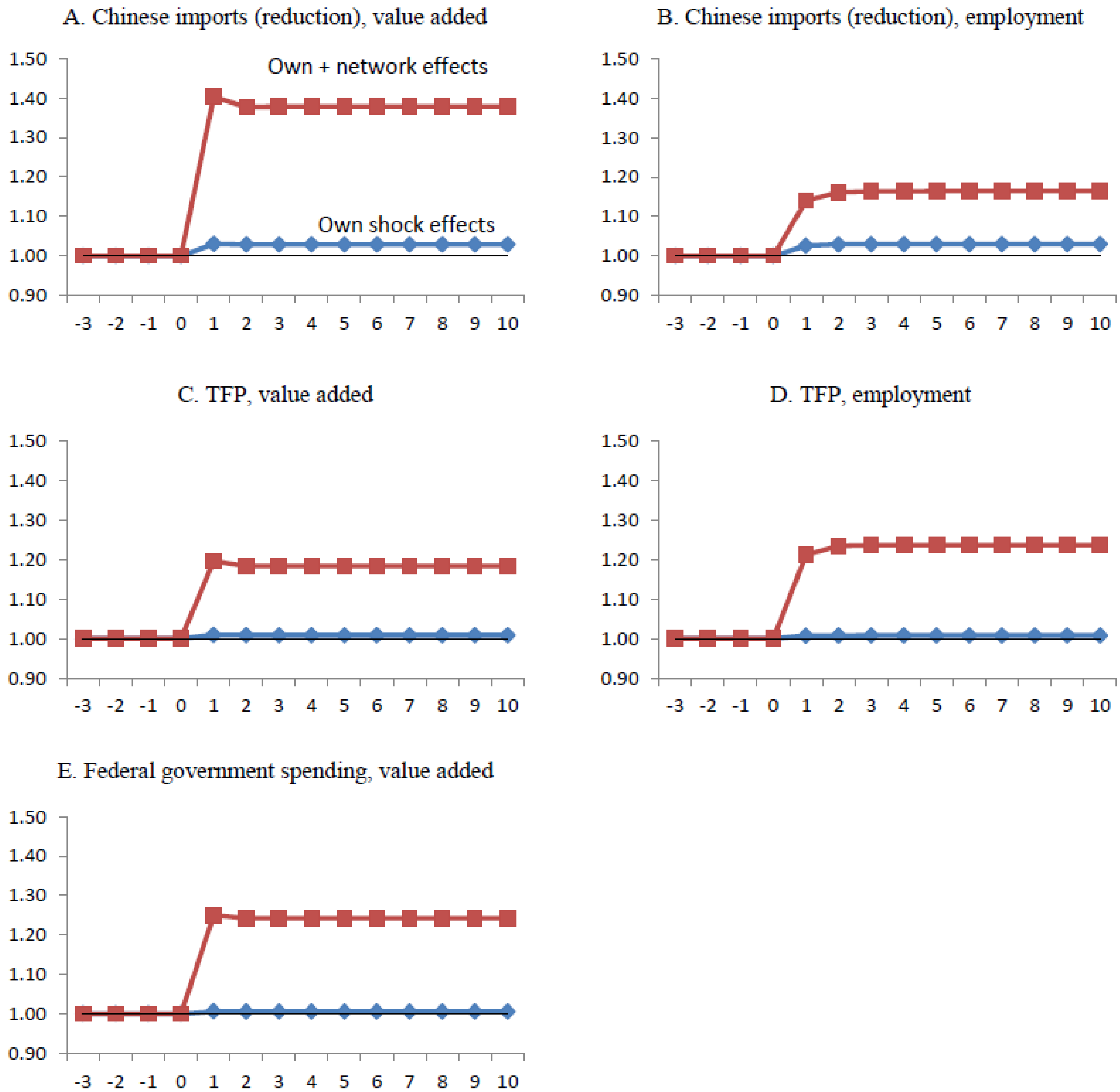
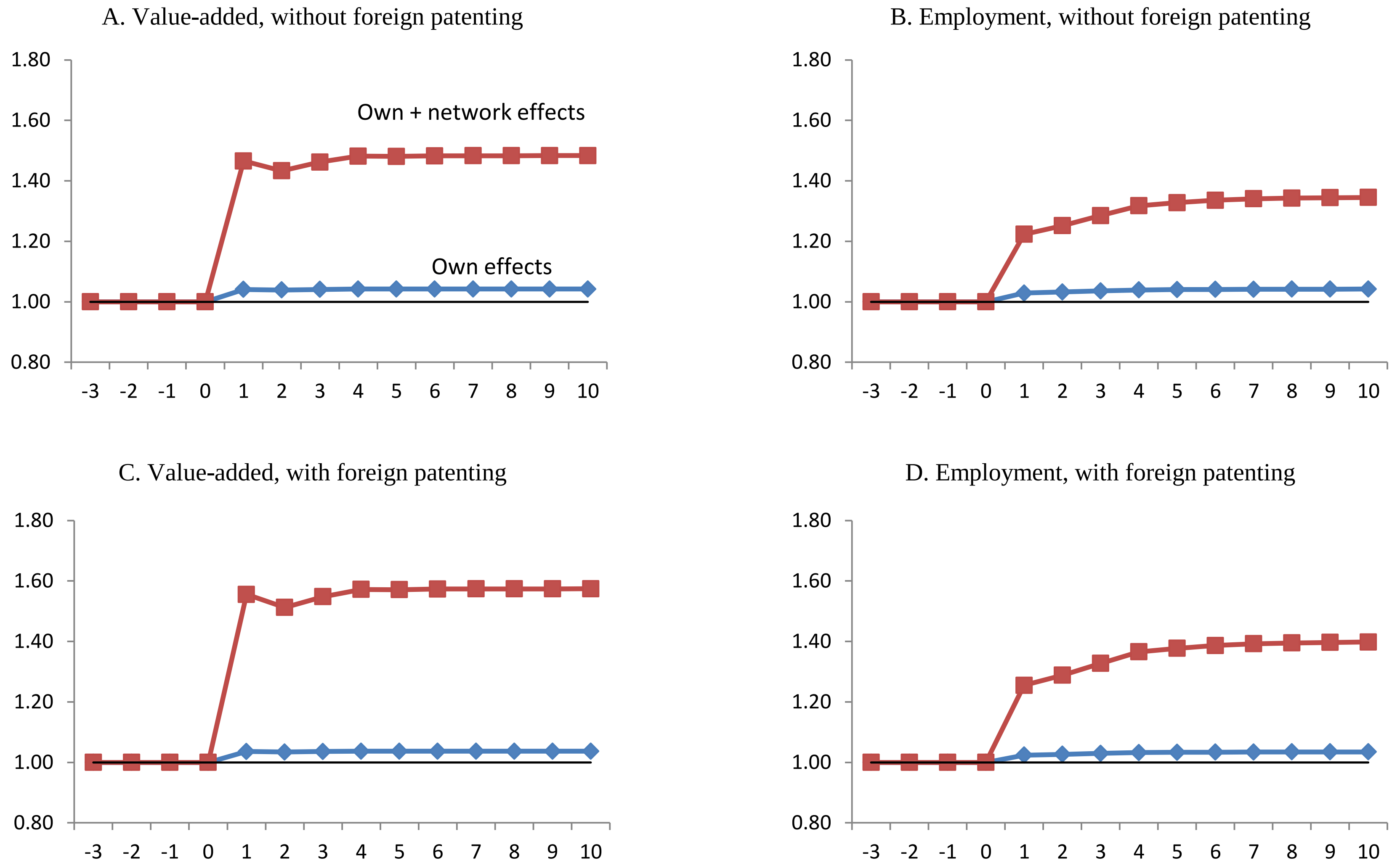
Appendix B: Tables and Figures

Appendix Figure 1: VAR responses to a one standard-deviation shock taken in isolation



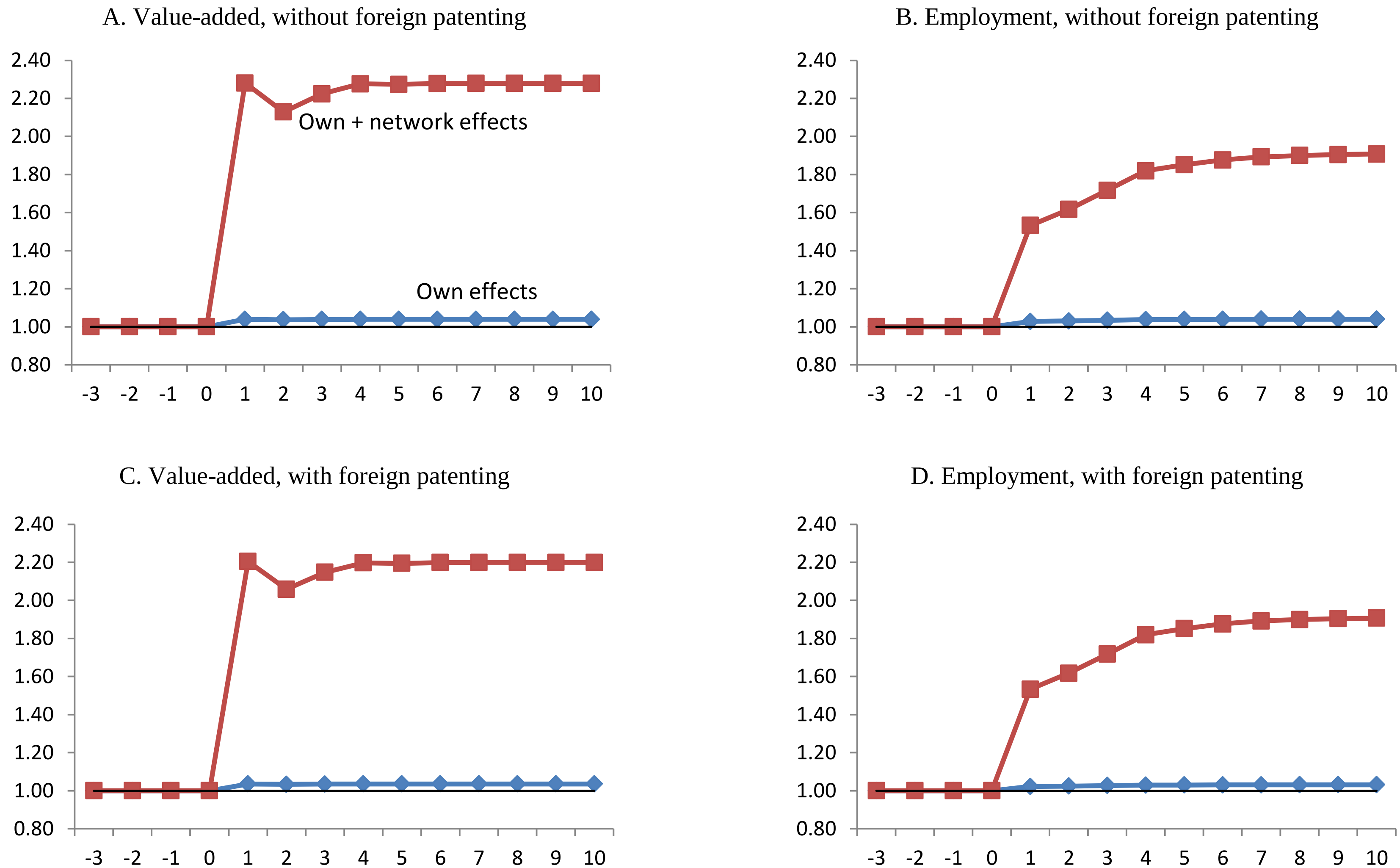
Notes: See Figure 1a. Figure plots estimated intermediated network effects akin to a VAR analysis. Estimations use upstream and downstream shocks in instrumental variable specifications where the endogenous regressor is the lagged actual value-added or employment change in the network. Results with foreign patenting and employment for federal spending are excluded.

Appendix Figure 2: Combined response to joint one standard-deviation shocks



Notes: See Figure 1a. Figure plots estimated response to joint one-time standard-deviation shocks. Panels A and B exclude foreign patenting, which has a negative own effect, while Panels C and D include it.

Appendix Figure 3: Combined response to joint one standard-deviation shocks with geographic effects



Notes: See Figures 1a and Appendix Figure 2. Figure plots estimated response to joint one-time standard-deviation shocks that includes geographic effects.

Appendix Table 1: First-stage relationships for Chinese imports instruments

	Real value-added growth, one lag			Real value-added growth, three lags		
	Downstream effects t-1	Upstream effects t-1	Own effects t-1	Downstream effects t-1	Upstream effects t-1	Own effects t-1
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Log real value added t-1	-0.012***	-0.014	-0.008	-0.013***	-0.015	-0.023
	(0.004)	(0.010)	(0.084)	(0.005)	(0.011)	(0.082)
Δ Log real value added t-2				-0.004	0.032**	-0.027
				(0.005)	(0.015)	(0.068)
Δ Log real value added t-3				-0.005	0.004	-0.018
				(0.005)	(0.013)	(0.080)
IV Downstream effects t-1	0.638***	0.101**	0.832**	0.640***	0.110**	0.835**
	(0.041)	(0.044)	(0.368)	(0.041)	(0.045)	(0.364)
IV Upstream effects t-1	0.005	0.886***	-0.244**	0.005	0.879***	-0.237***
	(0.009)	(0.045)	(0.076)	(0.009)	(0.045)	(0.077)
IV Own effects t-1	-0.001	-0.008***	0.461***	-0.001	-0.009***	0.458***
	(0.002)	(0.003)	(0.075)	(0.002)	(0.003)	(0.073)
Shea's Partial R-Squared	0.361	0.514	0.224	0.360	0.509	0.222

Notes: See Table 2a.

Appendix Table 2a: Robustness checks on China trade shock analysis using real shipments growth

	Baseline estimation	Excluding own lagged shock	Weighting by 1991 log value added	Weighting by 1991 employees	Adding SIC2 fixed effects	Adding SIC3 fixed effects	Adding SIC4 fixed effects	Adding resource constraints
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Δ Log real shipments							
Δ Dependent variable t-1	0.176***	0.179***	0.182***	0.332***	0.140***	0.103***	0.061***	0.173***
	(0.026)	(0.026)	(0.028)	(0.065)	(0.026)	(0.024)	(0.021)	(0.027)
Downstream effects t-1	-0.140**	-0.067	-0.147**	-0.186**	-0.025	0.084	0.128	-0.176
	(0.059)	(0.055)	(0.060)	(0.091)	(0.076)	(0.076)	(0.098)	(0.067)
Upstream effects t-1	0.054***	0.048***	0.055***	0.045*	0.034*	0.033	0.031	0.098***
	(0.019)	(0.019)	(0.019)	(0.024)	(0.020)	(0.026)	(0.035)	(0.037)
Own effects t-1	0.021***		0.020***	0.018	0.007	0.004	0.002	0.018***
	(0.006)		(0.006)	(0.011)	(0.006)	(0.007)	(0.010)	(0.006)
Observations	6560	6560	6560	6560	6560	6560	6560	6560
p-value: Upstream=Own	0.068		0.053	0.143	0.154	0.272	0.460	0.027

Notes: See Table 2a.

Appendix Table 2b: Variations in psi parameter for China trade shock analysis

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
						A. Δ Log real value added					
Downstream effects t-1	-0.146*	-0.116	-0.086	-0.056	-0.026	0.004	0.034	0.065	0.095	0.125	0.155*
	(0.087)	(0.083)	(0.080)	(0.078)	(0.076)	(0.074)	(0.074)	(0.074)	(0.075)	(0.077)	(0.080)
Upstream effects t-1	0.077***	0.073***	0.069***	0.064***	0.060***	0.056***	0.052***	0.048***	0.043**	0.039**	0.035*
	(0.024)	(0.022)	(0.021)	(0.020)	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Own effects t-1	0.034***	0.033***	0.033***	0.032***	0.032***	0.031***	0.031***	0.030***	0.030***	0.029***	0.029***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)
						B. Δ Log employment					
Downstream effects t-1	-0.073	-0.062	-0.050	-0.038	-0.027	-0.015	-0.003	0.008	0.020	0.032	0.043
	(0.046)	(0.042)	(0.039)	(0.037)	(0.035)	(0.034)	(0.034)	(0.035)	(0.036)	(0.039)	(0.042)
Upstream effects t-1	0.056***	0.052***	0.047***	0.042***	0.038***	0.033***	0.028***	0.024**	0.019**	0.014	0.010
	(0.018)	(0.017)	(0.016)	(0.014)	(0.013)	(0.012)	(0.011)	(0.010)	(0.009)	(0.009)	(0.009)
Own effects t-1	0.026***	0.024***	0.022***	0.020***	0.018***	0.016***	0.014***	0.012***	0.010***	0.008**	0.006
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)

Notes: See Table 2a. Estimations impose the psi parameter for the lagged dependent variable dependence given in the column header.

Appendix Table 2c: Longer changes on China trade shock analysis

	Baseline annual analysis	Using two-year periods	Using three-year periods	Using four-year periods	Using five-year periods
	(1)	(2)	(3)	(4)	(5)
			A. Δ Log real value added		
Δ Dependent variable t-1	0.019	0.085**	0.092*	0.027	0.072
	(0.025)	(0.037)	(0.047)	(0.056)	(0.076)
Downstream effects t-1	-0.140	-0.323***	-0.417**	-1.549***	-1.092
	(0.086)	(0.120)	(0.198)	(0.348)	(0.671)
Upstream effects t-1	0.076***	0.089***	0.149***	0.292***	0.719***
	(0.024)	(0.024)	(0.040)	(0.067)	(0.175)
Own effects t-1	0.034***	0.041***	0.087***	0.118***	0.153***
	(0.009)	(0.010)	(0.017)	(0.029)	(0.054)
Observations	6560	3080	1920	1152	768
p-value: Upstream=Own	0.071	0.035	0.093	0.005	0.001
			B. Δ Log employment		
Δ Dependent variable t-1	0.149***	0.242***	0.284***	0.266***	0.297***
	(0.020)	(0.028)	(0.041)	(0.047)	(0.058)
Downstream effects t-1	-0.056	-0.041	-0.207***	-0.055	0.685*
	(0.040)	(0.058)	(0.076)	(0.221)	(0.408)
Upstream effects t-1	0.049***	0.063***	0.100***	0.215***	0.655***
	(0.016)	(0.019)	(0.027)	(0.060)	(0.160)
Own effects t-1	0.023***	0.036***	0.067***	0.102***	0.111***
	(0.005)	(0.008)	(0.012)	(0.027)	(0.039)
Observations	6560	3080	1920	1152	768
p-value: Upstream=Own	0.086	0.138	0.172	0.066	0.001

Notes: See Table 2a. All sample periods start with 1991 and extend as far as data allow. For example, Column 5 effectively considers 1996-2001 and 2001-2006, with lags extending back to 1991-1996.

Appendix Table 3a: Robustness checks on federal spending shock analysis using real shipments growth

	Baseline estimation	Excluding own lagged shock	Weighting by 1991 log value added	Weighting by 1991 employees	Adding SIC2 fixed effects	Adding SIC3 fixed effects	Adding SIC4 fixed effects	Adding resource constraints
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Δ Log real shipments				
Δ Dependent variable t-1	0.178***	0.178***	0.184***	0.334***	0.138***	0.101***	0.058***	0.178***
	(0.026)	(0.026)	(0.027)	(0.061)	(0.026)	(0.026)	(0.021)	(0.026)
Downstream effects t-1	-0.002	0.019	-0.003	-0.002	-0.022	0.011	-0.025	0.000
	(0.018)	(0.016)	(0.017)	(0.009)	(0.018)	(0.019)	(0.046)	(0.018)
Upstream effects t-1	0.022***	0.022***	0.021***	0.024**	0.013*	0.024*	0.055***	0.017*
	(0.008)	(0.008)	(0.008)	(0.010)	(0.007)	(0.013)	(0.019)	(0.010)
Own effects t-1	0.005*		0.004*	0.001	0.003	0.007	0.010	0.005*
	(0.003)		(0.003)	(0.001)	(0.003)	(0.005)	(0.010)	(0.003)
Observations	6560	6560	6560	6560	6560	6560	6560	6560
p-value: Upstream=Own	0.063		0.065	0.019	0.304	0.211	0.055	0.259

Notes: See Table 3a.

Appendix Table 3b: Variations in psi parameter for federal spending shock analysis

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
						A. Δ Log real value added					
Downstream effects t-1	0.017	0.016	0.014	0.012	0.010	0.009	0.007	0.005	0.004	0.002	0.000
	(0.022)	(0.020)	(0.018)	(0.016)	(0.014)	(0.012)	(0.011)	(0.009)	(0.008)	(0.008)	(0.008)
Upstream effects t-1	0.022**	0.020**	0.018**	0.017**	0.015**	0.013**	0.011**	0.009**	0.007**	0.005*	0.004
	(0.010)	(0.009)	(0.008)	(0.007)	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)
Own effects t-1	0.004	0.004	0.003	0.003	0.003	0.003	0.002*	0.002**	0.002**	0.001**	0.001
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
						B. Δ Log employment					
Downstream effects t-1	0.009	0.008	0.007	0.006	0.005	0.004	0.003	0.002	0.001	0.000	-0.001
	(0.016)	(0.015)	(0.014)	(0.013)	(0.012)	(0.011)	(0.010)	(0.009)	(0.008)	(0.008)	(0.007)
Upstream effects t-1	0.011	0.010*	0.009*	0.009*	0.008*	0.007*	0.007*	0.006*	0.005*	0.004*	0.004
	(0.007)	(0.006)	(0.006)	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Own effects t-1	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002*	0.002**	0.002***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)

Notes: See Table 3a. Estimations impose the psi parameter for the lagged dependent variable dependence given in the column header.

Appendix Table 3c: Longer changes on federal spending shock analysis

	Baseline annual analysis	Using two-year periods	Using three-year periods	Using four-year periods	Using five-year periods
	(1)	(2)	(3)	(4)	(5)
			A. Δ Log real value added		
Δ Dependent variable t-1	0.019	0.094**	0.114**	0.083	0.138*
	(0.025)	(0.037)	(0.048)	(0.059)	(0.072)
Downstream effects t-1	0.017	0.031	0.094*	0.197**	0.122
	(0.021)	(0.033)	(0.054)	(0.095)	(0.130)
Upstream effects t-1	0.022**	0.020	0.037*	0.056	-0.009
	(0.009)	(0.014)	(0.021)	(0.039)	(0.051)
Own effects t-1	0.004	0.013***	0.023**	0.011	0.017
	(0.003)	(0.005)	(0.010)	(0.016)	(0.016)
Observations	6560	3080	1920	1152	768
p-value: Upstream=Own	0.076	0.634	0.569	0.286	0.657
			B. Δ Log employment		
Δ Dependent variable t-1	0.158***	0.264***	0.332***	0.346***	0.379***
	(0.021)	(0.027)	(0.040)	(0.047)	(0.054)
Downstream effects t-1	0.007	0.029	0.051	0.044	0.176*
	(0.015)	(0.021)	(0.032)	(0.044)	(0.102)
Upstream effects t-1	0.010*	0.018**	0.040***	0.063***	-0.025
	(0.006)	(0.008)	(0.013)	(0.023)	(0.036)
Own effects t-1	0.003	0.006*	0.015***	0.022***	0.036***
	(0.003)	(0.004)	(0.006)	(0.008)	(0.013)
Observations	6560	3080	1920	1152	768
p-value: Upstream=Own	0.321	0.214	0.088	0.103	0.144

Notes: See Table 3a.

Appendix Table 4a: Robustness checks on TFP shock analysis using real shipments growth

	Baseline estimation	Excluding own lagged shock	Weighting by 1991 log value added	Weighting by 1991 employees	Adding SIC2 fixed effects	Adding SIC3 fixed effects	Adding SIC4 fixed effects
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Δ Log real shipments			
Δ Dependent variable t-1	0.226***	0.164***	0.231***	0.307***	0.168***	0.122***	0.088***
	(0.026)	(0.024)	(0.026)	(0.045)	(0.026)	(0.027)	(0.027)
Downstream effects t-1	0.054***	0.048***	0.055***	0.065***	0.037**	0.026*	0.026*
	(0.017)	(0.017)	(0.017)	(0.023)	(0.016)	(0.014)	(0.014)
Upstream effects t-1	0.012	0.010	0.013	0.039***	0.008	0.004	0.006
	(0.010)	(0.010)	(0.010)	(0.012)	(0.009)	(0.011)	(0.011)
Own effects t-1	-0.012***		-0.011***	-0.004	-0.007*	-0.005	-0.006*
	(0.004)		(0.004)	(0.009)	(0.004)	(0.004)	(0.003)
Observations	6560	6560	6560	6560	6560	6560	6560
p-value: Downstream=Own	0.000		0.000	0.034	0.014	0.134	0.008

Notes: See Table 4a.

Appendix Table 4b: Variations in psi parameter for TFP shock analysis

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
						A. Δ Log real value added					
Downstream effects t-1	0.059***	0.054***	0.050**	0.045**	0.040*	0.035	0.031	0.026	0.021	0.017	0.012
	(0.020)	(0.020)	(0.020)	(0.021)	(0.021)	(0.022)	(0.022)	(0.023)	(0.024)	(0.024)	(0.025)
Upstream effects t-1	0.023**	0.021*	0.019*	0.017	0.015	0.013	0.011	0.008	0.006	0.004	0.002
	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)	(0.013)	(0.014)
Own effects t-1	0.002	-0.011***	-0.023***	-0.035***	-0.047***	-0.059***	-0.072***	-0.084***	-0.096***	-0.108***	-0.120***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
						B. Δ Log employment					
Downstream effects t-1	0.018*	0.017*	0.016*	0.015	0.013	0.012	0.011	0.010	0.009	0.007	0.006
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)	(0.011)	(0.011)
Upstream effects t-1	0.010	0.009	0.009	0.008	0.007	0.006	0.005	0.004	0.003	0.003	0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
Own effects t-1	0.010***	0.007***	0.005***	0.003	0.000	-0.002	-0.004**	-0.007***	-0.009***	-0.011***	-0.014***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)

Notes: See Table 4a. Estimations impose the psi parameter for the lagged dependent variable dependence given in the column header.

Appendix Table 4c: Longer changes on TFP shock analysis

	Baseline annual analysis	Using two-year periods	Using three-year periods	Using four-year periods	Using five-year periods
	(1)	(2)	(3)	(4)	(5)
			A. Δ Log real value added		
Δ Dependent variable t-1	-0.024	0.067	0.157***	0.123*	0.125*
	(0.040)	(0.047)	(0.056)	(0.069)	(0.068)
Downstream effects t-1	0.060***	0.189***	0.118*	0.253***	0.269**
	(0.020)	(0.047)	(0.067)	(0.089)	(0.104)
Upstream effects t-1	0.024**	0.033	0.041	-0.055	-0.077
	(0.011)	(0.021)	(0.036)	(0.050)	(0.056)
Own effects t-1	0.004	-0.004	-0.027	-0.032	-0.016
	(0.007)	(0.013)	(0.022)	(0.031)	(0.037)
Observations	6560	3080	1920	1152	768
p-value: Downstream=Own	0.005	0.000	0.092	0.006	0.025
			B. Δ Log employment		
Δ Dependent variable t-1	0.141***	0.252***	0.336***	0.349***	0.363***
	(0.021)	(0.028)	(0.042)	(0.047)	(0.054)
Downstream effects t-1	0.016*	0.015	-0.016	0.032	0.053
	(0.009)	(0.022)	(0.027)	(0.036)	(0.053)
Upstream effects t-1	0.009	0.017	0.021	-0.069**	-0.099**
	(0.006)	(0.010)	(0.018)	(0.033)	(0.039)
Own effects t-1	0.006***	0.006	-0.004	-0.011	-0.016
	(0.002)	(0.004)	(0.006)	(0.008)	(0.014)
Observations	6560	3080	1920	1152	768
p-value: Downstream=Own	0.041	0.485	0.690	0.169	0.217

Notes: See Table 4a.

Appendix Table 5a: Robustness checks on foreign patent shock analysis using real shipments growth

	Baseline estimation	Excluding own lagged shock	Weighting by 1991 log value added	Weighting by 1991 employees	Adding SIC2 fixed effects	Adding SIC3 fixed effects	Adding SIC4 fixed effects
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Δ Log real shipments			
Δ Dependent variable t-1	0.181***	0.181***	0.187***	0.342***	0.139***	0.103***	0.060***
	(0.026)	(0.026)	(0.028)	(0.063)	(0.027)	(0.025)	(0.021)
Downstream effects t-1	0.022***	0.019**	0.022***	0.025	0.019**	0.017**	0.018**
	(0.008)	(0.008)	(0.008)	(0.019)	(0.008)	(0.008)	(0.008)
Upstream effects t-1	0.002	0.002	0.002	0.007	0.002	0.002	0.002
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)
Own effects t-1	-0.003		-0.003	0.004	-0.001	-0.001	-0.002
	(0.003)		(0.003)	(0.006)	(0.003)	(0.003)	(0.003)
Observations	6543	6543	6543	6543	6543	6543	6543
p-value: Downstream=Own	0.015		0.021	0.683	0.039	0.057	0.025

Notes: See Table 5a.

Appendix Table 5b: Variations in psi parameter for foreign patenting shock analysis

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
						A. Δ Log real value added					
Downstream effects t-1	0.043***	0.041***	0.039***	0.037***	0.036***	0.034***	0.032**	0.030**	0.028**	0.026*	0.024
	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.013)	(0.013)	(0.014)	(0.015)
Upstream effects t-1	-0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.004	0.005	0.005	0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.007)
Own effects t-1	-0.006	-0.005	-0.005	-0.004	-0.003	-0.002	-0.002	-0.001	-0.000	0.001	0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.006)
						B. Δ Log employment					
Downstream effects t-1	0.018***	0.018***	0.018***	0.018***	0.018***	0.018***	0.018***	0.018**	0.018**	0.018**	0.018**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
Upstream effects t-1	-0.002	-0.001	-0.001	0.000	0.001	0.001	0.002	0.003	0.003	0.004	0.004
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Own effects t-1	-0.009***	-0.008***	-0.007***	-0.006**	-0.006**	-0.005	-0.004	-0.003	-0.002	-0.001	-0.000
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)

Notes: See Table 5a. Estimations impose the psi parameter for the lagged dependent variable dependence given in the column header.

Appendix Table 5c: Longer changes on foreign patent shock analysis

	Baseline annual analysis	Using two-year periods	Using three-year periods	Using four-year periods	Using five-year periods
	(1)	(2)	(3)	(4)	(5)
			A. Δ Log real value added		
Δ Dependent variable t-1	0.020	0.099***	0.113**	0.075	0.133*
	(0.025)	(0.038)	(0.050)	(0.060)	(0.071)
Downstream effects t-1	0.043***	-0.032	0.040	0.088	-0.012
	(0.011)	(0.023)	(0.034)	(0.064)	(0.067)
Upstream effects t-1	-0.000	-0.020**	-0.013	0.004	0.014
	(0.005)	(0.009)	(0.012)	(0.018)	(0.021)
Own effects t-1	-0.006	0.012	-0.015	0.044*	0.004
	(0.004)	(0.011)	(0.017)	(0.023)	(0.033)
Observations	6543	3072	1915	1149	766
p-value: Downstream=Own	0.000	0.051	0.144	0.902	0.592
			B. Δ Log employment		
Δ Dependent variable t-1	0.159***	0.265***	0.330***	0.324***	0.347***
	(0.021)	(0.028)	(0.041)	(0.046)	(0.053)
Downstream effects t-1	0.018***	0.005	0.046**	0.104***	0.039
	(0.006)	(0.012)	(0.023)	(0.037)	(0.048)
Upstream effects t-1	-0.001	-0.011**	-0.009	0.005	0.006
	(0.003)	(0.005)	(0.008)	(0.012)	(0.015)
Own effects t-1	-0.008***	-0.002	-0.022**	-0.006	-0.006
	(0.003)	(0.007)	(0.010)	(0.015)	(0.030)
Observations	6543	3072	1915	1149	766
p-value: Downstream=Own	0.001	0.890	0.030	0.055	0.616

Notes: See Table 5a.

Appendix Table 6: Comparison of alternatives to real value added growth

	China trade shocks				Federal spending shocks			
	Δ Log real value added	Δ Log nominal value added	Δ Log real shipments	Δ Log nominal shipments	Δ Log real value added	Δ Log nominal value added	Δ Log real shipments	Δ Log nominal shipments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Dependent variable t-1	0.019	0.034*	0.176***	0.201***	0.019	0.034*	0.178***	0.201***
	(0.025)	(0.021)	(0.026)	(0.020)	(0.025)	(0.020)	(0.026)	(0.019)
Downstream effects t-1	-0.140	-0.013	-0.140**	-0.025	0.017	0.014	-0.002	-0.004
	(0.086)	(0.073)	(0.059)	(0.050)	(0.021)	(0.019)	(0.018)	(0.016)
Upstream effects t-1	0.076***	0.077***	0.054***	0.056***	0.022**	0.020**	0.022***	0.019**
	(0.024)	(0.025)	(0.019)	(0.021)	(0.009)	(0.009)	(0.008)	(0.008)
Own effects t-1	0.034***	0.044***	0.021***	0.029***	0.004	0.003	0.005*	0.004
	(0.009)	(0.011)	(0.006)	(0.007)	(0.003)	(0.003)	(0.003)	(0.002)
Observations	6560	6560	6560	6560	6560	6560	6560	6560

Notes: See Tables 2a-5a.

Appendix Table 6, continued

	TFP shocks				Foreign patenting shocks			
	Δ Log real value added	Δ Log nominal value added	Δ Log real shipments	Δ Log nominal shipments	Δ Log real value added	Δ Log nominal value added	Δ Log real shipments	Δ Log nominal shipments
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Dependent variable t-1	-0.024	0.058**	0.226***	0.246***	0.020	0.032	0.181***	0.201***
	(0.040)	(0.029)	(0.026)	(0.021)	(0.025)	(0.020)	(0.026)	(0.020)
Downstream effects t-1	0.060***	0.018	0.054***	0.026**	0.043***	0.037***	0.022***	0.018**
	(0.020)	(0.016)	(0.017)	(0.012)	(0.011)	(0.010)	(0.008)	(0.007)
Upstream effects t-1	0.024**	0.039***	0.012	0.031***	-0.000	-0.012***	0.002	-0.008**
	(0.011)	(0.011)	(0.010)	(0.008)	(0.005)	(0.005)	(0.004)	(0.003)
Own effects t-1	0.004	-0.008**	-0.012***	-0.013***	-0.006	-0.011***	-0.003	-0.007**
	(0.007)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Observations	6560	6560	6560	6560	6543	6543	6543	6543

Appendix Table 7: Summed coefficients over deeper lags

	Δ Log real value added				Δ Log employment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Include 3 lags of DV	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Include 3 lags of own shock		Yes		Yes		Yes		Yes
Include 3 lags of network shocks			Yes	Yes			Yes	Yes
Table 2a: Imports								
Downstream effects	-0.124	-0.121	-0.191*	-0.225**	-0.044	-0.040	-0.034	-0.065*
Upstream effects	0.076***	0.079***	0.069***	0.074***	0.039***	0.045***	0.038***	0.043***
Own effects	0.031***	0.042***	0.030***	0.046***	0.018***	0.029***	0.018***	0.032***
Table 3a: Federal Spending								
Downstream effects	0.023	0.023	0.042*	0.036*	0.013	0.013	0.015	0.015
Upstream effects	0.020**	0.020**	0.018**	0.018**	0.011**	0.011**	0.013***	0.013***
Own effects	0.008**	0.010***	0.008**	0.009***	0.006***	0.007***	0.006***	0.006***
Table 4a: TFP								
Downstream effects	0.047**	0.048**	0.085**	0.087**	0.011	0.012	-0.005	-0.003
Upstream effects	0.020*	0.019*	0.017	0.017	0.008	0.008	0.013	0.014*
Own effects	0.007	-0.001	0.007	-0.002	0.007***	0.005*	0.007***	0.006*
Table 5a: Foreign Patent								
Downstream effects	0.044***	0.043***	0.037*	0.030	0.018***	0.018***	0.022**	0.021**
Upstream effects	0.000	0.001	-0.014**	-0.014**	-0.000	0.000	-0.009**	-0.009**
Own effects	-0.007*	0.001	-0.007*	0.003	-0.006**	-0.004	-0.006**	-0.005

Notes: Table documents the sum of coefficients across variations of lag structure. Columns 1 and 5 are baseline specifications from respective tables.

Appendix Table 8: Joint analysis without foreign patenting shocks

		Δ Log real value added		Δ Log employment	
		(1)	(2)	(3)	(4)
Δ Dependent variable t-1		-0.040	-0.048	0.126***	0.105***
		(0.041)	(0.041)	(0.020)	(0.020)
Δ Dependent variable t-2			0.041*		0.108***
			(0.022)		(0.020)
Δ Dependent variable t-3			0.033		0.090***
			(0.021)		(0.016)
Trade:	Downstream effects t-1	-0.042	-0.025	-0.006	0.017
		(0.083)	(0.081)	(0.043)	(0.040)
	Upstream effects t-1	0.106***	0.107***	0.065***	0.054***
		(0.030)	(0.031)	(0.020)	(0.020)
	Own effects t-1	0.030***	0.028***	0.022***	0.016***
		(0.009)	(0.009)	(0.005)	(0.004)
Federal:	Downstream effects t-1	-0.003	0.001	-0.006	0.003
		(0.024)	(0.025)	(0.017)	(0.014)
	Upstream effects t-1	0.036**	0.041***	0.021**	0.023***
		(0.014)	(0.014)	(0.009)	(0.008)
	Own effects t-1	0.001	0.004	0.001	0.005*
		(0.003)	(0.004)	(0.003)	(0.003)
TFP:	Downstream effects t-1	0.061***	0.049**	0.019*	0.013
		(0.020)	(0.020)	(0.010)	(0.010)
	Upstream effects t-1	0.029**	0.027**	0.013*	0.011
		(0.013)	(0.013)	(0.007)	(0.008)
	Own effects t-1	0.007	0.009	0.007***	0.008***
		(0.007)	(0.007)	(0.002)	(0.002)
Observations		6560	5776	6560	5776

Notes: See Table 7.

Appendix Table 9a: Robustness checks on joint geographic analysis

		Baseline estimation	Excluding own lagged shock	Weighting by 1991 log value added	Weighting by 1991 employees	Adding SIC2 fixed effects	Adding SIC3 fixed effects	Adding SIC4 fixed effects
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		A. Δ Log real value added						
Δ Dependent variable t-1		-0.028	0.009	-0.027	-0.065	-0.074*	-0.120***	-0.139***
		(0.040)	(0.023)	(0.040)	(0.070)	(0.039)	(0.038)	(0.038)
Trade:	Geographic effects t-1	0.125***	0.121***	0.121***	0.068**	0.090***	0.074**	0.047
		(0.035)	(0.034)	(0.035)	(0.029)	(0.032)	(0.030)	(0.031)
	Own effects t-1	0.032***		0.031***	0.020*	0.020**	0.020**	0.023*
		(0.009)		(0.009)	(0.011)	(0.009)	(0.010)	(0.013)
Federal:	Geographic effects t-1	0.112***	0.112***	0.110***	0.063**	0.086***	0.075***	0.012
		(0.032)	(0.030)	(0.032)	(0.026)	(0.029)	(0.028)	(0.030)
	Own effects t-1	0.001		0.000	-0.001	-0.001	0.004	0.014
		(0.004)		(0.004)	(0.003)	(0.004)	(0.005)	(0.009)
TFP:	Geographic effects t-1	0.032***	0.032***	0.030***	0.011*	0.025***	0.022**	0.018**
		(0.010)	(0.010)	(0.010)	(0.006)	(0.010)	(0.009)	(0.009)
	Own effects t-1	0.008		0.008	0.031**	0.011*	0.015**	0.013**
		(0.006)		(0.007)	(0.014)	(0.006)	(0.006)	(0.005)
Patent:	Geographic effects t-1	0.005***	0.005***	0.005***	0.002***	0.005***	0.005***	0.004***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Own effects t-1	-0.002		-0.001	0.007	0.000	-0.000	-0.001
		(0.004)		(0.004)	(0.006)	(0.004)	(0.004)	(0.004)
Observations		6543	6560	6543	6543	6543	6543	6543

Notes: See Table 8.

Appendix Table 9a, continued

		Baseline estimation	Excluding own lagged shock	Weighting by 1991 log value added	Weighting by 1991 employees	Adding SIC2 fixed effects	Adding SIC3 fixed effects	Adding SIC4 fixed effects
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		B. Δ Log employment						
Δ Dependent variable t-1		0.130***	0.156***	0.135***	0.240***	0.081***	0.020	-0.019
		(0.021)	(0.020)	(0.020)	(0.034)	(0.021)	(0.019)	(0.019)
Trade:	Geographic effects t-1	0.055***	0.057***	0.053***	0.030**	0.027*	0.030*	0.036**
		(0.018)	(0.017)	(0.017)	(0.012)	(0.015)	(0.015)	(0.018)
	Own effects t-1	0.023***		0.023***	0.022***	0.011***	0.007*	0.004
		(0.005)		(0.005)	(0.007)	(0.004)	(0.004)	(0.004)
Federal:	Geographic effects t-1	0.046***	0.050***	0.043***	0.027***	0.022*	0.021	0.010
		(0.015)	(0.014)	(0.014)	(0.010)	(0.013)	(0.013)	(0.017)
	Own effects t-1	0.002		0.002	0.000	0.001	0.009**	0.021***
		(0.003)		(0.002)	(0.001)	(0.003)	(0.004)	(0.007)
TFP:	Geographic effects t-1	0.014***	0.014***	0.013***	0.006**	0.008*	0.009*	0.011**
		(0.005)	(0.005)	(0.005)	(0.003)	(0.005)	(0.005)	(0.005)
	Own effects t-1	0.008***		0.008***	0.006***	0.008***	0.009***	0.010***
		(0.002)		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Patent:	Geographic effects t-1	0.001	0.001	0.001	0.001	0.001	0.001	0.000
		(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
	Own effects t-1	-0.005**		-0.005**	-0.002	-0.003	-0.002	-0.002
		(0.003)		(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Observations		6543	6560	6543	6543	6543	6543	6543

Notes: See Table 8.

Appendix Table 9b: Geographic effects and networks analysis with single shocks

		Δ Log real value added							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Dependent variable t-1		0.022	0.019	0.018	0.017	-0.013	-0.024	0.021	0.020
		(0.025)	(0.025)	(0.024)	(0.024)	(0.040)	(0.040)	(0.025)	(0.025)
Trade:	Geographic effects t-1	0.001	0.002						
		(0.007)	(0.007)						
	Downstream effects t-1		-0.142*						
			(0.086)						
	Upstream effects t-1		0.076***						
			(0.024)						
	Own effects t-1	0.032***	0.034***						
		(0.009)	(0.009)						
Federal:	Geographic effects t-1			0.021**	0.018**				
				(0.009)	(0.009)				
	Downstream effects t-1				0.005				
					(0.021)				
	Upstream effects t-1				0.018**				
					(0.008)				
	Own effects t-1			0.004	0.003				
				(0.003)	(0.003)				
TFP:	Geographic effects t-1					0.005	0.003		
						(0.005)	(0.005)		
	Downstream effects t-1						0.060***		
							(0.020)		
	Upstream effects t-1						0.023**		
							(0.011)		
	Own effects t-1					0.007	0.004		
						(0.007)	(0.007)		
Patent:	Geographic effects t-1							0.004***	0.003***
								(0.001)	(0.001)
	Downstream effects t-1								0.041***
									(0.011)
	Upstream effects t-1								-0.001
									(0.004)
	Own effects t-1							-0.002	-0.006
								(0.004)	(0.004)
Observations		6560	6560	6560	6560	6560	6560	6543	6543

Notes: See Table 8.

Appendix Table 9b, continued

		Δ Log employment							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Dependent variable t-1		0.152***	0.149***	0.159***	0.158***	0.142***	0.141***	0.159***	0.159***
		(0.020)	(0.020)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Trade:	Geographic effects t-1	0.004	0.004						
		(0.004)	(0.004)						
	Downstream effects t-1		-0.059						
			(0.041)						
	Upstream effects t-1		0.049***						
			(0.016)						
	Own effects t-1	0.022***	0.023***						
		(0.005)	(0.005)						
Federal:	Geographic effects t-1			0.005	0.004				
				(0.003)	(0.003)				
	Downstream effects t-1				0.005				
					(0.014)				
	Upstream effects t-1				0.009				
					(0.006)				
	Own effects t-1			0.003	0.003				
				(0.002)	(0.003)				
TFP:	Geographic effects t-1					0.003	0.002		
						(0.003)	(0.003)		
	Downstream effects t-1						0.016*		
							(0.009)		
	Upstream effects t-1						0.009		
							(0.006)		
	Own effects t-1					0.007***	0.006***		
						(0.002)	(0.002)		
Patent:	Geographic effects t-1							0.000	0.000
								(0.001)	(0.001)
	Downstream effects t-1								0.018***
									(0.006)
	Upstream effects t-1								-0.001
									(0.003)
	Own effects t-1							-0.006**	-0.008***
								(0.003)	(0.003)
Observations		6560	6560	6560	6560	6560	6560	6543	6543

Notes: See Table 8.

Appendix Table 9c: Joint estimates with three lags of dependent variable

		Δ Log real value added		Δ Log employment	
		(1)	(2)	(3)	(4)
Δ Dependent variable t-1		-0.052	-0.055	0.103***	0.103***
		(0.041)	(0.042)	(0.020)	(0.019)
Δ Dependent variable t-2		0.032	0.033	0.106***	0.106***
		(0.021)	(0.021)	(0.019)	(0.019)
Δ Dependent variable t-3		0.022	0.023	0.089***	0.088***
		(0.019)	(0.019)	(0.016)	(0.016)
Trade:	Geographic effects t-1	0.193***	0.147***	0.074***	0.066***
		(0.044)	(0.039)	(0.021)	(0.019)
	Downstream effects t-1	-0.006	-0.027	0.021	0.012
		(0.076)	(0.076)	(0.041)	(0.041)
	Upstream effects t-1	0.090***	0.095***	0.048**	0.049***
		(0.030)	(0.030)	(0.019)	(0.019)
	Own effects t-1	0.029***	0.031***	0.017***	0.017***
		(0.009)	(0.009)	(0.004)	(0.004)
Federal:	Geographic effects t-1	0.178***	0.134***	0.063***	0.055***
		(0.040)	(0.036)	(0.019)	(0.017)
	Downstream effects t-1	-0.048*	-0.041*	-0.012	-0.012
		(0.025)	(0.025)	(0.015)	(0.015)
	Upstream effects t-1	0.028**	0.030**	0.020**	0.020**
		(0.013)	(0.013)	(0.008)	(0.008)
	Own effects t-1	0.002	0.002	0.004	0.004
		(0.005)	(0.004)	(0.003)	(0.003)
TFP:	Geographic effects t-1	0.047***	0.044***	0.020***	0.020***
		(0.013)	(0.013)	(0.006)	(0.006)
	Downstream effects t-1	0.040**	0.043**	0.009	0.010
		(0.019)	(0.019)	(0.010)	(0.010)
	Upstream effects t-1	0.015	0.019	0.006	0.007
		(0.013)	(0.013)	(0.008)	(0.008)
	Own effects t-1	0.008	0.009	0.007***	0.007***
		(0.006)	(0.006)	(0.002)	(0.002)
Patent:	Geographic effects t-1		0.005***		0.001
			(0.001)		(0.001)
	Downstream effects t-1		0.040***		0.016**
			(0.011)		(0.007)
	Upstream effects t-1		0.002		0.000
			(0.005)		(0.003)
	Own effects t-1		-0.006		-0.006**
			(0.004)		(0.003)
Observations		5776	5761	5776	5761

Notes: See Table 2a.

1 Appendix C: Omitted Proofs and Results and Monte Carlo Exercises

Details for Example 1

The expressions and Example 1 follow readily from equation (6) in the text or equation (A7) in Appendix A. We provide the detailed algebra here for completeness and verification. Suppose, for this purpose and without loss of any generality, that $u(c_1, c_2, c_3, l) = \gamma(l) \prod_{i=1}^{3} c_i^{1/3}$ (since in this case preference heterogeneity does not matter). Recall that the production function for sector $i \in \{1, 2, 3\}$ is:

$$y_i = e^{z_i} l_i^{\alpha_i^l} x_{ij}^{a_{ij}}. \tag{C1}$$

In what follows, we denote the supplier of the focal sector i by j and the customer of i by k (for instance, $\{i, j, k\} = \{1, 2, 3\}$, $\{i, j, k\} = \{2, 3, 1\}$, and $\{i, j, k\} = \{3, 1, 2\}$). With this convention, the resource market clearing condition can be written as

$$y_i = c_i + x_{ki}.$$

Combining the first-order conditions of the representative household and firms to eliminate prices, we can write

$$a_{ij} = \frac{c_i x_{ij}}{c_j y_i} \text{ and } \alpha_i^l = \frac{3 c_i l_i}{y_i}. \tag{C2}$$

Substituting this expression into (C1) we obtain

$$c_i = e^{z_i} \Omega_{ij} c_j^{a_{ij}}, \tag{C3}$$

where $\Omega_{ij} \equiv \left(\alpha_i^l\right)^{\alpha_i^l} a_{ij}^{a_{ij}} 3^{-\alpha_i^l}$ for $i = 1, 2, 3$. Solving these three equations summarized in (C3) jointly, we have

$$c_i = \tilde{\Omega}_i e^{\delta_i} \tag{C4}$$

where

$$\delta_i \equiv \frac{z_i + z_j a_{ij} + z_c a_{ij} a_{jk}}{1 - a_{ij} a_{jk} a_{ki}},$$

and $\tilde{\Omega}_i$ is a constant. Using the production functions (C1) and optimal labor choices (C2) and the equilibrium consumption choices (C4), we can express express y_i in terms of its intermediate input use, x_{ij}, only. Then combining these with the resource constraints we obtain

$$y_i = \tilde{\Omega}_i e^{\delta_i} + y_k e_k^{\frac{\alpha_k^l \delta_k - z_k}{1 - \alpha_k^l}} \Gamma_i,$$

where the Γ_i's denote constants. Solving this system of equations gives:

$$y_i = e^{\delta_i} \frac{\left[\tilde{\Omega}_i + \tilde{\Omega}_k \Gamma_k + \tilde{\Omega}_j \Gamma_j \Gamma_k\right]}{1 - \Gamma_i \Gamma_j \Gamma_k}.$$

Finally, taking the logs and differentiating this expression delivers the desired result:

$$d \ln y_i = \frac{dz_i + a_{ij} dz_j + a_{ij} a_{jk} dz_c}{1 - a_{ij} a_{jk} a_{ki}} \text{ for each } i = 1, 2, 3.$$

Details for Example 2

Once again the expressions in Example 2 follow from our general results, in particular equation (A10) in Appendix A (recalling that in this case $u(c_1, c_2, c_3, l) = \gamma(l) \prod_{i=1}^{3} c_i^{1/3}$). Once again we provide the algebraic detail for completeness. Note that the unit cost functions for the three sectors can be written as

$$C_i(\mathbf{p}, w) = \mu_i w^{\alpha_i^l} p_j^{a_{ij}},$$

where $\mu_i \equiv \left(\frac{\alpha_i^l}{a_{ij}}\right)^{a_{ij}} + \left(\frac{a_{ij}}{\alpha_i^l}\right)^{\alpha_i^l}$. In equilibrium, we have

$$p_i = C_i(\mathbf{p}, w) = \mu_i w^{\alpha_i^l} p_j^{a_{ij}}. \tag{C5}$$

Using the fact that the wage is the numeraire, we can solve for the price system in (C5) as

$$p_i = \gamma^{\frac{1}{1-a_{ij}a_{jk}a_{ki}}},$$

where $\gamma \equiv \mu_i \mu_j^{a_{ij}} \mu_k^{a_{ij}a_{jk}}$, confirming our general results that prices are constant regardless of demand shocks. Given this constancy, we switch to working with nominal values, which we denote by a tilde, "~". Then the resource constraint implies

$$d\tilde{y}_i = d\tilde{c}_i + d\tilde{x}_{ki} + d\tilde{G}_i.$$

Using the first-order condition of firms, $a_{ij} = \frac{\tilde{x}_{ij}}{\tilde{y}_i}$, we have

$$d\tilde{x}_{ij} = a_{ij} d\tilde{y}_i.$$

Combining this with the resource constraint, we obtain

$$d\tilde{y}_i = d\tilde{c}_i + a_{ki} d\tilde{y}_k + d\tilde{G}_i. \tag{C6}$$

Recall that the household optimization implies

$$\tilde{c}_i = \frac{1}{(1+\lambda)\,3} - \frac{\tilde{G}_i + \tilde{G}_j + \tilde{G}_k}{(1+\lambda)\,3}.$$

Differentiating this expression yields

$$d\tilde{c}_i = -\frac{d\tilde{G}_j + d\tilde{G}_i + \tilde{G}_k}{(1+\lambda)\,3}. \tag{C7}$$

Combining (C7) in (C6), we arrive at the system of equation (for $i = 1, 2, 3$):

$$d\tilde{y}_i = -\frac{d\tilde{G}_i + d\tilde{G}_j + \tilde{G}_k}{(1+\lambda)\,3} + a_{ki} d\tilde{y}_k + d\tilde{G}_i.$$

Solving this system of equations delivers the desired result:

$$d\tilde{y}_i = \frac{1}{1 - a_{ij}a_{jk}a_{ki}} \left\{ \begin{array}{c} d\tilde{G}_i + a_{ki}a_{jk} d\tilde{G}_j + a_{ki} d\tilde{G}_k \\ -\frac{(1+a_{ki}+a_{ki}a_{jk})}{(1+\lambda)3} \left[d\tilde{G}_i + d\tilde{G}_j + d\tilde{G}_k \right] \end{array} \right\}.$$

The Long and Plosser (1983) Model

Long and Plosser's (1983) model is closely related to the one we studied in the main text, with the main difference that there is a one period delay in production, so that inputs dated $t-1$ produce output dated t, which implies that shocks spread across industries only slowly. More specifically, the production function for sector i at time t is

$$y_{i,t} = e^{z_{i,t}} l_{i,t-1}^{\alpha_i^l} \prod_{j=1}^{n} x_{ij,t-1}^{a_{ij}}. \tag{C8}$$

The Long-Plosser model also includes capital, from which we abstract to simplify the discussion here. We also assume that the government budget has to be balanced at each date.

The preferences of the representative household are now defined over sequences of consumption bundles as

$$\sum_{t=0}^{\infty} \delta^t \left[\ln \gamma(l_t) + \beta_i \sum_{i=1}^{n} \ln c_{i,t} \right],$$

where $\delta \in (0,1)$ is the discount factor.[1] The representative household can save using a risk-free asset, with gross interest rate R_t at time t (meaning that one dollar invested at time $t-1$ in this risk-free asset pays R_t dollars for sure at time t), and because there is no capital, this asset must be in zero net supply.

Since there is no capital, the resource constraint takes the same form as in the static economy:

$$y_{i,t} = c_{i,t} + \sum_{j=1}^{n} x_{ji,t} + G_{i,t-1}, \tag{C9}$$

where we have adopted the timing convention that government spending decisions from time $t-1$ are implemented at time t.

An equilibrium is now defined as sequence of prices such that markets at each date clear. The equilibrium in this dynamic model continues to be very tractable and can be represented by a log-linear equation for the evolution of sectoral outputs as shown in the next proposition.

Proposition C1 *In the dynamic Long-Plosser model:*

1. *The equilibrium evolution of sectoral outputs in the presence of technology shocks (and no government spending shocks) is given by*

$$\mathbf{d} \ln \mathbf{y}_{t+1} = \mathbf{A} \times \mathbf{d} \ln \mathbf{y}_t + \mathbf{dz}_{t+1}. \tag{C10}$$

2. *Suppose that Suppose $\gamma(l) = (1-l)^{\lambda}$. Then the equilibrium evolution of sectoral output in the presence of government spending shocks (and no technology shocks) is given by*

$$\mathbf{d}\tilde{\mathbf{y}}_{t+1} = \left(\mathbf{I} - \delta \mathbf{A}^T\right)^{-1} \left(- \frac{\sum_{j=1}^{n} d\tilde{G}_{j,t}}{1+\lambda} \boldsymbol{\beta} + \mathbf{d}\tilde{\mathbf{G}}_t \right), \tag{C11}$$

where $\tilde{\mathbf{G}}_t$ is the vector of nominal government spending across sectors at time t, and $\tilde{\mathbf{y}}_t$ denotes the vector of nominal sectoral output at time t.

[1] Differently from the static model, the utility function is no longer invariant to monotone transformations, thus Cobb-Douglas and log preferences are no longer equivalent, and we adopt the standard log preferences used by Long and Plosser (1983).

Proof. Part 1. Since there is no capital, the profit maximization of sector i at time t can be written as

$$\max_{l_{i,t},x_{ij,t}} \left\{ \frac{p_{i,t+1}}{R_t} e^{z_{i,t+1}} l_{i,t}^{\alpha_i^l} \prod_{j=1}^{n} x_{ij,t}^{\alpha_{ij}} - w_t l_{i,t} - \sum_{j=1}^{n} p_{j,t} x_{ij,t} \right\}, \tag{C12}$$

where output prices are discounted by the gross interest rate between dates t and $t+1$, R_t, because they accrue with one period delay. Consider the dual of this problem, which gives the unit cost function for sector i as

$$C_{i,t+1}\left(\mathbf{p}_t, w_t\right) = e^{-z_{i,t+1}} B_i w_t^{\alpha_i^l} \prod_{j=1}^{n} p_{j,t}^{a_{ij}},$$

where $B_i \equiv \left[1/\alpha_i^l\right]^{\alpha_i^l} \prod_{j=1}^{n} \left[\frac{1}{a_{ij}}\right]^{a_{ij}}$. In the competitive equilibrium, we have

$$\frac{p_{i,t+1}}{R_t} = e^{-z_{i,t+1}} B_i w_t^{\alpha_i^l} \prod_{j=1}^{n} p_{j,t}^{a_{ij}}$$

to ensure zero profits (recall that R_t is known at time t). Given the interest rates representing intertemporal prices, we can set wages in each period as the numeraire, i.e., $w_t = 1$ for all t, and taking logs, we arrive at

$$\ln p_{i,t+1} - \ln R_t = -z_{i,t+1} + \ln B_i + \sum_{j=1}^{n} a_{ij} \ln p_{j,t}. \tag{C13}$$

The representative household's problem can be represented as

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \delta^t \left\{ \ln \gamma\left(l_t\right) + \sum_{j=1}^{n} \beta_i \ln c_{i,t} + \mu_t \left[R_t A_t + w_t l_t - A_{t+1} - \sum_{j=1}^{n} p_{i,t} c_{i,t} \right] \right\},$$

where the term in square brackets is the flow dynamic budget constraint of the household, with A_t denoting asset holdings, and μ_t is the Lagrange multiplier or the marginal value of income at time t. This problem has the familiar first-order conditions given by

$$c_{i,t} \quad : \quad \frac{\beta_i}{p_{i,t} c_{i,t}} = \mu_t \implies \ln \beta_i - \ln c_{i,t} - \ln \mu_t = \ln p_{i,t} \tag{C14}$$

$$A_{t+1} \quad : \quad -\delta^t \mu_t + \delta^{t+1} R_t \mathbb{E}_t \mu_{t+1} = 0 \tag{C15}$$

$$l_t \quad : \quad \frac{\gamma'\left(l_t\right)}{\gamma\left(l_t\right)} + \mu_t w_t = 0 \tag{C16}$$

Combining (C13) and (C14), we obtain

$$\ln \beta_i - \ln c_{i,t+1} - \ln \mathbb{E}_t \mu_{t+1} - \ln R_t = -z_{i,t+1} + \ln B_i + \sum_{j=1}^{n} a_{ij} \left[\ln \beta_j - \ln c_{j,t} - \ln \mu_t\right]$$

or

$$d \ln c_{i,t+1} + d \ln \mathbb{E}_t \mu_{t+1} + d \ln R_t = d z_{i,t+1} + \sum_{j=1}^{n} a_{ij} \left[d \ln c_{j,t} + d \ln \mu_t\right] \tag{C17}$$

Because the risk-free asset is in zero net supply, we must have $A_t = 0$ for all t, so that from the representative household's budget constraint

$$l_t w_t = \frac{p_{i,t} c_{i,t}}{\beta_i} = \frac{p_{j,t} c_{j,t}}{\beta_j} \tag{C18}$$

for all i, j and t. Combining this equation with (C14), we obtain

$$\mu_t = \frac{1}{l_t}, \tag{C19}$$

which together with (C16) implies

$$1 = -\frac{l_t \gamma' (l_t)}{\gamma (l_t)},$$

and thus

$$l_t = l^* \text{ for all } t. \tag{C20}$$

Finally combining this result with (C15) and (C19), we obtain that, regardless of the realization of the stochastic shocks,

$$\mu_t = \mu^* \text{ and } R_t = \frac{1}{\delta}.$$

This equation, combined with (C17) gives the law of motion of consumption of the output of different sectors as

$$d \ln c_{i,t+1} = \sum_{j=1}^{n} a_{ij} d \ln c_{j,t} + dz_{i,t+1},$$

or as

$$\mathbf{d} \ln \mathbf{c}_{t+1} = \mathbf{A} \times \mathbf{d} \ln \mathbf{c}_t + \mathbf{dz}_{t+1}. \tag{C21}$$

Consider next the first-order conditions of the profit-maximization problem, (C12):

$$a_{ij} \frac{p_{i,t+1}}{R_t} y_{i,t+1} = p_{j,t} x_{ij,t}. \tag{C22}$$

Using this expression for substituting for $x_{ji,t}$ in the resource constraint, (C9), using the fact that in this part, $G_{i,t-1} = 0$, and rearranging, we obtain:

$$1 = \frac{c_{i,t}}{y_{i,t}} + \delta \sum_{j=1}^{n} a_{ji} \frac{p_{j,t+1} y_{j,t+1}}{p_{i,t} y_{i,t}},$$

and finally, since from (C18) $\frac{p_{i,t} c_{i,t}}{\beta_i} = l^*$, this equation can be written as

$$\beta_i \frac{y_{i,t}}{c_{i,t}} = \beta_i + \delta \sum_{j=1}^{n} a_{ji} \beta_j \frac{y_{j,t+1}}{c_{j,t+1}},$$

or defining $\psi_{i,t} \equiv \beta_i \frac{y_{i,t}}{c_{i,t}}$ and denoting the vector of $\psi_{i,t}$'s by $\boldsymbol{\psi}_t$, as

$$\boldsymbol{\psi}_t = \boldsymbol{\beta} + \delta \mathbf{A}^T \boldsymbol{\psi}_{t+1}.$$

Substituting this equation forward, we obtain

$$\boldsymbol{\psi}_t = \boldsymbol{\beta} + \delta \mathbf{A}^T \boldsymbol{\beta} + \delta^2 \left(\mathbf{A}^T\right)^2 \boldsymbol{\beta} + ... + \delta^K \left(\mathbf{A}^T\right)^K \boldsymbol{\psi}_{t+K}.$$

Because $\mathbf{A}$'s largest eigenvalue is less than 1 in absolute value, as $K \to \infty$, the last term converges to zero, yielding

$$\boldsymbol{\psi}_t = \left(\mathbf{I}-\delta\mathbf{A}^T\right)^{-1}\boldsymbol{\beta},$$

which implies that $\psi_{i,t}$ is constant for all i and t, and thus

$$d\ln y_{i,t} = d\ln c_{i,t}.$$

Combined with (C21), this yields (C10).

Part 2. The analysis until equation (C18) from part 1 still applies. This equation needs to be modified, however, because of taxes to finance government spending. In particular, $A_t = 0$ now implies

$$\begin{aligned} l_t w_t - T_t &= \frac{p_{i,t}c_{i,t}}{\beta_i} = \frac{p_{j,t}c_{j,t}}{\beta_j} \\ &= \frac{1}{\mu_t}, \end{aligned} \tag{C23}$$

with the second line following from (C14). Combining (C16) with (C23), we obtain

$$\begin{aligned} l_t &= \frac{1+\lambda T_t}{1+\lambda} \\ \mu_t &= \frac{1+\lambda}{1-T_t} \\ R_t &= \frac{1-\mathbb{E}_t T_{t+1}}{\delta\left(1-T_t\right)}, \end{aligned} \tag{C24}$$

where the last equation of (C24) has expected taxes next period, because next period's government spending shocks and thus taxes are unknown at time t. Since, by assumption, $\mathbb{E}_t\tilde{\mathbf{G}}_\tau = \tilde{\mathbf{G}}_t$ for all $\tau > t$, we also have $\mathbb{E}_t T_{t+1} = T_t$, and thus

$$R_t = \left(\frac{1-\mathbb{E}_{t+1}T_{t+1}}{\delta\left(1-T_t\right)}\right) = \frac{1}{\delta}. \tag{C25}$$

Next multiplying the resource constraint, (C9), with $p_{i,t}$ to convert it into nominal terms and substituting $p_{i,t}c_{i,t} = \frac{\beta_i}{\mu_t}$ (from (C23)), and using (C22), we have

$$\tilde{y}_{i,t} = \frac{\beta_i}{\mu_t} + \sum_{j=1}^{n} a_{ji}\frac{\tilde{y}_{j,t+1}}{R_t} + \tilde{G}_{i,t-1},$$

where note that we write $\tilde{y}_{i,t+1}$ instead of $\mathbb{E}_t\tilde{y}_{i,t+1}$, since there are no productivity shocks and thus given the input choices at time t, $\tilde{y}_{i,t+1}$ is known at time t. Substituting for μ_t from (C24) and for R_t from (C25), and writing it in matrix notation, we have

$$\tilde{\mathbf{y}}_t = g_{t-1}\boldsymbol{\beta}+\delta\mathbf{A}^{\mathbf{T}}\tilde{\mathbf{y}}_{t+1} + \tilde{\mathbf{G}}_{t-1}, \tag{C26}$$

where $g_t \equiv \frac{1-\sum_{j=1}^{n} d\tilde{G}_{j,t}}{1+\lambda}$. Writing the same equation at future dates and taking expectations at time t, we have

$$\tilde{\mathbf{y}}_{t+1} = g_t\boldsymbol{\beta}+\delta\mathbf{A}^{\mathbf{T}}\tilde{\mathbf{y}}_{t+2} + \tilde{\mathbf{G}}_t,$$

and

$$\mathbb{E}_t\tilde{\mathbf{y}}_{t+k} = \mathbb{E}_t g_{t+k-1}\boldsymbol{\beta}+\delta\mathbf{A}^{\mathbf{T}}\mathbb{E}_t\tilde{\mathbf{y}}_{t+k+1} + \mathbb{E}_t\tilde{\mathbf{G}}_{t+k-1}.$$

Substituting these terms forward, we obtain

$$\tilde{\mathbf{y}}_t = g_{t-1}\boldsymbol{\beta} + \tilde{\mathbf{G}}_{t-1}+\delta\mathbf{A}^{\mathbf{T}}\left(\mathbb{E}_t g_t\boldsymbol{\beta} + \mathbb{E}_t\tilde{\mathbf{G}}_t\right)+\delta^2\left(\mathbf{A}^{\mathbf{T}}\right)^2\times\left(\mathbb{E}_t g_{t+1}\boldsymbol{\beta} + \mathbb{E}_t\tilde{\mathbf{G}}_{t+1}\right)+\ldots+\delta^K\left(\mathbf{A}^{\mathbf{T}}\right)^K\times\mathbb{E}_t\tilde{\mathbf{y}}_{t+K}.$$

Using the fact that $\delta^K\left(\mathbf{A}^{\mathbf{T}}\right)^K \to 0$ as $K \to \infty$ (again because $\mathbf{A}$'s largest eigenvalues less than one in absolute value) and that $\mathbb{E}_t\tilde{\mathbf{G}}_\tau = \tilde{\mathbf{G}}_t$ for all $\tau > t$, and leading by one period, we have

$$\tilde{\mathbf{y}}_{t+1} = g_t\boldsymbol{\beta} + \tilde{\mathbf{G}}_t + \delta\mathbf{A}^{\mathbf{T}}\times\left(g_t\boldsymbol{\beta} + \tilde{\mathbf{G}}_t\right) + \delta^2\left(\mathbf{A}^{\mathbf{T}}\right)^2\left(g_t\boldsymbol{\beta} + \tilde{\mathbf{G}}_t\right) + \ldots.$$

Finally, differentiating, we obtain

$$\begin{aligned}\mathbf{d}\tilde{\mathbf{y}}_{t+1} &= dg_t\boldsymbol{\beta} + \mathbf{d}\tilde{\mathbf{G}}_t + \delta\left(\mathbf{A}^{\mathbf{T}}(dg_t\boldsymbol{\beta} + \mathbf{d}\tilde{\mathbf{G}}_t\right) + \delta^2((\mathbf{A}^{\mathbf{T}})^2(dg_t\boldsymbol{\beta} + \mathbf{d}\tilde{\mathbf{G}}_t)+\ldots \\ &= \left(\mathbf{I} - \delta\mathbf{A}^{\mathbf{T}}\right)^{-1}\left(-\frac{\sum_{j=1}^n d\tilde{G}_{j,t}}{1+\lambda}\boldsymbol{\beta} + \mathbf{d}\tilde{\mathbf{G}}_t\right),\end{aligned}$$

verifying (C11). ■

There are three important features to emphasize. First, despite the intertemporal nature of the linkages, the equilibrium still takes a simple form, with many of the same features as the ones that emerged in our static economy. Secondly, and relatedly, equilibrium dynamics in the case of technology/productivity shocks, summarized in equation (C10), are particularly close to the responses in the static model derived in the main text. Dynamics in the presence of government spending shocks are a little more complicated, however, because in this dynamic environment, changes in government spending affect the interest rate and via this channel sectoral prices (whereas in the static model prices remained constant in response to changes in government spending). This complication notwithstanding, equation (C11) still takes relatively simple form and shows how sectoral outputs evolve in response to changes in government spending patterns (and we will see its close relationship to equation (7) in the text in the next proposition). Finally, equilibrium dynamics now depend on the input-output matrix, $\mathbf{A}$ or $\hat{\mathbf{A}}$, and not on the Leontief inverse. This is because, given that one period delay in converting inputs into output, indirect effects take place over time. Consequently, for tracing the effect of last period's output on today's output, which focuses on direct effect, it is the input-output matrix that is relevant. Nevertheless, because the indirect effects now accumulate over time, the long-run response to shocks is again given by the Leontief inverse as we show in the next proposition.

Proposition C2 1. *Consider a one-time productivity shock to industries,* $\mathbf{dz}_t$ *(with* $\mathbf{dz}_t = 0$ *for all* $\tau > t$*). Then*

$$\mathbf{d}\ln\mathbf{y}_\infty = (\mathbf{I} - \mathbf{A})^{-1}\times\mathbf{dz}_t. \tag{C27}$$

2. *Consider a one-time government spending shock to industries at time* t*,* $\mathbf{d}\tilde{\mathbf{G}}_t$ *(with* $\mathbf{d}\tilde{\mathbf{G}}_\tau = 0$ *for all* $\tau > t$*), and suppose that* $\delta \to 1$*. Then*

$$\mathbf{d}\tilde{\mathbf{y}}_{t+1} = \mathbf{H}^T\left(-\frac{\sum_{j=1}^n d\tilde{G}_{j,t}}{1+\lambda}\boldsymbol{\beta} + \mathbf{d}\tilde{\mathbf{G}}_t\right),$$

or in log form

$$\mathbf{d}\ln\tilde{\mathbf{y}}_{t+1}=\hat{\mathbf{H}}^{\mathbf{T}}\boldsymbol{\Lambda}\mathbf{d}\tilde{\mathbf{G}}_t. \tag{C28}$$

where $\boldsymbol{\Lambda}_t$ is the date-t version of the matrix defined in Appendix A equation (A8), given in equation (C29) below.

Proof. Part 1. Take $t=0$ for simplicity. Then, from equation (C10), we have

$$\begin{aligned}\ln\mathbf{y}_0 &= \mathbf{A}\times\ln\mathbf{y}_{-1}+\mathbf{z}_0\\ \ln\mathbf{y}_1 &= \mathbf{A}^2\times\ln\mathbf{y}_{-1}+\mathbf{A}\times\mathbf{z}_0+\mathbf{z}_1\\ &\vdots\\ \ln\mathbf{y}_K &= \mathbf{A}^{K+1}\times\ln\mathbf{y}_{-1}+\mathbf{A}^K\times\mathbf{z}_0+\mathbf{A}^{K-1}\times\mathbf{z}_1+...+\mathbf{z}_K\end{aligned}$$

Since $\mathbf{dz}_t=\mathbf{0}$ for all $t>0$, $\mathbf{z}_t=\mathbf{z}_0$ for all $t>0$, and thus

$$\ln\mathbf{y}_K=\mathbf{A}^{K+1}\times\ln\mathbf{y}_{-1}+\mathbf{A}^K\times\mathbf{z}_0+\mathbf{A}^{K-1}\times\mathbf{z}_0+...+\mathbf{z}_0.$$

Differentiating, we have

$$\mathbf{d}\ln\mathbf{y}_K=\left[\mathbf{A}^K+\mathbf{A}^{K-1}+...+\mathbf{I}\right]\mathbf{dz}_0.$$

As $K\to\infty$, we obtain (C27).

Part 2. This result is obtained directly from (C11) by taking the limit $\delta\to 1$, which yields

$$\mathbf{d}\tilde{\mathbf{y}}_{t+1}=\mathbf{H}\times\begin{pmatrix} d\tilde{G}_{1,t}-\frac{\beta_1}{1+\lambda}\sum_{j=1}^n d\tilde{G}_{j,t}\\ d\tilde{G}_{2,t}-\frac{\beta_1}{1+\lambda}\sum_{j=1}^n d\tilde{G}_{j,t}\\ \vdots\end{pmatrix},$$

verifying equation (A10) in Appendix A. Moreover, following the same steps as in Appendix A (in particular, equation (A8)), we can equivalently write this in log form as follows:

$$\begin{aligned} d\tilde{y}_{i,t+1} &= \sum_{j=1}^n h_{ji}\left(d\tilde{G}_{j,t}-\frac{\beta_j}{1+\lambda}\sum_{k=1}^n d\tilde{G}_{k,t}\right)\text{ for each } i\\ \frac{d\tilde{y}_{i,t+1}}{\tilde{y}_{i,t+1}} &= \sum_{j=1}^n \hat{h}_{ji}\frac{1}{\tilde{y}_{j,t}}\left(d\tilde{G}_{j,t}-\frac{\beta_j}{1+\lambda}\sum_{k=1}^n d\tilde{G}_{k,t}\right),\end{aligned}$$

and thus

$$\mathbf{d}\ln\tilde{\mathbf{y}}_{t+1}=\hat{\mathbf{H}}^T\boldsymbol{\Lambda}_t\mathbf{d}\tilde{\mathbf{G}}_t$$

where where

$$\boldsymbol{\Lambda}_t=\begin{pmatrix}\left(1-\frac{\beta_1}{(1+\lambda)}\right)\frac{1}{p_{1,t}y_{1,t}} & -\frac{\beta_1}{(1+\lambda)}\frac{1}{p_{1,t}y_{1,t}} & \cdots & \\ -\frac{\beta_2}{(1+\lambda)}\frac{1}{p_{2,t}y_{2,t}} & \left(1-\frac{\beta_2}{(1+\lambda)}\right)\frac{1}{p_{2,t}y_{2,t}} & & \\ & & \ddots & \\ & & & \left(1-\frac{\beta_n}{(1+\lambda)}\right)\frac{1}{p_{n,t}y_{n,t}}\end{pmatrix}, \tag{C29}$$

thus yielding the desired result. ■

The most noteworthy results in this proposition are the coincidence of equations (C27) and (C28) with (6) and (7) in the text. In particular, (C27) highlights that the long-run response to a one-time (permanent) technology shock in this dynamic model is identical to the equilibrium response to technology shocks in the static model given by (6). Equation (C28), on the other hand, highlights that the dynamic response to a one-time (permanent) government spending shock is identical to the equilibrium response to government shocks in the static model given by (7) provided that the discount factor δ is close enough to 1. These results underpin our claims that our results and empirical strategy continue to be valid even if data are generated by a dynamic model in which shocks spread across sectors over time.

Monte Carlo Evidence

We now use the results of the previous subsection as the basis of our Monte Carlo exercise. We use the equations of the Long-Plosser model, (C10) and (C11), derived above to trace out the dynamics of output in response to technology in government spending shocks. We also add an additional error term to capture other sources of productivity and demand shocks (as well as measurement error). In the case of technology shocks, equation (C10) thus becomes

$$\text{technology shocks} : \mathbf{d}\ln \mathbf{y}_t = \mathbf{A} \times \mathbf{d}\ln \mathbf{y}_{t-1} + \mathbf{z}_t^{tfp} + \boldsymbol{\epsilon}_t^{tfp} \tag{C30}$$

where $\mathbf{z}_t^{tfp}$ denotes the vector of technology shocks, and $\boldsymbol{\epsilon}_t^{tfp}$ is the vector of additional shocks assumed to be *iid*. We take productivity and government spending shocks to be persistent (since we are considering short time periods, such as months or quarters, which will then be time averaged into annual observations). In particular, we assume that

$$z_{i,t}^{tfp} = \rho z_{i,t-1}^{tfp} + \nu_t,$$

where $\nu_t \sim N(0,1)$. When time periods correspond to quarters, we set $\rho = 0.85$, which implies an annual persistence of 0.52, corresponding approximately to the average persistence of the shocks we study in our empirical work.

For equation (C11), we approximate $R_t \simeq 1/\delta \simeq 1$, since time periods are taken to be short (quarters or months), and then use the same steps as in the proof of Proposition C2 to convert the equation in nominal terms into log changes and thus write (C11) as

$$\mathbf{d}\ln \mathbf{y}_{t+1} = \hat{\mathbf{H}}^T \boldsymbol{\Lambda}_t \mathbf{d}\tilde{\mathbf{G}}_t,$$

where

$$\boldsymbol{\Lambda}_t = \begin{pmatrix} \left(1 - \frac{\beta_1}{(1+\lambda)}\right)\frac{1}{p_{1,t}y_{1,t}} & -\frac{\beta_1}{(1+\lambda)}\frac{1}{p_{1,t}y_{1,t}} & \cdots & \\ -\frac{\beta_2}{(1+\lambda)}\frac{1}{p_{2,t}y_{2,t}} & \left(1 - \frac{\beta_2}{(1+\lambda)}\right)\frac{1}{p_{2,t}y_{2,t}} & & \\ & & \ddots & \\ & & & \left(1 - \frac{\beta_n}{(1+\lambda)}\right)\frac{1}{p_{n,t}y_{n,t}} \end{pmatrix}.$$

Thus the equation we use to generate our simulated data the case of government spending shocks is

$$\text{government spending shocks} : \mathbf{d}\ln \mathbf{y}_t = \hat{\mathbf{H}}^T \boldsymbol{\Lambda}_t \mathbf{z}_t^G + \boldsymbol{\epsilon}_t^G,$$

where $\mathbf{z}_t^G$ denotes the vector of government spending shocks, and $\boldsymbol{\epsilon}_t^G$ denotes the additional shock in this case. We again take this latter shock to be *iid*, and impose the same persistence structure on our shock of interest, i.e.,

$$z_{i,t}^G = \rho z_{i,t-1}^G + \nu_t.$$

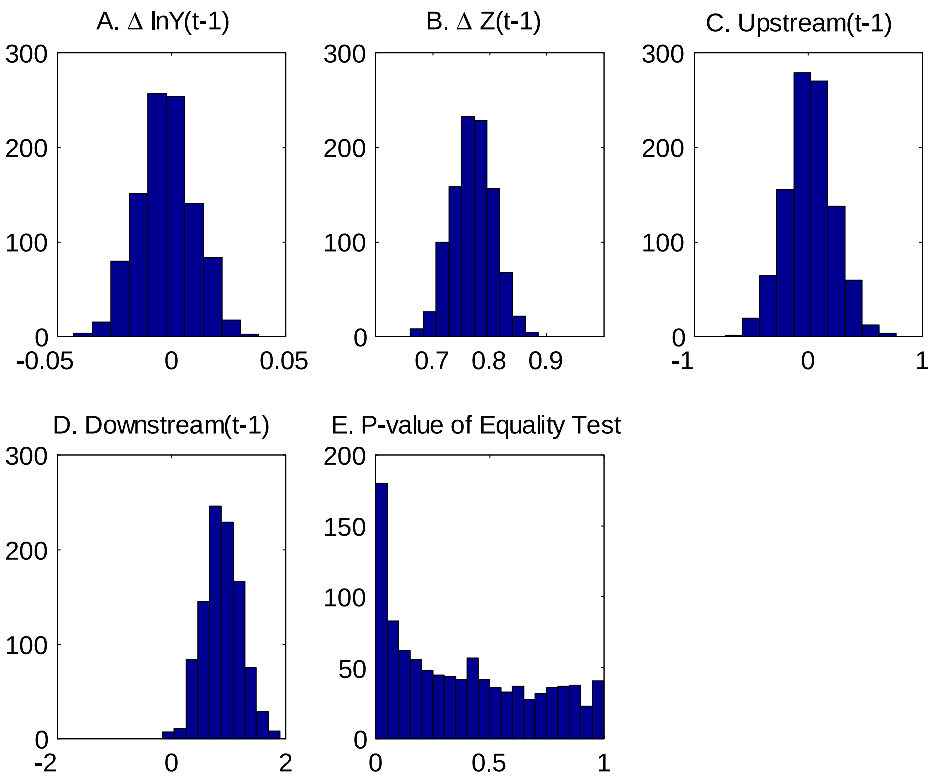
We also assume that $\boldsymbol{\epsilon}_t^{tfp}, \boldsymbol{\epsilon}_t^G$ are *iid* and distributed $N(0, 10)$ so as to generate sufficient noise in our simulated data. Throughout, we take the number of sectors to be 392 as in our empirical work, and we use the actual input-output matrices from the U.S. data that featured in our empirical work.

For quarterly data, we burn the first 160 quarters of simulated data, and then take 20 years of quarterly data, which we then time-average into annual observations, thus giving us 20 years of annual data with 392 sectors, which matches our empirical frame. We repeat this procedure 1000 times.

We then estimate our main specification from the text, equation (12), on these simulated datasets. As in our main text, upstream and downstream effects are computed from equations (13) and (14). The following regression equation reports mean values and the standard deviation of the estimates across the 1000 runs, starting with the case of technology shocks:

$$\mathbf{d}\ln \mathbf{y}_t = \underset{(0.012)}{-0.002} \times \mathbf{d}\ln \mathbf{y}_{t-1} + \underset{(0.037)}{0.770} \times \mathbf{dz}_{t-1}^{tfp} + \underset{(0.206)}{0.014} \times \mathbf{dz}_{t-1}^{tfp,up} + \underset{(0.327)}{0.881} \times \mathbf{dz}_{t-1}^{tfp,down}.$$

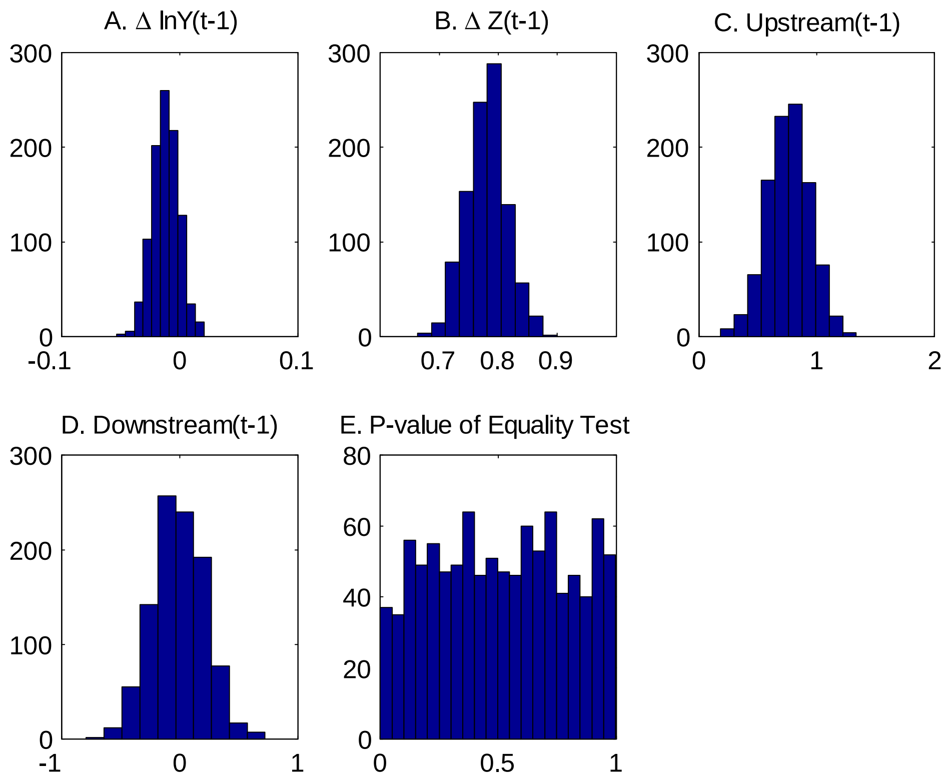
Panels A-D of Appendix Figure 4 illustrate the distributions of each coefficient across these 1000 simulations. Both our summary equation and the figure clearly show that we estimate no upstream effect and significant downstream effects as predicted by theory. The coefficient on the lagged dependent variable is zero, reflecting the fact that there is no other source of persistence (such as capital accumulation) in our simulated data. Panel E of the figure turns to the implied tests of the theoretical restriction (where we again follow the theory and include all indirect effects from own shocks together with the own shock). It plots the distribution of $p-$values of the test for this theory-implied restriction. We see that this restriction is rejected in about 18% of the cases at the 5% level. This somewhat high rejection rate is a consequence of the fact that time averaging the simulated data affects the own and downstream effects differentially. Nevertheless, we find it encouraging that in the great majority of the cases, this restriction is not rejected.



Appendix Figure 4. Distribution of coefficient estimates and p-values for coefficient equality tests from 1000 Monte Carlo simulations in response to technology shocks at quarterly frequency.

The next equation summarizes the results from government spending shocks, with the full results shown in Appendix Figure 5. The overall pattern is very similar and again consistent with our theoretical predictions, with one notable difference that, in this case, despite time-averaging the theory-implied restriction between own and network effects is rejected in about 4% of the cases at the 5% level, approximately as we would expect.

$$\mathbf{d}\ln\mathbf{y}_t = \underset{(0.011)}{-0.012} \times \mathbf{d}\ln\mathbf{y}_{t-1} + \underset{(0.034)}{0.781} \times \mathbf{dz}^{\mathbf{G}}_{\mathbf{t-1}} + \underset{(0.182)}{0.761} \times \mathbf{dz}^{G,up}_{t-1} - \underset{(0.221)}{0.008} \times \mathbf{dz}^{G,down}_{t-1}.$$

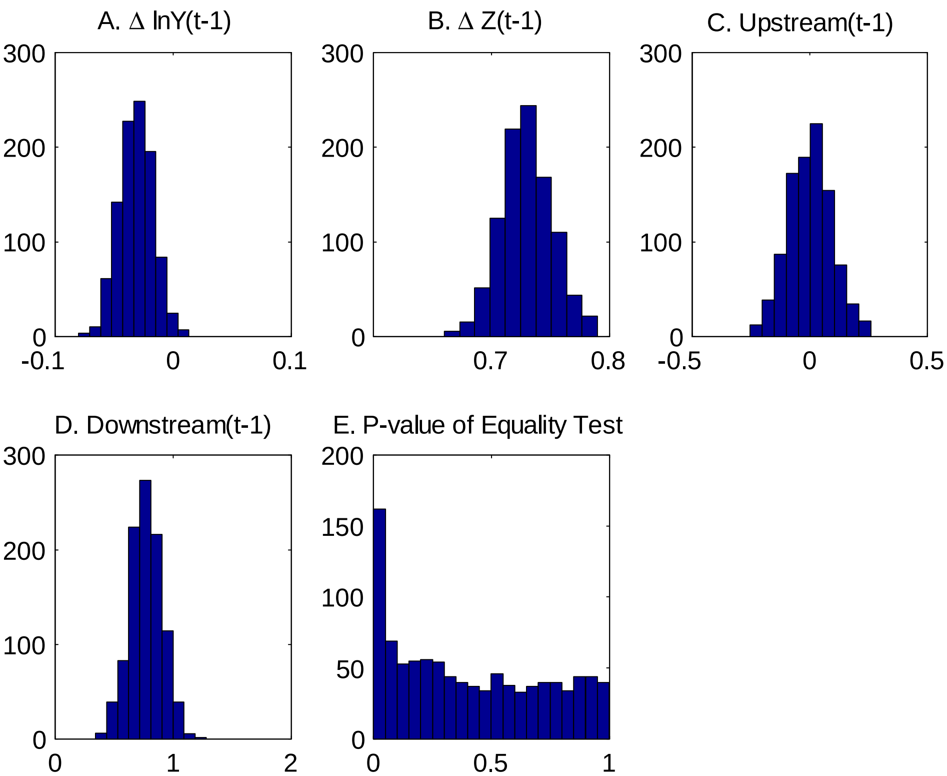


Appendix Figure 5. Distribution of coefficient estimates and p-values for coefficient equality tests from 1000 Monte Carlo simulations in response to government spending shocks at quarterly frequency.

We next depict the same analysis when simulating the model at the monthly frequency, which in particular implies that we set $\rho_{month} = 0.947$, so that we have the same annual persistence of shocks. We now use 1000 runs of 20 years each, and again burned the equivalent of 20 years of data (480 months). The results for technology shocks are once again similar, as summarized in the next equation and in Appendix Figure 6 below.

$$\mathbf{d}\ln\mathbf{y}_t = \underset{(0.014)}{-0.031} \times \mathbf{d}\ln\mathbf{y}_{t-1} + \underset{(0.022)}{0.730} \times \mathbf{dz}_{t-1}^{tfp} + \underset{(0.092)}{0.002} \times \mathbf{dz}_{t-1}^{tfp,up} + \underset{(0.133)}{0.769} \times \mathbf{dz}_{t-1}^{tfp,down}.$$

based on

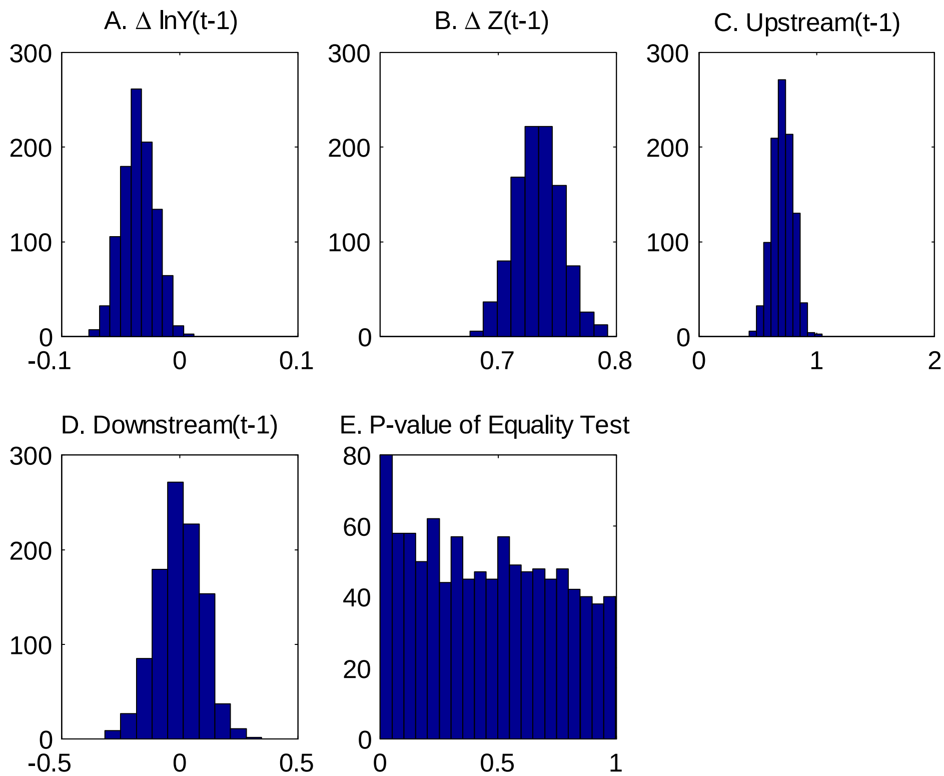


Appendix Figure 6. Distribution of coefficient estimates and p-values for coefficient equality tests from 1000 Monte Carlo simulations in response to technology shocks at monthly frequency.

Once again, in response to technology shocks, there are no upstream effects and well-estimated downstream effects, and theory-implied restrictions are accepted in the majority of the cases.

Turning next to government spending shocks, we find a similar pattern consistent with theory as summarized in the next equation and in Appendix Figure 7:

$$\mathbf{d}\ln\mathbf{y}_t = \underset{(0.014)}{-0.035} \times \mathbf{d}\ln\mathbf{y}_{t-1} + \underset{(0.020)}{0.734} \times \mathbf{dz}^{\mathbf{G}}_{\mathbf{t-1}} + \underset{(0.089)}{0.711} \times \mathbf{dz}^{G,up}_{t-1} - \underset{(0.098)}{0.0003} \times \mathbf{dz}^{G,down}_{t-1}.$$



Appendix Figure 7. Distribution of coefficient estimates and p-values for coefficient equality tests from 1000 Monte Carlo simulations in response to government spending shocks at monthly frequency.

Measurement Error

Our second Monte Carlo exercise investigates whether measurement error in the input-output matrix will lead to incorrect inference (partly because this measurement error might be magnified in the Leontief inverse). For this exercise, we directly simulate data at the annual frequency from our baseline model (thus using the Leontief inverse matrices), and since we would like to investigate whether, in the presence of measurement error, network effects from technology shocks might be incorrectly identified as resulting from government shocks and vice versa, we combine (C10) and (C11) and simulate the data in the presence of both types of shocks procreating according to theory as well as additional noise representing other shocks. Namely, we use the equation

$$\mathbf{d}\ln\mathbf{y}_{t+1} = \gamma \times \mathbf{d}\ln\mathbf{y}_t + \alpha^{down} \times \mathbf{H} \times \mathbf{dz}_t^{tfp} + \alpha^{up} \times \hat{\mathbf{H}} \times \mathbf{\Lambda_t} \times \mathbf{dz}_t^{G} + \boldsymbol{\epsilon}_t, \tag{C31}$$

where $\mathbf{dz}_t^{tfp}$ and $\mathbf{dz}_t^{G}$ are the vectors of technology and government spending shocks, and we take them to be *iid* and distributed $N(0,1)$. The additional noise ϵ_t is assume to be distributed $N(0,1/12)$. We set γ to the average of its empirical estimates, 0.085, and we again use the Leontief inverse matrices $\mathbf{H}$ and $\hat{\mathbf{H}}$ from the data as in our empirical work. To investigate whether positive downstream (upstream) effects will be correctly identified and whether we will also be able to estimate precisely zero effects when such propagation is absent, we consider four different scenarios for α^{up} and α^{down}: (*i*) $\alpha^{up} = 1$, $\alpha^{down} = 1$, (*ii*) $\alpha^{up} = 1$, $\alpha^{down} = 0$, (*iii*) $\alpha^{up} = 0$, $\alpha^{down} = 1$, and (*iv*) $\alpha^{up} = 0$, $\alpha^{down} = 0$, covering all four possibilities (where the normalization of the positive effects to 1 is without loss of any generality). We again run 1000 simulations in each case.

In estimating our main empirical model, equation (12), we introduce randomly-generated measurement error on the actual matrix, so that the matrix we use in the estimation becomes

$$\mathbf{A}^{\epsilon} = \begin{pmatrix} a_{11} + \epsilon_{11} & a_{12} + \epsilon_{12} & & \cdots & \\ a_{21} + \epsilon_{21} & a_{22} + \epsilon_{22} & & & \\ & & \ddots & & \\ & & & & \\ & & & & a_{nn} + \epsilon_{nn} \end{pmatrix}$$

and $\hat{\mathbf{A}}^{\epsilon}$ is constructed analogously. To make this demanding test of our empirical strategy, we introduce a considerable amount of measurement error and set the standard deviation of ϵ equal to the average entry of the input-output matrix, $\bar{a} \equiv \frac{1}{n^2} \sum_i \sum_j a_{ij}$. That is,

$$\epsilon_{ij}, \hat{\epsilon}_{ij} \sim N\left(0, \bar{a}\right),$$

and different draws are independent. With this amount of measurement error, the ranking of the entries of the input-output matrices can be considerably different than what we measure. We then compute the Leontief inverses in the usual manner: $\mathbf{H}^{\epsilon} = \left(\mathbf{I} - \mathbf{A}^{\epsilon}\right)^{-1}$ and $\hat{\mathbf{H}}^{\epsilon} = \left(\mathbf{I} - \hat{\mathbf{A}}^{\epsilon T}\right)^{-1}$. We again estimate equation (12) computing the downstream and upstream effects according to equations (13) and (14).

We next report the results of this exercise, starting with the benchmark of no measurement error when there are both upstream and downstream effects, and then moving to the four cases indicated above. Throughout, given our motivation explained above, we estimate network effects from technology and government spending shocks simultaneously.[2]

Case 0, No Measurement Error, $\alpha^{up} = 1$, $\alpha^{down} = 1$

In this case, both own effects and network effects are precisely estimated, and are consistent with theory. In particular, we find downstream propagation of technology shocks and zero upstream propagation of these shocks, and upstream propagation but no downstream propagation of government spending shocks. Quantitatively, own shocks and the relevant network effects are of the same magnitude as predicted by theory. These results are summarized in the next equation.

$$d\ln \mathbf{y}_{t+1} = \left\{ \begin{array}{c} \underset{(0.006)}{0.085} \times d\ln \mathbf{y}_t - \underset{(0.054)}{0.003} \times \mathbf{z}_t^{tfp,up} + \underset{(0.065)}{1.002} \times \mathbf{z}_t^{tfp,down} + \underset{(0.010)}{1.000} \times \mathbf{z}_t^{tfp,own} \\ + \underset{(0.055)}{0.980} \times \mathbf{z}_t^{G,up} - \underset{(0.064)}{0.004} \times \mathbf{z}_t^{G,down} + \underset{(0.010)}{1.000} \times \mathbf{z}_t^{G,own} \end{array} \right\}. \tag{C32}$$

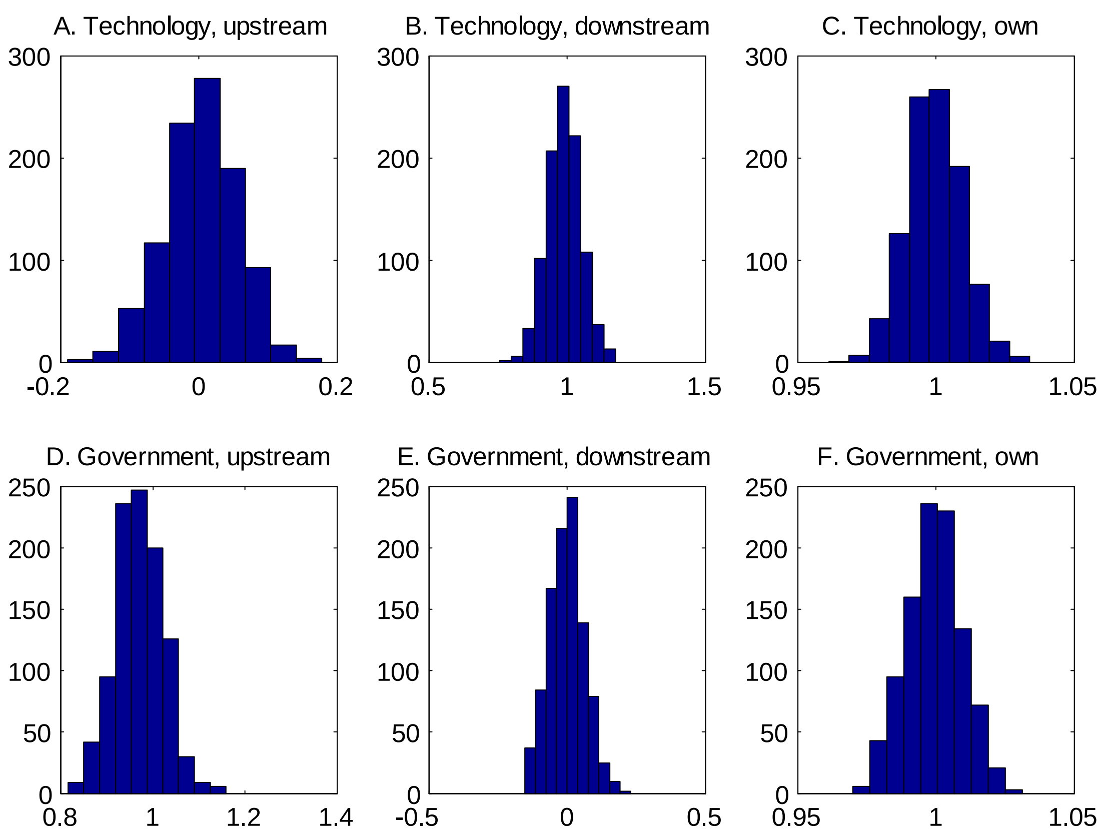
[2] The results are similar if the two types of network effects are estimated separately.

Case 1, Measurement Error, $\alpha^{up} = 1$, $\alpha^{down} = 1$

In this case, as shown by the next summary equation, we find the expected pattern of downstream propagation of technology shocks and upstream propagation of government spending shocks, and no upstream propagation from technology shocks and no downstream propagation from government spending shocks. Moreover, despite the sizable amount of measurement error in the input-output matrices, the estimated magnitudes of the relevant network effects are consistent with theory: on average, downstream network effects from technology shocks have the same magnitude as the own effect of technology shocks, and upstream network effects from government spending shocks likewise have the same magnitude as the own effect of government spending shocks.

$$d\ln \mathbf{y}_{t+1} = \left\{ \begin{array}{c} \underset{(0.006)}{0.085} \times d\ln \mathbf{y}_t - \underset{(0.054)}{0.001} \times \mathbf{z}_t^{tfp,up} + \underset{(0.063)}{0.992} \times \mathbf{z}_t^{tfp,down} + \underset{(0.011)}{1.000} \times \mathbf{z}_t^{tfp,own} \\ +\underset{(0.053)}{0.970} \times \mathbf{z}_t^{G,up} - \underset{(0.061)}{0.002} \times \mathbf{z}_t^{G,down} + \underset{(0.010)}{1.000} \times \mathbf{z}_t^{G,own} \end{array} \right\}.$$

The full distribution of the parameter estimates, focusing on upstream effect, downstream effects and own effects, are shown in Appendix Figure 8.



Appendix Figure 8.

Distribution of coefficient estimates from 1000 Monte Carlo simulations in response to technology and government spending shocks with measurement error and $\alpha^{up} = 1$ and $\alpha^{down} = 1$.

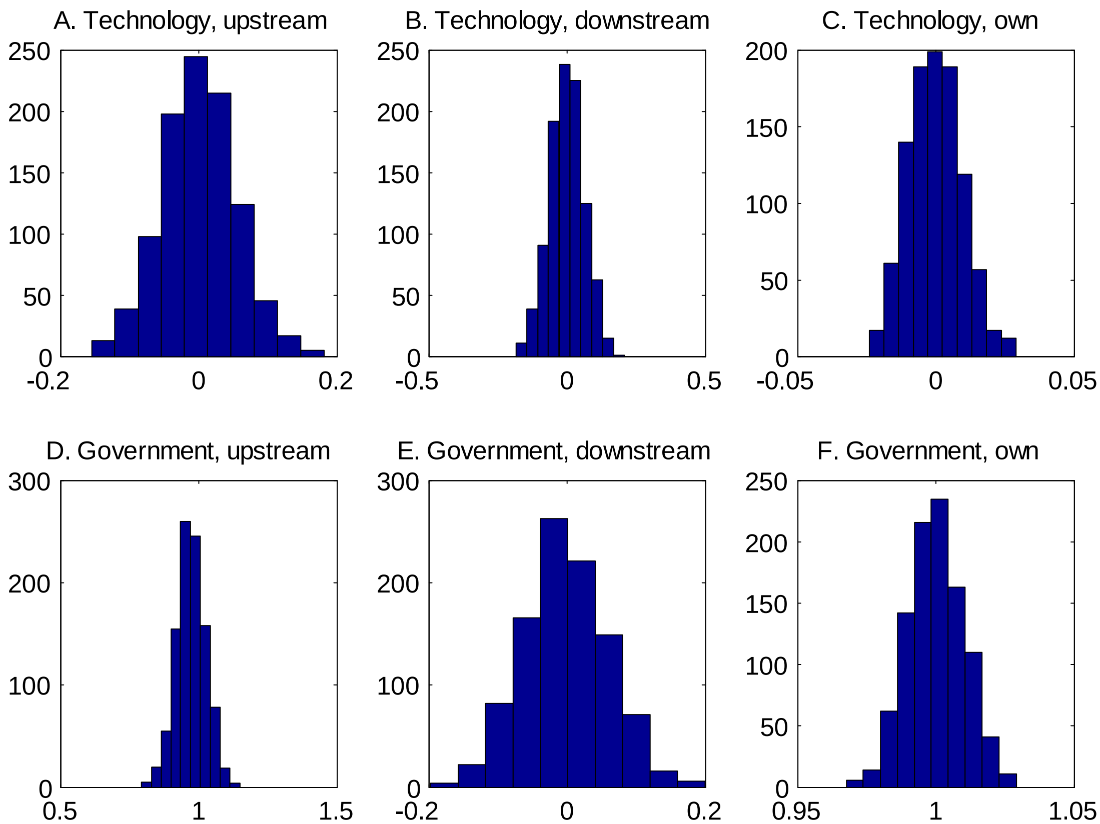
In summary, in this case, with both government spending and technology shocks, despite the substantial amount of measurement error, our regressions correctly identify the theory-implied network effects and estimate zero propagation when there should not be any.

Case 2, Measurement Error, $\alpha^{up} = 1$, $\alpha^{down} = 0$

We next turn to the (hypothetical) case in which the data generating process includes upstream propagation in response to government spending shocks, but no downstream propagation in response to technology shocks.[3] The results are again encouraging for our empirical strategy as summarized by the next equation and Appendix Figure 9, and show that our regressions estimate the relevant network effects correctly and estimate zero effects when there are no network effects.

$$d\ln \mathbf{y}_{t+1} = \left\{ \begin{array}{c} \underset{(0.006)}{0.085} \times d\ln \mathbf{y}_t + \underset{(0.052)}{0.001} \times \mathbf{z}_t^{tfp,up} - \underset{(0.066)}{0.001} \times \mathbf{z}_t^{tfp,down} + \underset{(0.010)}{0.000} \times \mathbf{z}_t^{tfp,own} \\ + \underset{(0.056)}{0.974} \times \mathbf{z}_t^{G,up} - \underset{(0.063)}{0.005} \times \mathbf{z}_t^{G,down} + \underset{(0.010)}{1.000} \times \mathbf{z}_t^{G,own} \end{array} \right\}.$$

[3] This case is not possible when our theory applies, since upstream propagation in response to government spending shocks and downstream propagation in response to technology shocks are determined by the same input-output linkages. Nevertheless, this hypothetical case enables us to investigate whether our regressions will correctly identify the presence or the absence of these effects when one is present and the other one is not as might be the case under alternative theories.



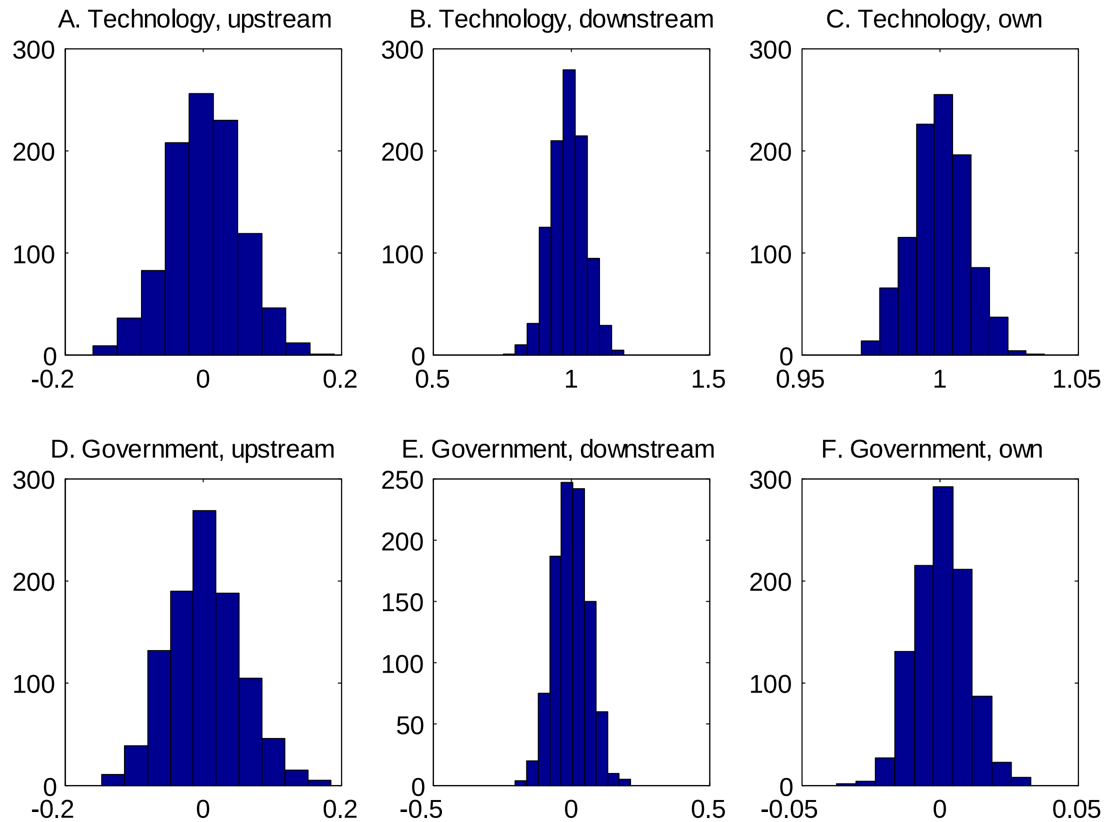
Appendix Figure 9. Distribution of coefficient estimates from 1000 Monte Carlo simulationsin response to government spending shocks with measurement error and $\alpha^{up} = 1$ and $\alpha^{down} = 0$.

The results show zero own effects and zero network effects from technology shocks, and zero downstream propagation from government spending shocks, and correctly identify the own effects and upstream propagation from government spending shocks, with the right magnitudes.

Case 3, Measurement Error, $\alpha^{up} = 0$, $\alpha^{down} = 1$

We find the same pattern when there is downstream propagation in response to technology shocks but no upstream propagation in response to government shocks as summarized next:

$$d\ln \mathbf{y}_{t+1} = \left\{ \begin{array}{c} \underset{(0.008)}{0.085} \times d\ln \mathbf{y}_t + \underset{(0.052)}{0.004} \times \mathbf{z}_t^{tfp,up} + \underset{(0.062)}{0.989} \times \mathbf{z}_t^{tfp,down} + \underset{(0.011)}{1.001} \times \mathbf{z}_t^{tfp,own} \\ -\underset{(0.052)}{0.003} \times \mathbf{z}_t^{G,up} - \underset{(0.061)}{0.002} \times \mathbf{z}_t^{G,down} + \underset{(0.010)}{0.000} \times \mathbf{z}_t^{G,own} \end{array} \right\}.$$



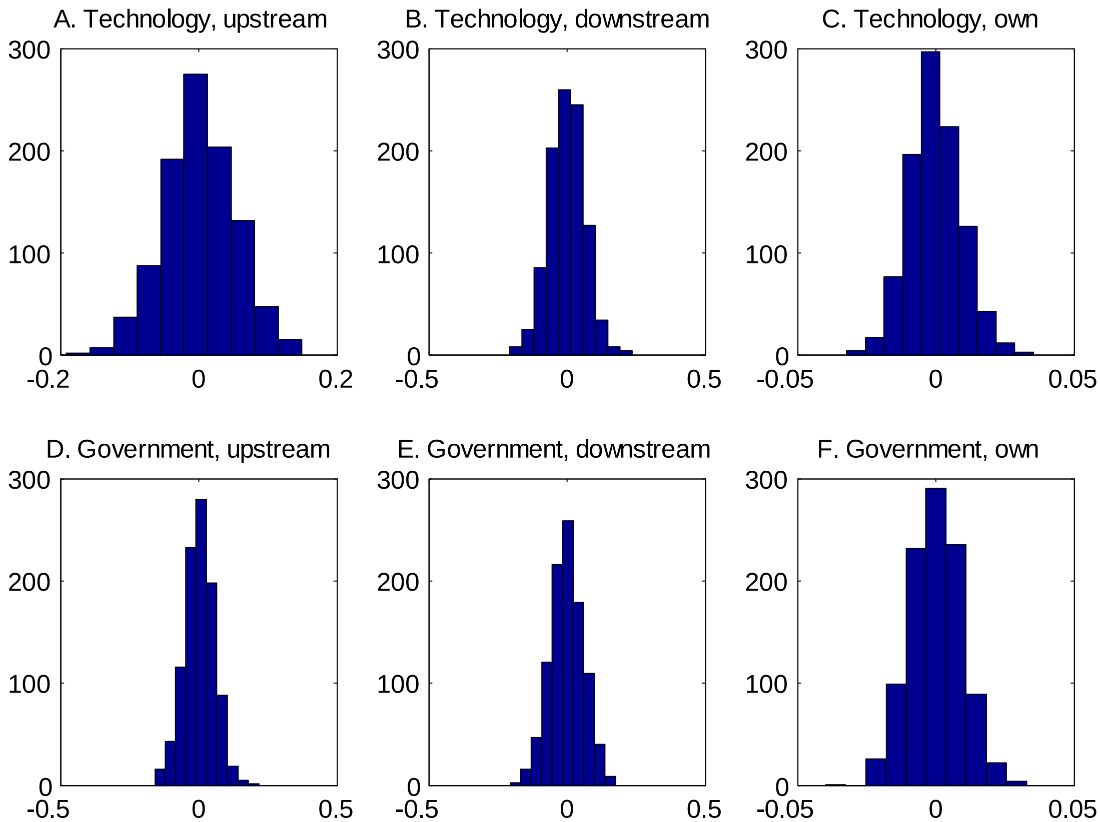
Appendix Figure 10.

Distribution of coefficient estimates from 1000 Monte Carlo simulations in response to technology and government spending shocks with measurement error and $\alpha^{up} = 0$ and $\alpha^{down} = 1$.

Case 4, $\alpha^{up} = 0,\ \alpha^{down} = 0$

Finally, we turn to the case in which there are no network effects, and in this case our equations, as summarized next, correctly identify no upstream or downstream propagation in response to either government spending or technology shocks (as well as no own effects).

$$d\ln \mathbf{y}_{t+1} = \left\{ \begin{array}{c} \underset{(0.011)}{0.085} \times d\ln \mathbf{y}_t + \underset{(0.052)}{0.000} \times \mathbf{z}_t^{tfp,up} + \underset{(0.062)}{0.002} \times \mathbf{z}_t^{tfp,down} + \underset{(0.010)}{0.000} \times \mathbf{z}_t^{tfp,own} \\ -\underset{(0.053)}{0.001} \times \mathbf{z}_t^{G,up} + \underset{(0.064)}{0.000} \times \mathbf{z}_t^{G,down} + \underset{(0.010)}{0.000} \times \mathbf{z}_t^{G,own} \end{array} \right\}.$$



Appendix Figure 11.

Distribution of coefficient estimates from 1000 Monte Carlo simulations in response to technology and government spending shocks with measurement error and $\alpha^{up} = 0$ and $\alpha^{down} = 0$.

Overall, these results bolster our confidence in the reliability of our empirical strategy, even in the presence of substantial measurement error.