Essays in Macroeconomics: Worker and Firm Dynamics

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Thomas Walsh

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Thomas Walsh

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Examining Board

Prof. Russell Cooper, EUI, Supervisor
Prof. Thomas Crossley, EUI, Co-Supervisor

Researcher declaration to accompany the submission of written work
Department of Economics – Doctoral Programme

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Chapter 1

Government Spending in Firm-level Production Networks: Size versus Centrality

Abstract: How large are network effects in government spending multipliers when we account for differential levels of constraints across firms and their location in the network? We document the empirical facts that more productive firms are likely to be both connected to more upstream and downstream partners, as well as to be less constrained financially. At the same time they are also more likely to win procurement contracts at the extensive margin, and receive more government dollars in procurement demand conditional on winning. We examine empirically to what extent network multiplier effects are dampened by large, unconstrained firms occupying the most central nodes of the network. Results imply fiscal authorities must tradeoff direct network effects versus indirect constraint-relaxation effects.

1.1 Introduction

In the modern economy, production takes place along complex supply chains. These chains of firm-to-firm transactions, both domestic and cross-border, mean firms cannot be viewed as entirely independent units, but instead a given firm's outcomes will comove with those

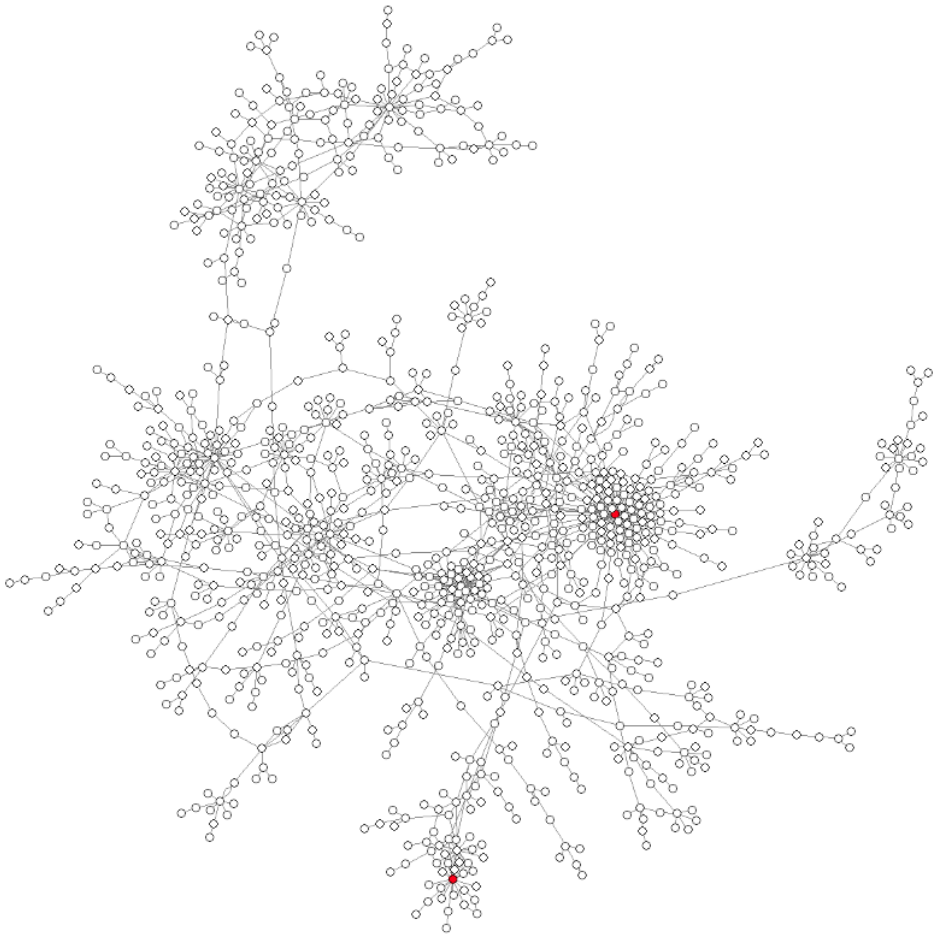
of suppliers and clients. Tightly connected supply networks create the possibility for shocks to an individual firm to propagate quickly and widely, reaching many firms with few steps. Characteristics of the network – high degree of clustering and short average path length – play a key role in transmission of idiosyncratic shocks to trading partners up and down the production chain. In simple terms, even if all nodes were the same, with large heterogeneity in links, *network structure matters*.

At the same time, fiscal policy on the spending side is conducted as many procurement transactions of various sizes with private enterprises, and not simply one large aggregate transaction. Since firms differ in how important they are to the network, the distribution of procurement contracts over firms in the network matters for aggregate fiscal multipliers. *Where spending is targeted in the network matters*. Even if firms were all identical, not all spending would be equal in its aggregate effects since some nodes propagate shocks more than others.

In this paper we investigate how firm heterogeneity matters for network effects in fiscal spending. Existing work on this topic has largely abstracted from which firms occupy the various nodes of the network. We argue it turns out firm characteristics such as productivity, age, and size will matter, since firm attributes will reflect who is constrained and who is not, as well as their position in the network. *Who occupies which node matters.* Spending can therefore generate larger multipliers targeting central nodes to exploit direct network effects or target constrained firms to generate indirect effects that come from relaxing constraints, but not both channels simultaneously. Models of endogeneous network formation will yield exactly this race between size and centrality.

We contribute to work on fiscal multipliers and propagation of shocks. To the best of our knowledge we are the first to examine the distribution of heterogeneous firms over centrality and the implications for fiscal policy. Empirically, we document three sets of stylised facts. First, we show that extremely granular government procurement contracts typically have a size gradient. Larger firms receive more federal dollars in contracts. Secondly, larger firms also have more upstream and downstream links. Finally, fiscal spending loads on more central firms, which are less constrained along several key dimensions in their balance sheets. In regression analysis we show significant upstream propagation of federal spending, however direct responses to federal

Figure 1.1: Firm-level Production Network in 2010



Note: Network graph of firm-to-firm links. Source: Authors' calculations based on Compustat North America Customer Segment data. General Motors (L) and Walmart (R) are highlighted in red. For clarity, links with estimated input share below ten percent are omitted in this graph, but retained throughtout the analysis.

spending depend strongly on size.

This automatic dampening mechanism coming from a size-centrality tradeoff can go some way to explain why large implied multipliers at the firm-to-firm level are not necessarily reflected at the aggregate level, where estimates suggest much more modest effects typically.

Related Literature this work relates to several branches of existing work, namely, the role of networks in amplification of micro-level shocks, the propagation of demand shocks upstream to suppliers, and the role of financial constraints in firms' responsiveness.

Long Jr and Plosser (1983) construct a sectoral real business cycle model with input-output linkages which naturally generates comovement across the sectors. Acemoglu, Carvalho, Ozdaglar and Tahbaz-Salehi (2012) further show that even as the number of units in the economy becomes large, the speed at which firm-level shocks are averaged out in a law-of large-numbers argument is slow in an economy with IO links.

This paper also relates to recent empirical work examining the propagation of shocks along supply chains. Acemoglu, Akcigit and Kerr (2016) provide empirical evidence for the upstream transmission of demand shocks and downstream propagation of productivity shocks in the context of a sectoral IO network. Carvalho, Nirei, Saito and Tahbaz-Salehi (2021) show that disruption caused by the Great East Japan Earthquake of 2011 hit the indirect customers and suppliers of firms in the disaster zone. Barrot and Sauvagnat (2016) similarly show strong propagation of shocks from disaster-stricken firms in the US, with pass-through particularly high in cases when specialist manufacturers of high-specificity inputs are hit.

Liu (2019) and Bigio and La'O (2020) study distortions in production networks. In particular, Liu (2019) studies industrial policy in industry-to-industry networks in the presence of distortions, which accumulate in upstream sectors. Optimal policy targets "distortion centrality".

Hebous and Zimmermann (2021) and Gabriel (2022) highlight that government demand is particularly pledgable against credit lines, thus government demand can also boost firm capacity through expanded access to credit. This expansionary effect is not limited to direct recipients – Carvalho and Draca (2018) show military procurement drives innovation along the supply chain, not simply among direct recipients.

1.2 Facts

We present further facts related to US federal government procurement contracts with publicly listed enterprises, complementing work by Cox, Müller, Pasten, Schoenle and Weber (2020). We first document granularity and the fat right tail in the firm-quarter contract distribution. A small share of firms receive an out-sized share of total federal procurement dollars within a quarter. We then present correlational evidence linking firm size and measures of network connectivity,

procurement dollars at the extensive and intensive margins, and financial constraints.

Procurement Contract Distribution The distribution of government procurement across firm quarters displays very strong granularity – a small minority of the contracts account for a relatively large share in overall spending. The modal size of government spending received by a firm in a quarter is of the order 10^6 however the right tail is extremely drawn out, with some contracts several orders of magnitude large (up to 10^9 USD in a quarter)

Size Effects in Network Position, Procurement and Constraints To gauge the extent of correlations between indicators of interest, z_{it} and firm size, we run the following simple regression. Coefficients on firm size are summarised in the plot below.

$$z_{it} = \beta \, Firm\ size_{it} + \lambda_t + f_i + u_{it} \tag{1.1}$$

Large firms occuply more central nodes in the supply network. On average larger firms tend to be more central, as seen indirectly from the first two points in Figure 1.5. The number of outward and inward links a firm has is increasing in size.

Large firms are more involved in Federal procurement at extensive and intensive margins At the extensive margin, larger firms are also more likely to be receivers of procurement contracts from the federal government, and conditional on having a contract, tend to receive more dollars compared to small firms.

Large firms are less constrained financially. Financial constraints also exhibit a size gradient with larger firms being less constrained by our proxies. Larger firms can better cover interest expenses as a multiple of earnings net of costs (EBITDA), the interest they pay on their debt stock is lower, while they can simultaneously operate at higher leverage ratios. Comparing debt stocks to sales also shows a similar qualitative pattern that large firms can run proportionately higher debt ratios.

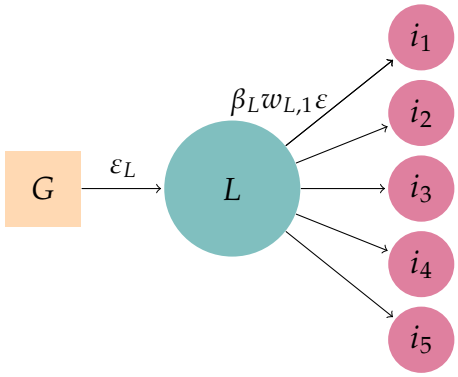
To summarise, the empirical patterns in the data show that larger firms sit in more central nodes of the network, and so we should expect them to larger total fiscal multipliers (*centrality channel*). At the same time, consistent with endogeneous network formation favouring productive

firms, these larger, more central firms are less likely to be financial constrained according to several balance sheet metrics.

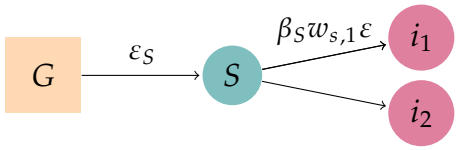
1.2.1 Stylised Framework

Figure 1.2: Propagation of a Demand Shock along Supply Chains based on Size

(a) Stylised Supply Chain for a Large Firm



(b) Stylised Supply Chain for a Small Firm



Note:

The large firm, L receives a demeand shock from the government, ε_L. β_L passthrough to suppliers, which is split across suppliers according to input shares $w_{L,j}$.

1.3 Data and Descriptive Statistics

We use three main datasets in our analysis: company financial accounts from Compustat North America Database, US Federal Government spending via private sector procurement from `usaspending.gov`, and finally supply chain information to create the firm-to-firm network from the Compustat customer segment.

Firm-level variables Quarterly firm-level balance sheet information for the universe of US publicly-traded firms is extracted from the Compustat North America database. The advantages

of this data source over similar datasets are its relatively long sample as well as higher quarterly frequency compared to annual records in other sources. While Compustat features only listed companies, Compustat represents a large share of aggregate employment, and investment dynamics track national statistics well. We limit our sample to firms based in USA, with trading currency in USD. Further information on data cleaning and sample selection can be found in the appendix.

Firm-to-firm links are extracted from the "customer segment" of Compustat. Listed firms are legally obliged to report information on customers which account for more than ten percent of sales in a given year, some report sales below this threshold.

Federal Procurement Contracts Federal spending contracts are taken from the database of Hebous and Zimmerman (2021) and matched to the sample of Compustat firms.

1.4 Empirical Framework

With the framework of section 1.2.1 in mind, our empirical strategy aims to quantify the propagation of government spending shocks, tracing the path from recipient of the procurement contracts (direct effect) to the suppliers for these firms, and the suppliers of the suppliers, up the supply chain (n-step indirect effect).

Our model suggests that both direct and indirect effects should be patterned such that (1) larger firms respond less to their own shocks (2) suppliers of these large recipient firms will receive a smaller passthrough shock, and so downstream-firm outcomes should respond less to an upstream procurement shock if the recipient is large.

1.4.1 Direct Effect of Federal Procurement

Our baseline regressions first concentrate on direct receipt of government procurement spending. We model the direct effect on recipient firms in a local projections (LP) framework as:

$$y_{i,t+h} - y_{i,t-1} = \alpha_h GovSpend_{it} + \mathbf{X}_{it}\Gamma_h + \lambda_{s,t,h} + f_{i,h} + u_{i,t+h} \tag{1.2}$$

Equation (1.2) is first estimated by OLS. We include a rich set of firm-level controls as well as firm and sector-quarter fixed effects to control for permanent differences in performance across firms as well as intermediate level sectoral shocks. OLS regressions rely on the assumption that within cells of observables, firms receiving the spending shocks are not systematically different from the remaining firms. This assumption that spening is really a random shock conditional on observables would correspond to null placebo coefficients in the local projection impulse response (i.e the differences between shocked firms and remaining firms is not statistically different from zero at baseline before the spending shock). Nevertheless, selection into procurement on unobservables is a concern.

Our preferred instrumental variables strategy draws inspiration from work such as Nakamura and Steinsson (2014), in which we would exploit aggregate changes in federal spending that are plausibly exogeneous to firm-level characteristics.

1.4.2 Heterogeneity by Recipient Firm Size

Heterogeneity in responsiveness to demand shocks across the firm size distribution is a central component of this analysis – based on the empirical observation that larger firms ten to win procurement contracts more often, for larger amounts, but at the same time are less constrained financially, running higher leverage for lower borrowing costs.

In order to examine heterogeneity in firm responses by size, we split our sample into firms above and below the median in terms of (log) total assets.

1.4.3 Customer-to-Supplier Pass-through of Federal Procurement

The final component to examine the size versus centrality channels is to estimate the pass-through from recipient firms to their direct suppliers. To make our estimates comparable, we follow the specification of Carvalho and Draca (2018). We sum all procurement spending to each firm's

direct customers, C_{it}, with the binary indicator w_{ij} used to denote firm j is a customer of i.

$$C_{it} = \sum_{j}^{N} w_{ij} g_{i,t} \tag{1.3}$$

We regress log-real sales growth over the following year on the log of real customer procurement sales, controlling for firm and quarter fixed effects, firm-level covariates, and direct receipt of federal procurement.

$$y_{it+4} - y_{it-1} = \beta C_{it} + X_{i,t-1}\Gamma + f_i + \lambda_{s,t+1} + u_{i,t+1} \tag{1.4}$$

1.5 Results

The dynamic multipliers associated with governement procurement shocks are reported below as impulse response functions (IRFs). Spending shocks are normalised by firm size in period $(t-1)$ to make our procurement variable comparable across firms of different sizes.

Direct Effect firms in receipt of federal procurement spending see a boost to sales relative to comparable non-recipients, with a hump-shaped response peaking at a horizon of around 4 quarters. Quantitatively, our IRFs suggest procurement to the value of 10% of previous-year's sales would add up to 1% per quarter at the peak. The cumulative response of sales shows similarly, over a horizon of five years, a demand shock of 10% of sales, would increase long run sales by around 15%. (Figure 1.6).

Size Effect The effect of procurement spending on firm sales depends strongly on firm size. Splitting the sample according to firms larger or smaller than median reveals that the total response is driven in large part by smaller firms (peak responses of approximately 0.15 versus 0.05). (Figures 1.7 and **??**.

Pass-through We evaluate the pass-through from procurement sales to supplier outcomes by regressing own log-sales on an adjusted C_{it} which is the log of average procurement of direct

customers, as opposed to the sum in the previous regression. Since the sum of customers' procurement is likely to be large relative to own sales, taking an average over customers makes the magnitudes more comparable to the direct procurement coefficient. The ratio of direct and indirect effect coefficients gives us an estimate of pass-through from government demand to changes in recipient demand to their suppliers. Our point estimates suggest and average pass-through rate of roughly 60% of the governement demand shock from direct recipient to suppliers.

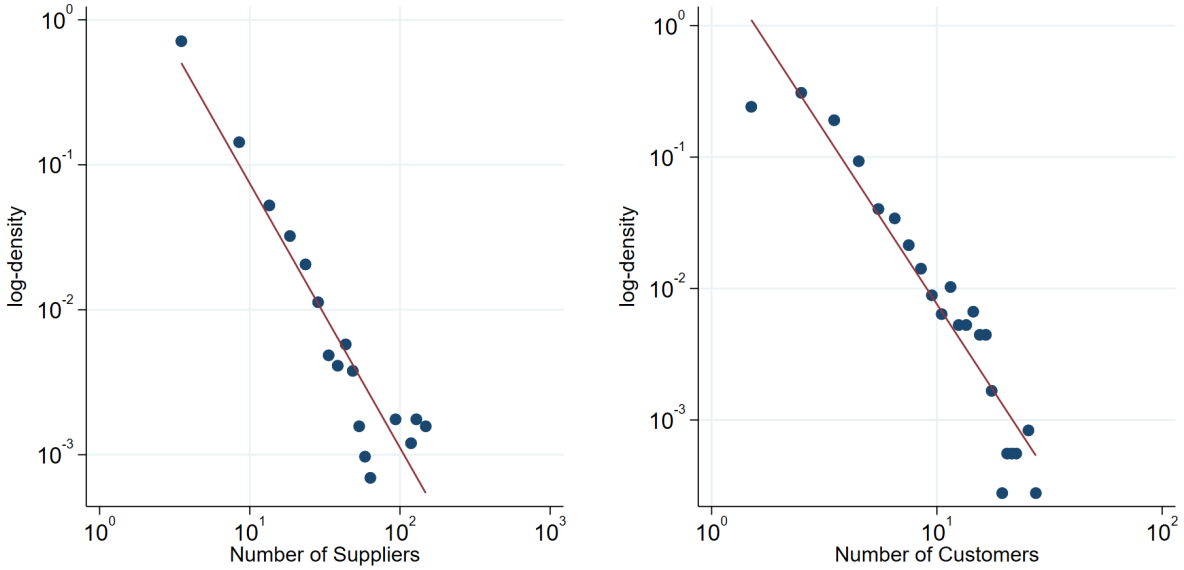
1.6 Conclusion

This paper studies government procurement spending in firm-level production networks. We first provide novel empirical evidence that large firms are more involved in government procurement at both the extensive and intensive margins. Large firms are also more central in production networks, suggesting larger multipliers by network effects associated with large firms winning procurement dollars. However, large, central players are also less constrained financially, and show much lower sales responses to procurement spending, highlighting a size-dampening effect.

1.7 Appendix to Chapter 3

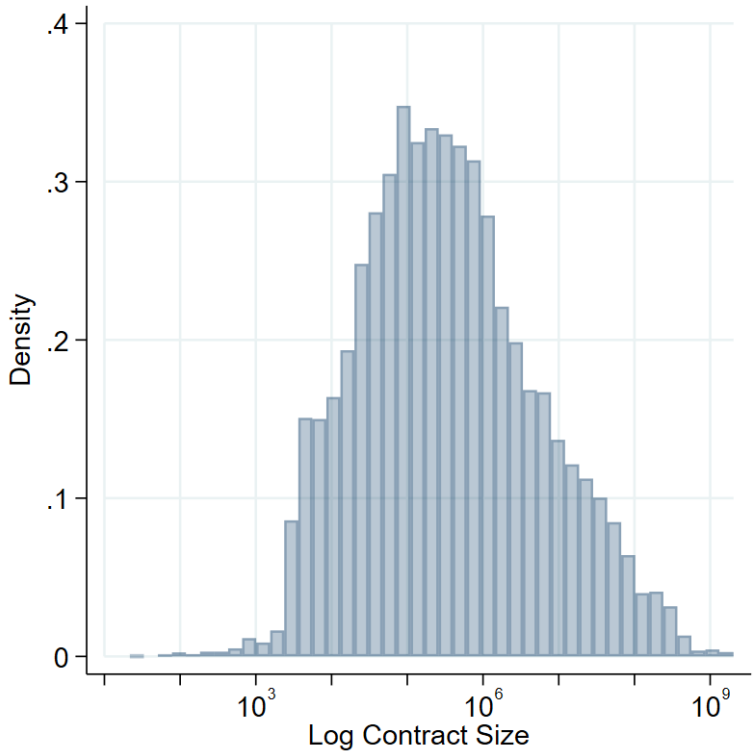
Figure 1.3: Firm-to-firm link distributions

(a) In-degree distribution (number of suppliers) (b) Out-degree distribution (number of customers)



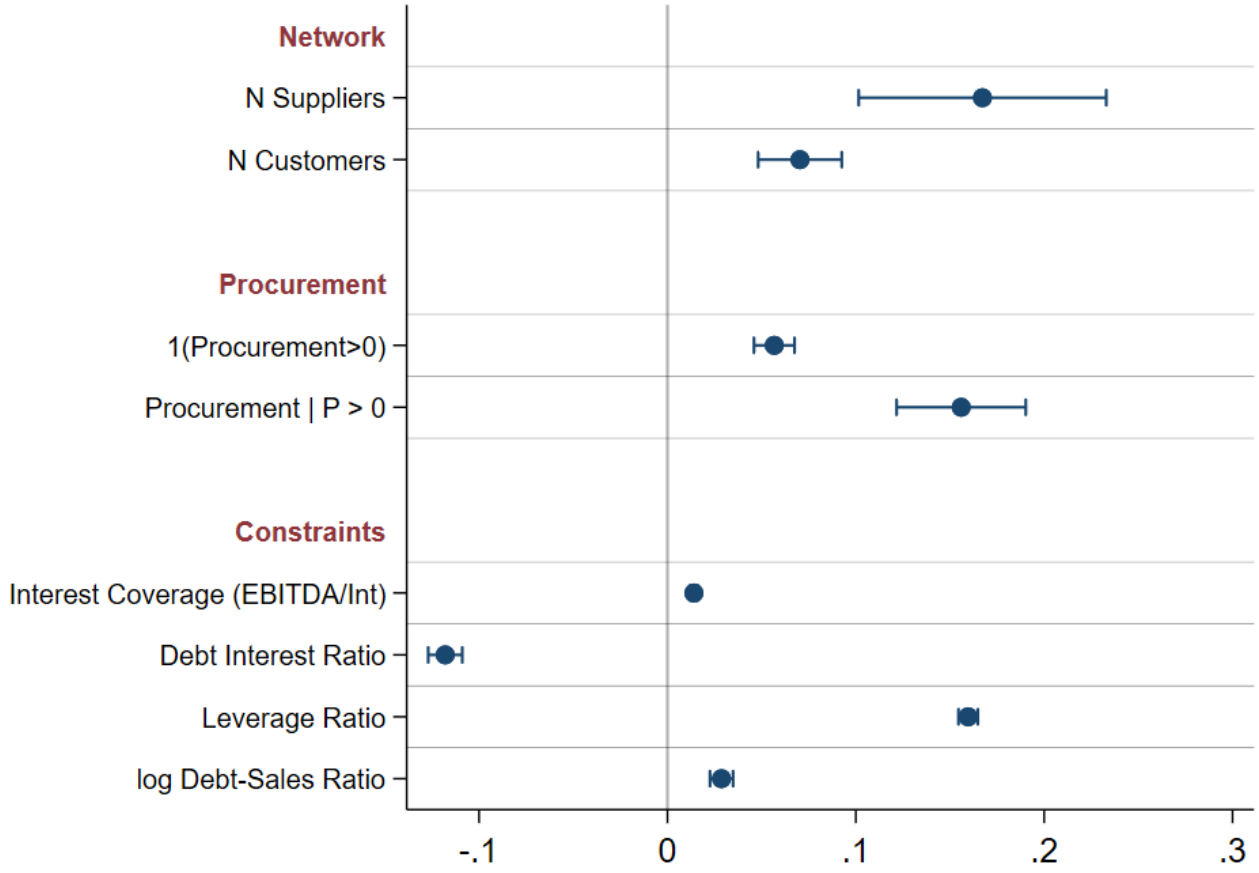
Note: log-log density plot of number of links per firm. L: distribution of number of suppliers, R: distribution of number of customers. Both axes are in log base 10.

Figure 1.4: Density plot of quarterly procurement amounts, logs real USD



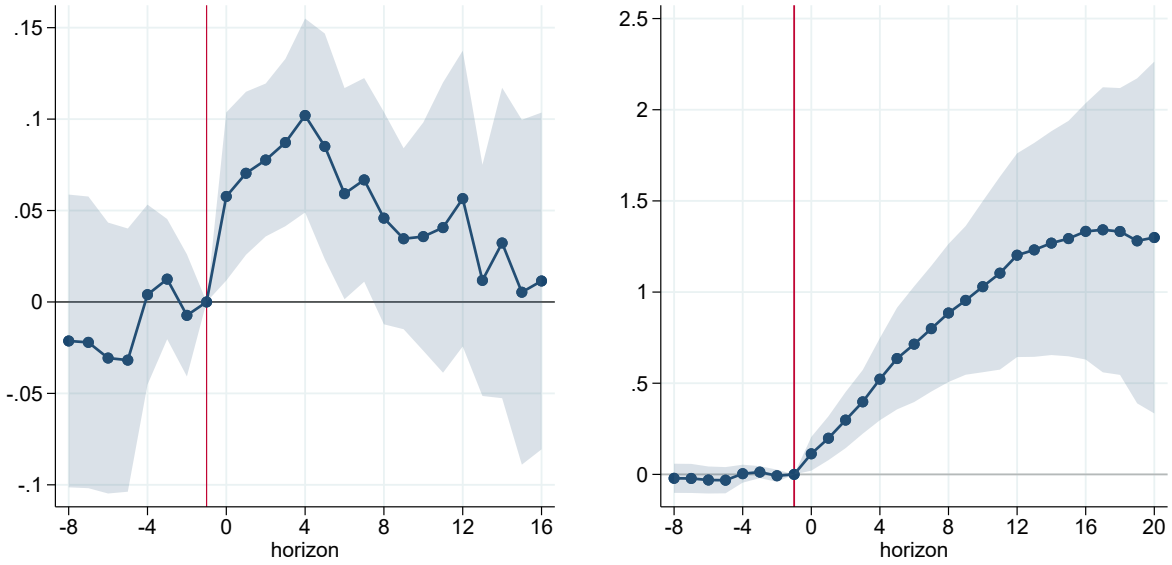
Note: Distribution of Federal procurement spending across firm-quarters. Log base10 axis.

Figure 1.5: Size Effects in Firm Network Position, Procurement Contracts and Financial Constraints



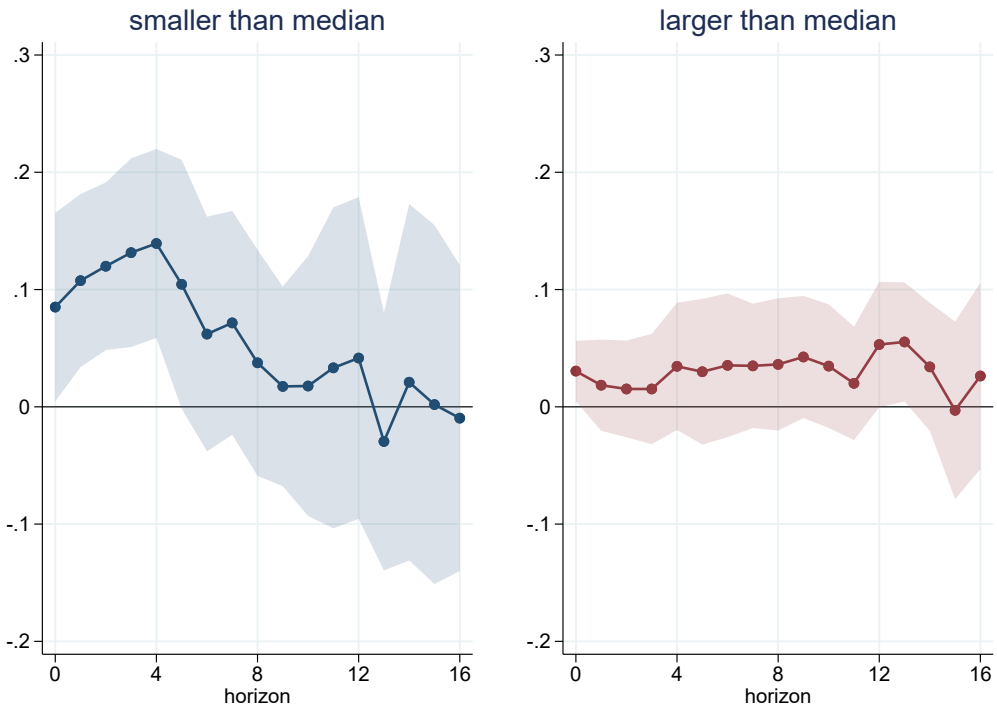
Note: Figure plots the estimate coeffient from a regression of $z_{it} = \alpha + \beta \text{size}_{it} + u_{it}$ on firm size (log total assets). Standard errors are clustered at firm and quarter levels. Outcomes are z-standardised to have mean zero and unit variance. Error bands represent 95 percent confidence intervals.

Figure 1.6: Sales Response to Procurment Spending, %



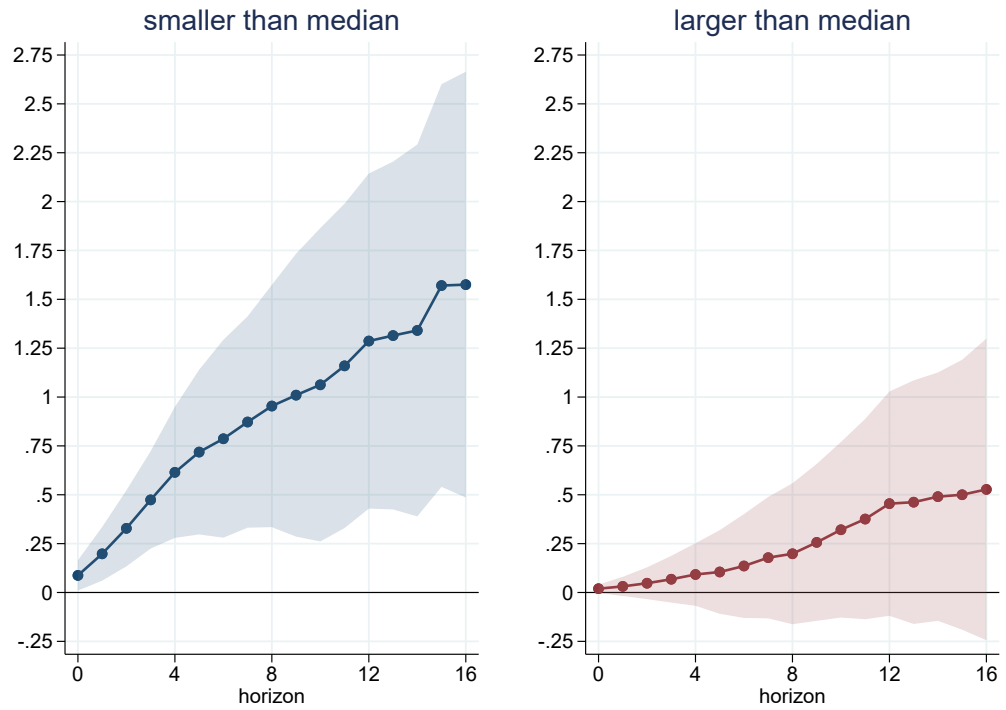
Note: The sequence of coefficients represents dynamic multipliers of government procurement spending on h-steps-ahead firm sales. The left panel presents the quarter-by-quarter response, while the right panel presents the cumulative effect over time. Robust standard errors are clustered at the firm and quarter level. 95% confidence intervals are represented by the shaded areas.

Figure 1.7: Quarterly Sales Response to Procurement Spending by Size, %



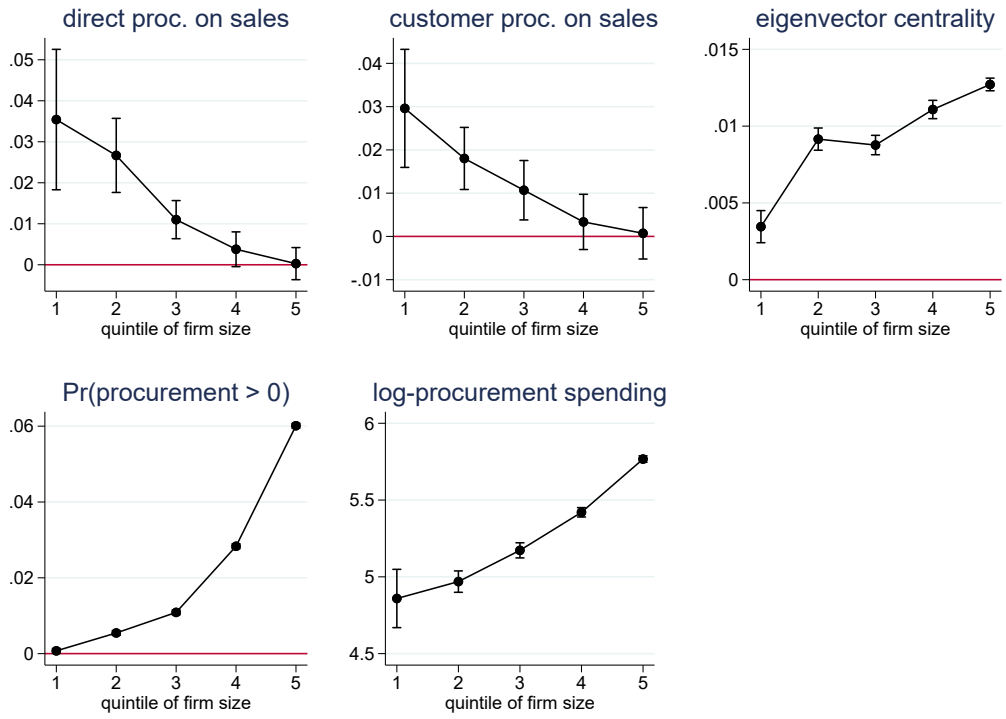
Note: The sequences of coefficients represent dynamic multipliers of government procurement spending on h-steps-ahead firm sales. The left panel presents the quarter-by-quarter response for firms below the sample median size, while the right panel presents the response for firms above the sample median size. Robust standard errors are clustered at the firm and quarter level. 95% confidence intervals are represented by the shaded areas.

Figure 1.8: Cumulative Sales Response to Procurement Spending by Size, %



Note: The sequences of coefficients represent dynamic multipliers of government procurement spending on h-steps-ahead firm sales. The left panel presents the cumulative response over time for firms below sample median size, while the right panel presents the response for firms above sample median size. Robust standard errors are clustered at the firm and quarter level. 95% confidence intervals are represented by the shaded areas.

Figure 1.9: Firm Heterogeneity by quintile of size distribution



Note: The first two panels present coefficients of direct and indirect government procurement spending on 4-quarters-ahead firm sales. The third panel calculated each firm's eigenvalue centrality in the production network at the start of the sample period. The final two panels present government procurement spending distributions across firm size, first at the extensive margin, and then at the intensive margin conditional on winning a contract. Robust standard errors are clustered at the firm and quarter level. 95% confidence intervals are represented by vertical error bars. log-procurement spending is in base 10.

1.7.1 Variable Construction and Data Description

Table 1.1: Data Description for Selected Variables

Variable	**Description**
Firm Size	log total assets (*real USD*)
Contract Size	sum of procurement dollars received in a given quarter (*real USD*)
Sales	total gross sales revenue in a quarter (*real USD*)
Sales Growth	fist difference in log Sales
Capital	Firm capital stock, computed using perpetual inverory method
N Suppliers	number of maintained links with suppliers, interpolated between gaps
N Customers	number of maintained links with customers, interpolated between gaps
1(procurement)	dummy: receives procurement contract
Procurment	procurement amount summed within a quarter, (excl. zeroes) (*real USD*)
Interest Coverage Ratio	Interest expenses/EBITDA, (%)
Debt Interest Ratio	Interest expenses/Total Debt (%)
Leverage Ratio	check winberry (%)
log Debt Sales Ratio	log(Debt/Sales) (%)

Table 1.2: Sample Firm Characteristics

	Mean	SD	p25	p50	p75	p95	p99
Size	5.112	2.764	3.283	5.229	7.038	9.418	10.959
Capital Stock	819.356	4517.928	2.805	22.698	194.725	3239.118	16520.395
N Suppliers	3.609	7.950	1.000	1.000	3.000	14.000	33.000
N Customers	1.921	1.756	1.000	1.000	2.000	5.000	10.000
1(Procurement)	0.015	0.120	0.000	0.000	0.000	0.000	1.000
$\log_{10}$ Procurement	5.527	1.175	4.685	5.441	6.272	7.649	8.365
Interest Coverage Ratio	13.994	730.561	-0.084	3.500	10.275	73.147	501.928
Debt Interest Ratio	-3.837	0.831	-4.195	-3.866	-3.557	-2.583	-0.888
Leverage Ratio	0.537	0.257	0.339	0.551	0.737	0.927	0.969
log Debt Sales Ratio	0.163	1.806	-0.774	0.200	1.282	2.832	4.430
N	1521802						

Table 1.3: Direct and Indirect Effects of Government Procurement

	$\log(\text{sales}_{it+4}) - \log(\text{sales}_{it-1})$		
	(1)	(2)	(3)
Federal Procurement	0.0165**		
	(0.00747)		
Total Customer Federal Procurement		0.0390***	
		(0.0118)	
Avg Customer Federal Procurement			0.0102***
			(0.00292)
Implied pass-through			0.6181
Own Procurement	-	×	×
Firm-level controls	×	×	×
Sector-Time Effects	×	×	×
Firm Fixed Effects	×	×	×
N	17252	18407	18407

Robust Standard errors in parentheses. Standard Errors clustered at the firm and quarter levels.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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