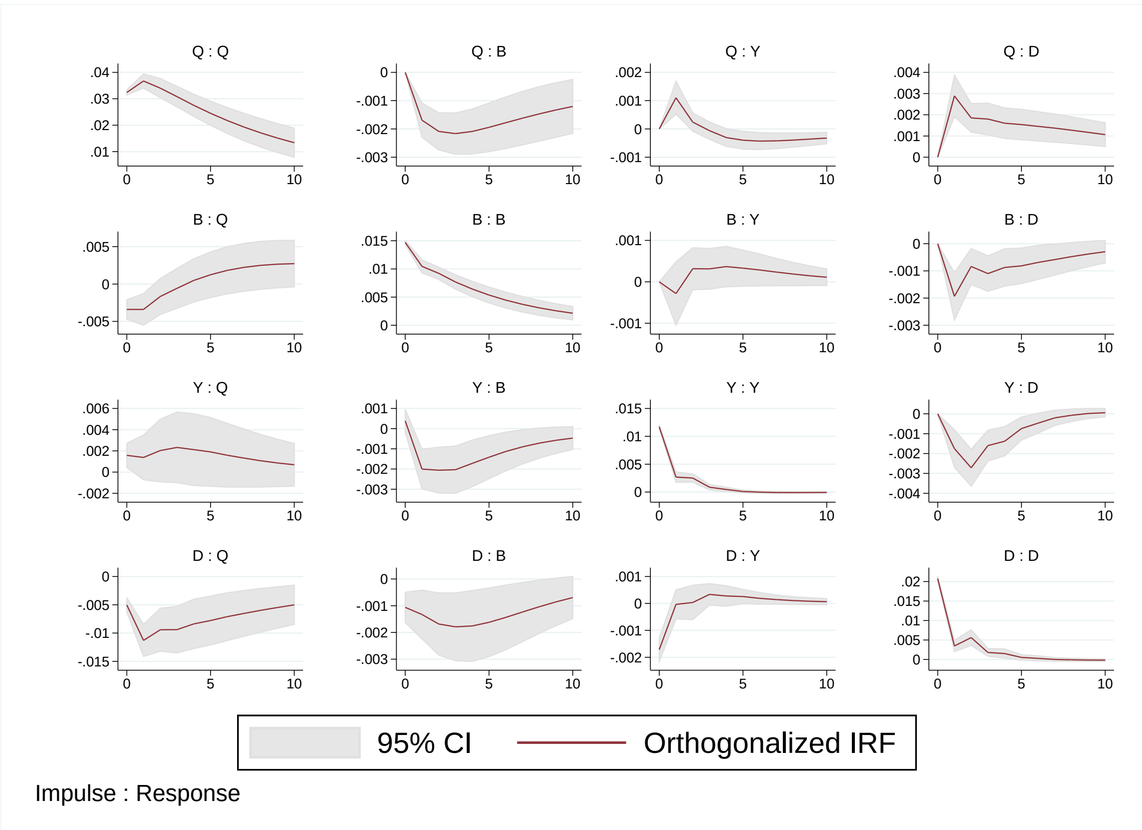


Figure A.4: Full set of orthogonalized impulse response functions for the comprehensive model with two lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws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

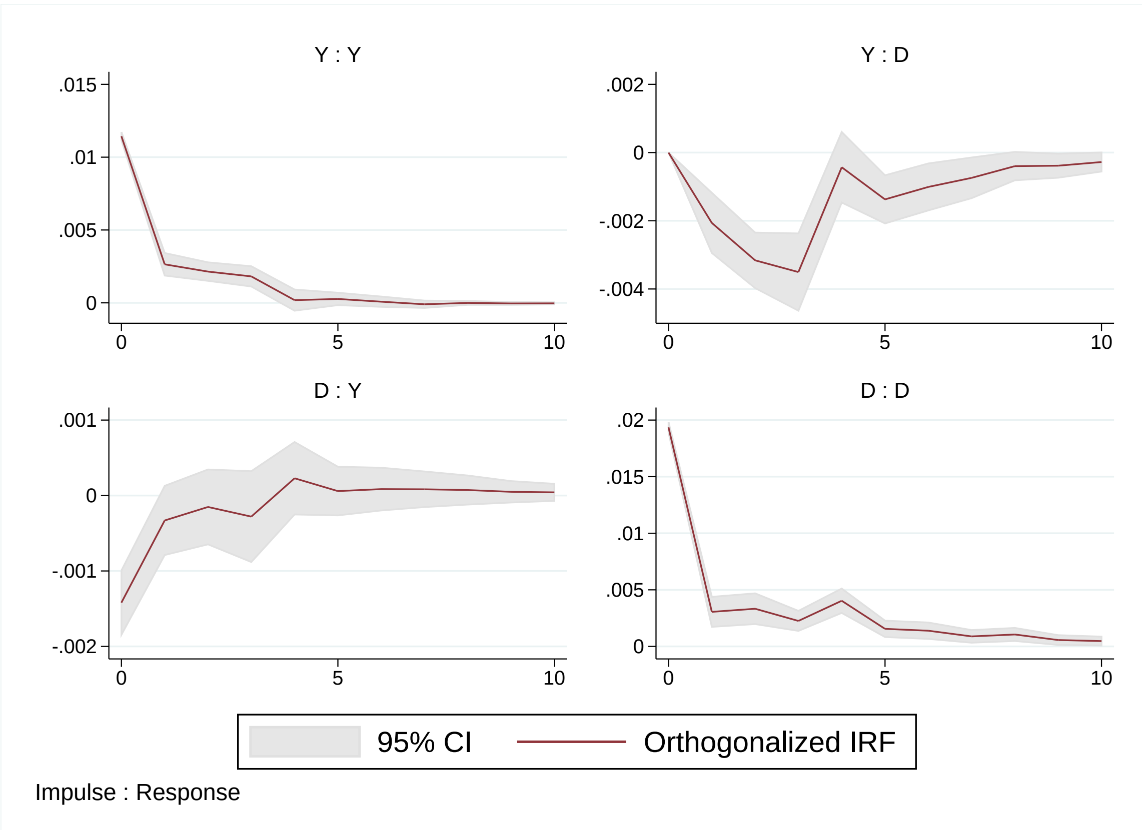


Figure A.5: Full set of orthogonalized impulse response functions for the parsimonious model with four lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws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

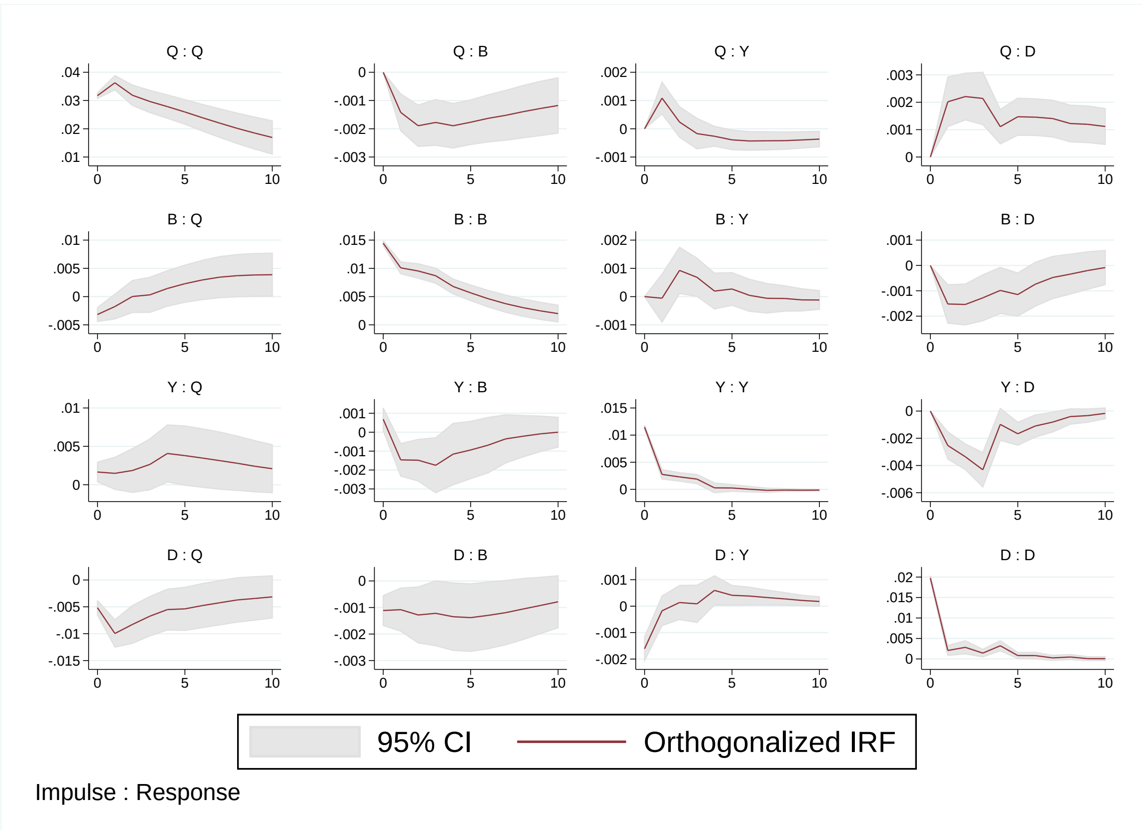


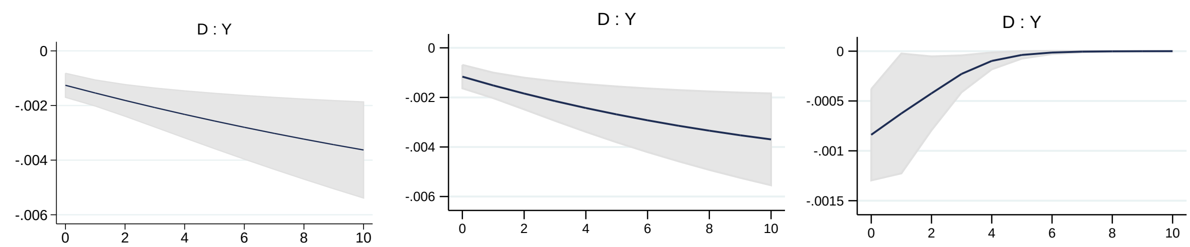
Figure A.6: Full set of orthogonalized impulse response functions for the comprehensive model with four lags, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws 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 excluded IRFs correspond to: (a) the use of trend-differenced variables instead of first differences, and *vice versa* (Figure A.7); (b) public debt on private bank debt with public debt ordered first (Figure A.8); and (c) the external account on debt for the full period instead of just after the 2008 crisis (Figure A.9).

We also include IRFs for debt shocks on growth using the parsimonious model for a number of subsamples. These include: (a) high versus low-debt countries (defined as above or below the median for total debt to GDP) (Figure A.10); (b) regions (economies from the Americas and Caribbean (AMC), East Asia and the Pacific (EAP), and Western and Eastern Europe (EUR)[51]) (Figure A.11); (c) income group (as defined in Table A.6) (Figure A.12); and (d) time period (pre- and post-crisis, and post-Great Recession) (Figure A.13).

Finally, we provide additional estimation details for the local projections whose impulse responses were shown in the main text. We report just the response variable of interest (output growth), with one-period lags of impulses from all endogenous variables, for just the initial impact period. Actual estimation entailed computing coefficients for all 10 periods in the projection horizon.



(a) Parsimonious (trend deviations) (b) Comprehensive (trend deviations) (c) Comprehensive (first differences)

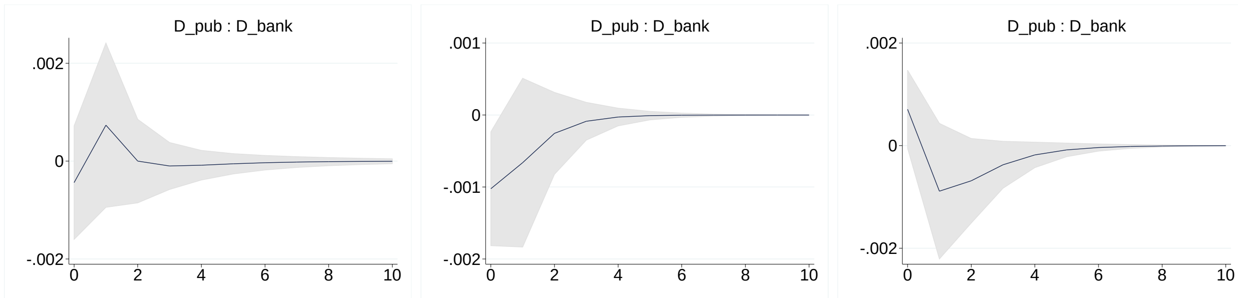
Figure A.7: Orthogonalized impulse response functions for debt on growth for the parsimonious and comprehensive model with trend deviations instead of first differences (top), and the comprehensive model with first differences instead of trend deviations (bottom), for one standard-deviation innovations, 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.

[51]We also considered a final region, the Middle East, Africa, and Subcontinent, comprised of the economies that were not included in the above groupings. However, this subsample resulted in a very small, unbalanced sample, and we were unable to generate IRFs in this case.

Table A.9: Estimates for local projections, parsimonious and comprehensive models, 1970Q1–2016Q3 (unbalanced)[†]

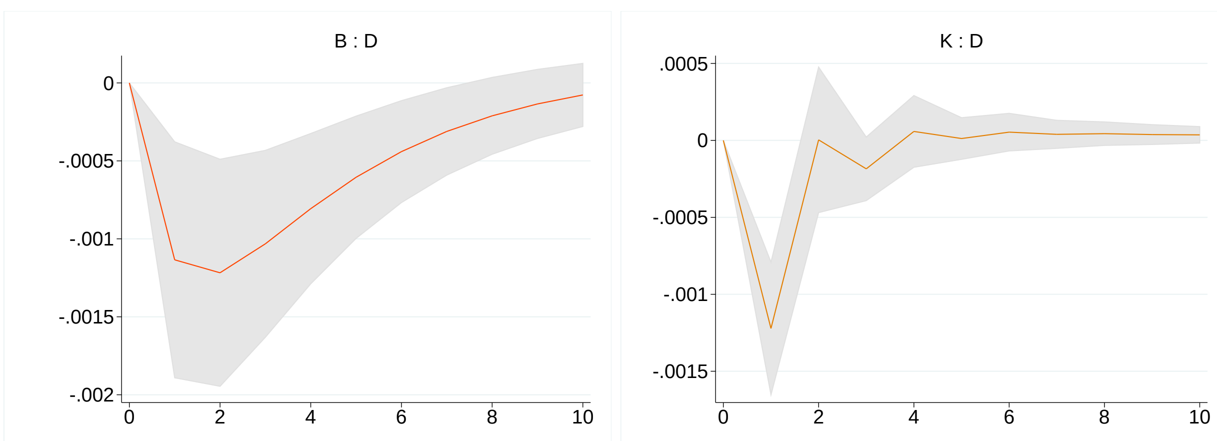
Response of	*Response to*			
	D_{t-1}	Y_{t-1}	B_{t-1}	Q_{t-1}
		Parsimonious		
Y_t	-0.029	-0.830		
	(0.02)	(0.04)***		
R^2 (overall)	0.365			
R^2 (within)	0.414			
Obs		3,215		
Ctry (Periods)		41 (78)		
		Comprehensive		
Y_t	-0.026	-0.829	-0.027	-0.024
	(0.02)	(0.04)***	(0.05)	(0.01)*
R^2 (overall)	0.382			
R^2 (within)	0.425			
Obs		2,600		
Ctry (Periods)		41 (63)		

[†] Panel VAR estimated via OLS with fixed effects. Coefficients correspond to the regression of output growth on lagged variables in each column; only the initial impact quarter is reported. Reported periods are averages, since the panel is unbalanced. Cluster-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.



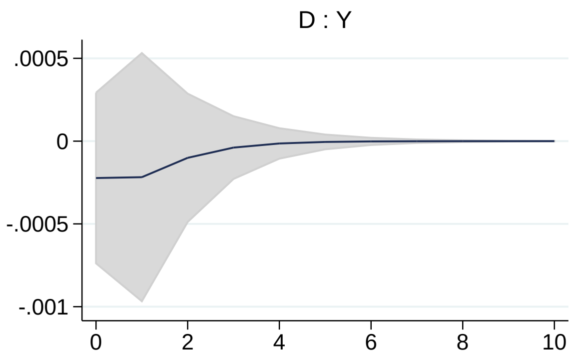
(a) Euro Area (b) All DMs (c) All countries

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.

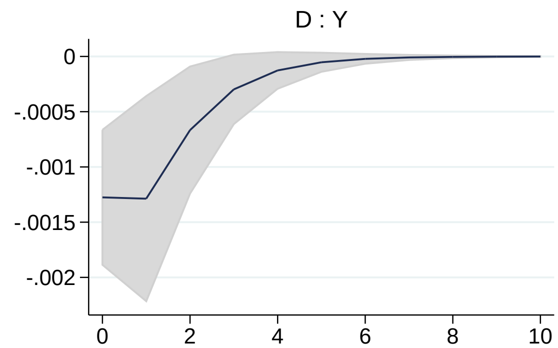


(a) Financial channel (full period) (b) Real channel (full period)

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.

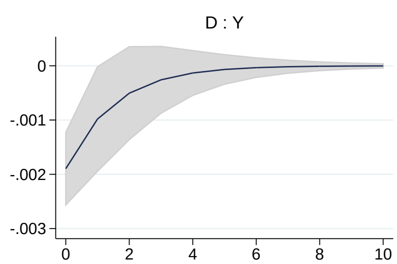


(a) High debt (subsample)

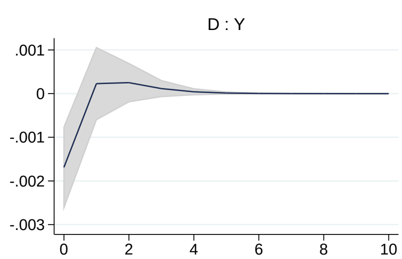


(b) Low debt (subsample)

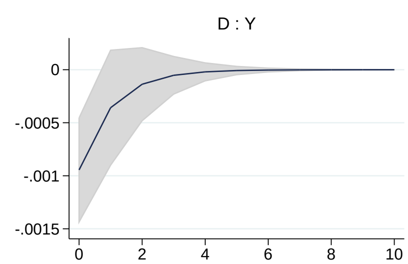
Figure A.10: Orthogonalized impulse response functions for the external account on debt for the parsimonious model for above-median (left) or below-median (right) total debt to GDP, for one standard-deviation innovations, 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. Economies with a low debt burden continue to exhibit the negative debt-growth response, and while this is also the case for high debt economies, the relationship is not statistically distinguishable from zero.



(a) AMC (subsample)

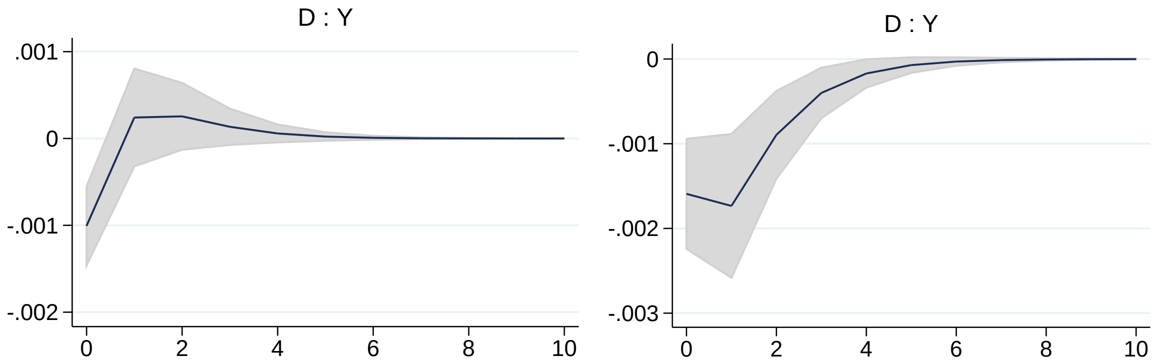


(b) EAP (subsample)



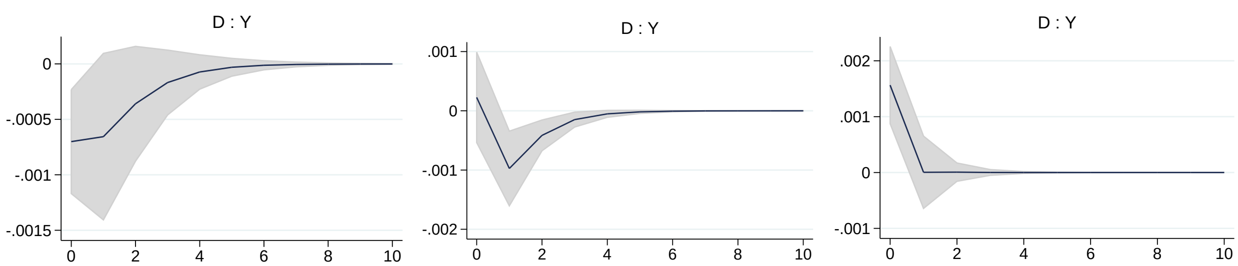
(c) EUR (subsample)

Figure A.11: Orthogonalized impulse response functions for the external account on debt for the parsimonious model for regional subsample groupings, for a one standard-deviation innovation in debt, for 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. All three regions exhibit a negative debt-growth relationship, although the impulse is least persistent in the EAP region, and half the magnitude in the EUR region.



(a) DM (subsample) (b) EM (subsample)

Figure A.12: Orthogonalized impulse response functions for the external account on debt for the parsimonious model for subsamples by income group, for a one standard-deviation innovation in debt, for 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 negative debt-growth relationship appears for both income groups, but is more persistent in the EM submsaple.



(a) pre-2007Q3 (subsample) (b) post-2008Q4 (subsample) (c) post-2010Q4 (subsample)

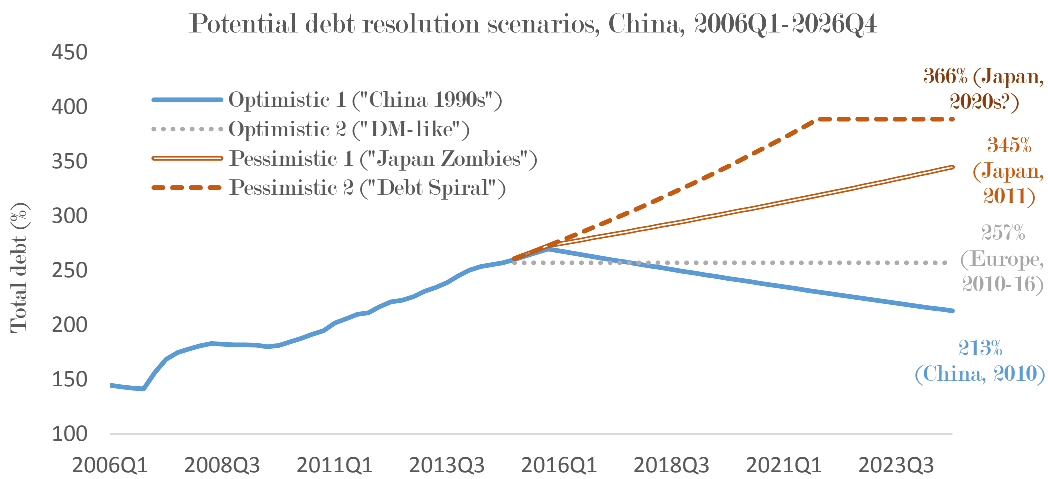
Figure A.13: Orthogonalized impulse response functions for the external account on debt for the parsimonious model for regional subsample groupings, for a one standard-deviation innovation in debt, for 10 quarters after the shock. The gray areas indicate the 95 percent confidence intervals generated using Gaussian approximation of 200 Monte Carlo draws from a fitted panel VAR. The negative effect holds for the precrisis and postcrisis subsamples, although only with a lag for the latter. The post-recession subsample actually exhibits a positive relationship.

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;[52] 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 *et al.* 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 is 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.



Source: Author's calculations, based on BIS (2017).
Notes: Optimistic 1 scenario assumes 2016 debt growth rate for 2017, followed by debt reduction at 1996-2006 historical rate of accumulation; Optimistic 2 assumes maintenance of current debt ratio; Pessimistic 1 assumes 2006-16 rate for 2017, before reversion of growth to 1996-06 rate with no contraction; Pessimistic 2 assumes 2006-16 rate for 2017 through 2023, before stabilization at

Figure A.14: 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).

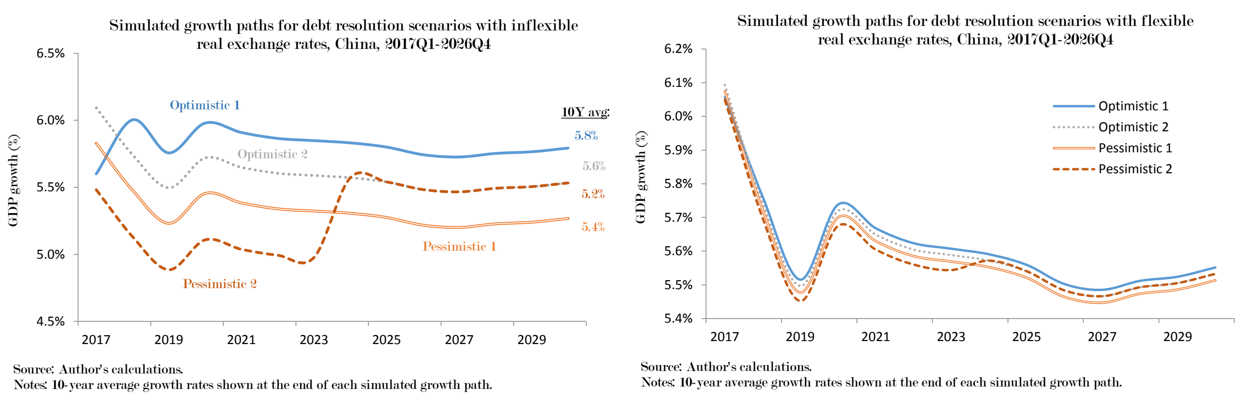
[52]Successful resolution along these lines is consistent with the implementation of the "comprehensive and proactive" debt resolution strategy outlined by authors such as Maliszewski *et al.* (2016).

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.10, as well as Figure A.15.

Table A.10: Simulated growth effects of alternative debt resolution scenarios for China, 2017Q1–2026Q4†

	Optim. 1	*Optim. 2*	*Pessim. 1*	*Pessim. 2*
	Parsimonious			
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.14. 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.



(a) Inflexible exchange rate

(b) Flexible exchange rate

Figure A.15: 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.

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 rate regime.