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Why Does GDP Move Before G? It's all in the Measurement

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Contents

Appendices

A Breaking Down the Response of GDP

In this section, we decompose the response of GDP to a defense news shock into its underlying components. To do so, we exploit the linearity of the OLS estimates which are used to construct the impulse response functions (IRFs) via local projection.

In particular, we first calculate the IRF of GDP to a defense news shock by regressing GDP on defense news shocks and four lags of investment, government spending, net-export, consumption total hours worked in the private sector, the 3-months T-Bill rate, defense news shocks and a linear time trend. We divide all nominal variables by nominal potential GDP (we take real potential GDP from Ramey and Zubairy (2018) and multiply it by the GDP price deflator). In particular, we group this set of lagged variables and the time trend into matrix X_t, and the IRF of GDP is the coefficient θ_h^{GDP} in the following linear equation:

$$\text{GDP}_{t+h} = \theta_h^{\text{GDP}} \cdot \text{News}_t + X_t \cdot \boldsymbol{\beta}^{\text{GDP}} + \varepsilon_{t+h} \quad h = 0, 1, ..., 8.$$

We report the estimated IRF of GDP in the left panel of Figure 1 in the main text. Repeating this procedure for all four components of GDP, we estimate the following set of linear equations:

$$\begin{aligned}
\text{G}_{t+h} &= \theta_h^{\text{G}} \cdot \text{News}_t + X_t \cdot \boldsymbol{\beta}^{\text{G}} + \varepsilon_{t+h}^{G} \quad h = 0, 1, ..., 8 \\
\text{C}_{t+h} &= \theta_h^{\text{C}} \cdot \text{News}_t + X_t \cdot \boldsymbol{\beta}^{\text{C}} + \varepsilon_{t+h}^{C} \quad h = 0, 1, ..., 8 \\
\text{I}_{t+h} &= \theta_h^{\text{I}} \cdot \text{News}_t + X_t \cdot \boldsymbol{\beta}^{\text{I}} + \varepsilon_{t+h}^{I} \quad h = 0, 1, ..., 8 \\
\text{NX}_{t+h} &= \theta_h^{\text{NX}} \cdot \text{News}_t + X_t \cdot \boldsymbol{\beta}^{\text{NX}} + \varepsilon_{t+h}^{NX} \quad h = 0, 1, ..., 8
\end{aligned}$$

Given that the decomposition of GDP is additive and all equations have the same set of controls X_t, it is easy to show that:

$$\hat{\theta}_h^{\text{GDP}} = \hat{\theta}_h^{\text{G}} + \hat{\theta}_h^{\text{C}} + \hat{\theta}_h^{\text{I}} + \hat{\theta}_h^{\text{NX}} \quad \text{for all } h = 0, 1, ..., 8.$$

where the $\hat{}$ denotes an OLS estimate. Therefore, we decompose IRF of GDP to a defense news shock into its four underlying components, reported in Figure 1.

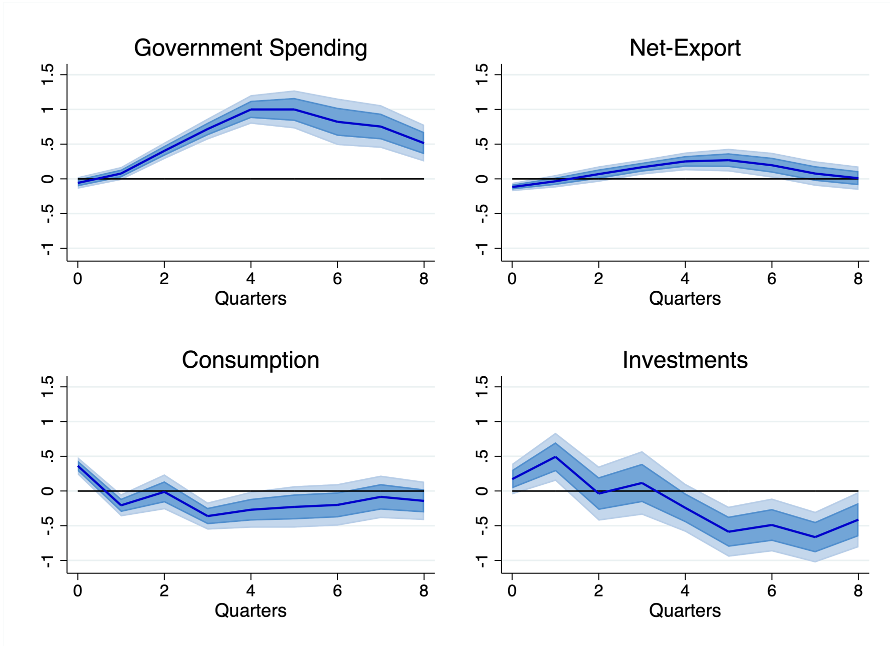


Figure 1: **Response of GDP Components to a Defense News Shock**: *IRFs of GDP, G, Investment and Changes in Inventories to a defense news shock are obtained via lag-augmented local projections. Bands represent the 68% and 90% heteroskedasticity robust standard errors. Defense news shocks are obtained from the updated series in Ramey and Zubairy (2018). Sample goes from 1947Q1 to 2015Q4. Values in the Figures are normalized by the peak response of G.*

Figure 1 shows that aggregate consumption at horizon 0 and aggregate investment at horizon 1 drive the early increase in GDP after a defense news shock.

Consumption and Investment We can further decompose the responses of consumption and investment to better understand what drives their early response. In particular, we apply the same methodology to estimate the IRFs of inventories and residential plus non-residential fixed investment (components of investment) to a defense news shock. Similarly, we estimate the IRFs of durable consumption and the sum of non-durable and service consumption. As before, we consider variables in nominal terms, divide by the GDP price deflator and multiply by real potential output (Gordon and Krenn (2010) transformation).

We report the IRFs of these four components of consumption and investments to a defense news shocks in Figure 2. We observe that the horizon 0 response of consumption largely shows up in durables while the horizon 1 response of investment is driven by inventories.

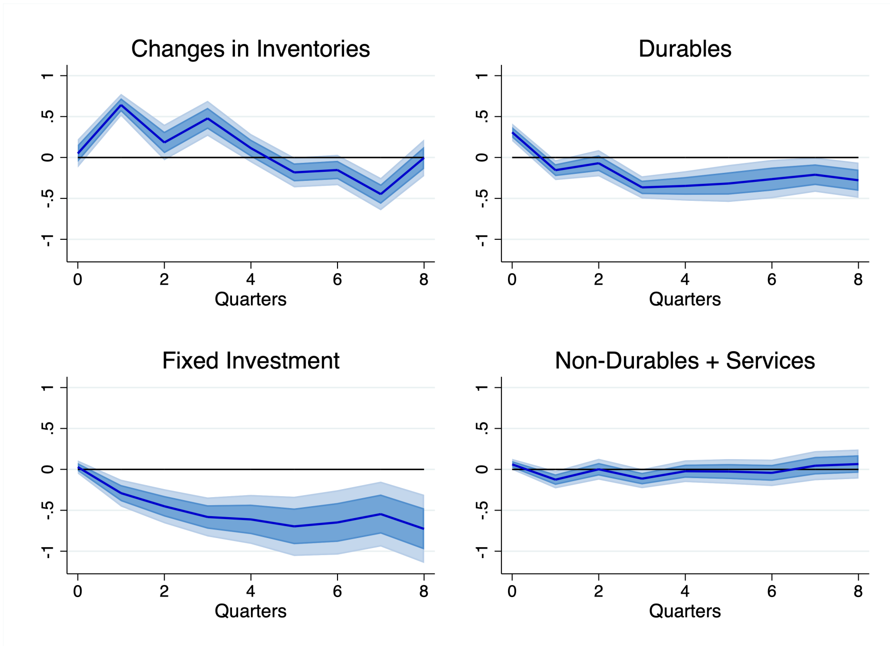


Figure 2: **Response of Consumption and Investment to a Defense News Shock**
See notes of Figure 1

B Robustness - Section I of the Paper

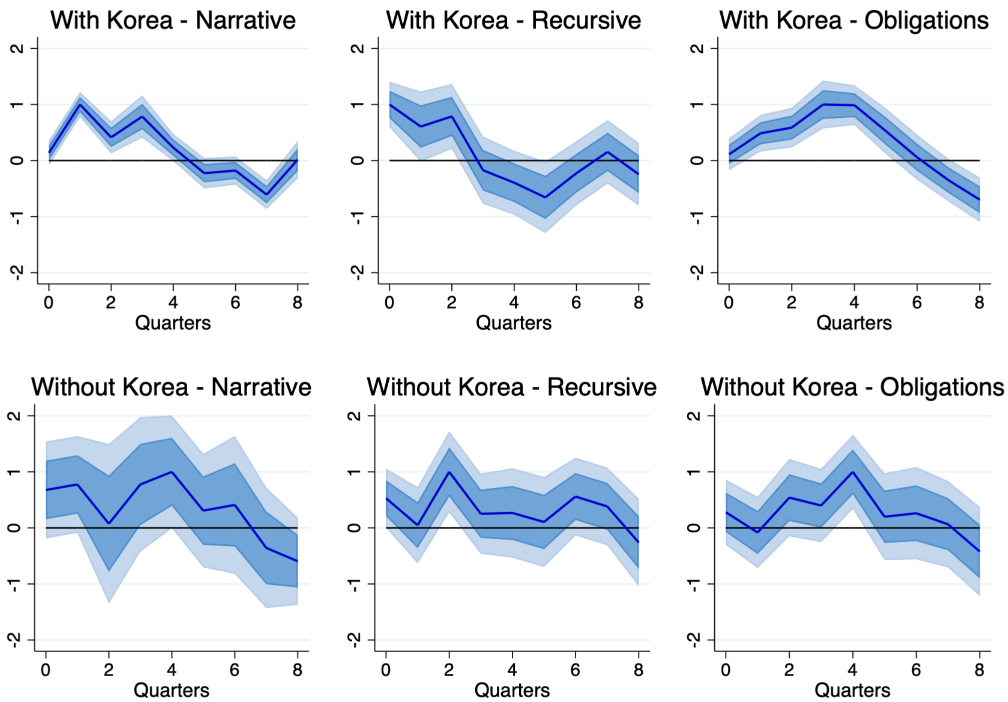


Figure 3: **Response of Inventories - Robustness**: *Response of inventories to different fiscal shocks over two samples (with and without Korean war). All the rest is identical to notes of Figure 1.*

In Figure 3, we verify that the positive response of inventories is robust to the inclusion of the Korean War in the sample period. In particular, we estimate IRFs of inventories via lag-augmented local projections with respect to three different fiscal shocks (narratively identified, recursively identified, and shocks to obligations) over two samples. The first sample includes the Korean war and goes from 1947Q1 to 2015Q4 (top row of Figure 3). The second sample runs from 1954Q1 to 2015Q4 and excludes the Korean war (bottom row of Figure 3).

For all results, we control for a linear time trend and four lags of government spending, consumption, investment, net-export, hours in the private sectors and 3-months T-Bill rate. To implement the narrative method, we include defense news shocks and its four lags and estimate the IRF using the OLS coefficients associated with defense news shocks (first column of Figure 3). To implement the recursive method, we add contemporaneous government spending and obtain the IRF from its OLS coefficient (second column of Figure 3). Finally, we consider shocks to defense procurement obligations. We control for four lags of obligations using the series discussed in the main text of the paper, and estimate the IRF from the OLS coefficient on contemporaneous defense procurement obligations (third column of Figure 3).

Although excluding the Korean War from the sample leads to less precise estimates of the IRF, our results are still significant especially at early horizons. The difference in precision is not a surprising result since the Korean War represents the largest military build-up after WWII. As discussed in the paper, we support the idea of including the Korean war in the sample since wars represent natural experiments where G increases exogenously.

C Details on Industry Level Analysis

In this section, we implement robustness checks for the industry-level analysis of inventories (see Appendix C.1) and provide details on our construction of industry weights θ_i (see Appendix C.2).

C.1 Robustness - Section II in the Paper

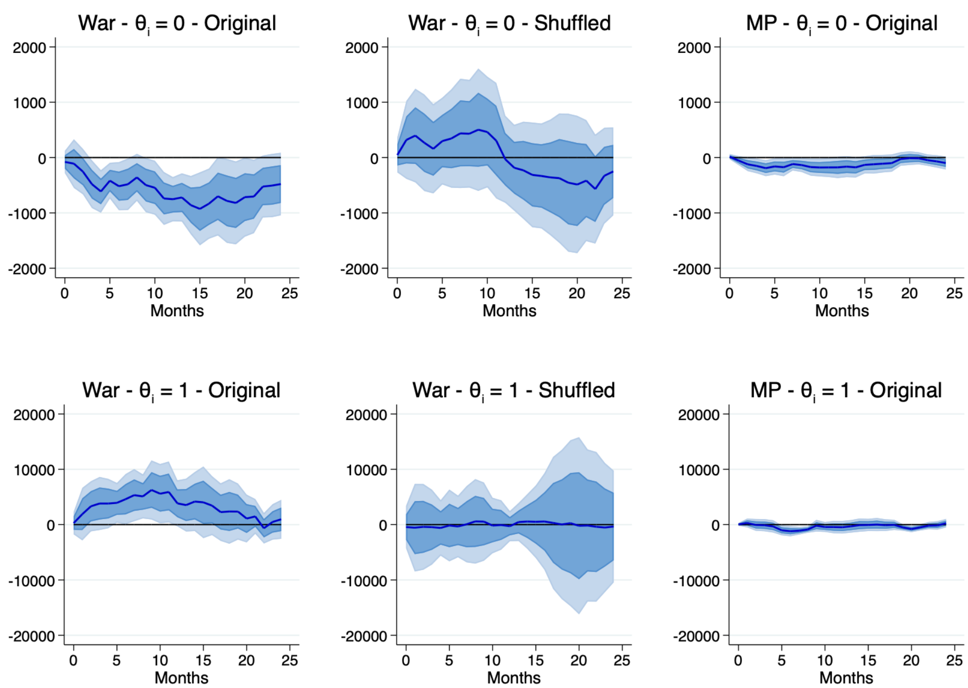


Figure 4: **Response of Sectoral Inventories to War Events (Robustness).** *Same as in Figure 2 of the Paper.*

Figure 4 shows the results of the robustness checks associated with Section II of the main text. The first column replicates the results reported in the paper, where our $Shock_t$ variable is war dates and industry weights (θ_i) are baseline weights constructed directly from the BEAs Make and Use tables. We report IRFs conditional on setting $\theta_i = 0$ (top panel) and $\theta_i = 1$ (bottom panel). Recall that setting $\theta_i = 0$

indicates the effect of a shock on a sector not connected to the government while setting $\theta_i = 1$ indicates the effect of such a shock on a sector which is fully connected to the government.

Additionally, in the middle panels we report the same results using shuffled weights. In this case, we randomly assign a weight θ_j to an industry i to verify that the result is not driven by the aggregate distribution of weights. Lastly, the right panels report the results when the weights are fixed at their empirical value, but where the shock is a monetary policy shock rather than a war date. The goal of this robustness check is to verify that the result is not driven by industry-level exposure to the business cycle. Notice that the inventory response of industries connected to the government $\theta_i = 1$ (bottom panels) vanishes for both robustness checks.

The Response of the Aircraft Industry Here we estimate the following lag-augmented local projection:

$$\bar{h}_{t+h}^{aircraft} = \beta_h \cdot Shock_t + lags_t + \varepsilon_{t+h}$$

where $\bar{h}_{t+h}^{aircraft}$ is average hours of production workers in the aircraft industry in quarter t+h, $Shock_t$ is either defense news shocks or defense procurement obligations, $lags_t$ is four lags of the dependent variable and four lags of the shock. We believe average hours of production workers in the aircraft industry is an excellent proxy for defense production (see Appendix C.3). We report IRFs in Figure 5. We observe that defense production quickly ramps up in response to defense news or newly awarded procurement contracts.

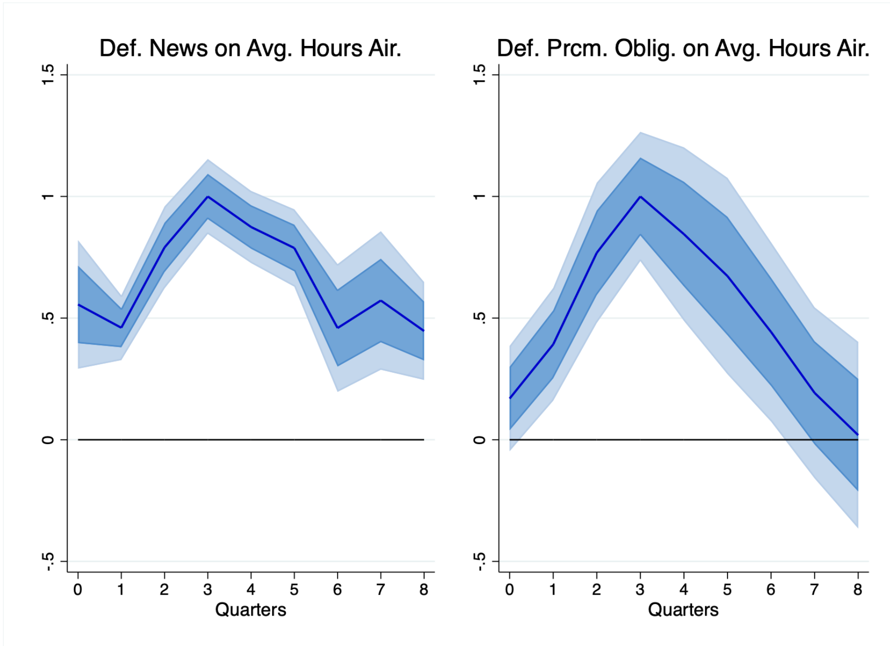


Figure 5: **Effects of Military Build-ups on Defense Production** *IRFs are obtained via lag-augmented local projections. Sample goes from 1947Q1 to 2002Q4 (sample stops in 2002 because data are no longer available). Data Source: BLS Discontinued Databases. Standard errors are heteroskedasticity robust. Confidence bands are 90% and 68%.*

C.2 Construction of Industry Weights

To construct industry weights, we combine information from the Make and Use table with more than 60 non-government sectors between 1963 to 1996. Following Horowitz and Planting (2009), we derive direct requirement industry-by-industry matrices A_t and direct sales from the private sectors to the government. We use these two elements to construct our final industry weights as follows.

Government Direct Purchases. We construct a vector of government purchases (i.e., direct requirements) relative to industry output:

$$\underset{n\times 1}{\gamma_{0,t}} = \begin{bmatrix} \frac{\text{SALES}_{1\to G,t}}{\text{SALES}_{1,t}} \\ \vdots \\ \frac{\text{SALES}_{n\to G,t}}{\text{SALES}_{n,t}}, \end{bmatrix}$$

where t denotes the year, n is the number of manufacturing sub-industries, G denotes the federal general government, and the 0 subscript in a vector's name refers to the order of included input-output connections (e.g., a zero subscript suggests that the vector only accounts for direct sales to the government). Moreover, $\text{SALES}_{i \to G,t}$ for a given sector i includes government gross investments, which show up as final uses in the Use tables. We report the time-average values of $\boldsymbol{\gamma}_{0,t}$ in the third column of Table 1.

Government Indirect Purchases Following Nekarda and Ramey (2011), we also include downstream input-output linkages to account for indirect sales to the government. In order to do so, we construct yearly $n \times n$ input-output matrices A_t in which (i, j)th element of matrix A_t is given by:

$$\frac{\text{SALES}_{i \to j,t}}{\text{SALES}_{i,t}}.$$

We then construct a vector of direct and first-order indirect sales shares as follows:

$$\boldsymbol{\gamma}_{1,t} = (I_n + A_t) \cdot \boldsymbol{\gamma}_{0,t}.$$

Notice that the ith element of $\boldsymbol{\gamma}_{1,t}$ is given by:

$$\gamma_{1,i,t} = \underbrace{\frac{\text{SALES}_{i \to G,t}}{\text{SALES}_{i,t}}}_{\text{Direct Sales}} + \underbrace{\sum_{j=1}^{n} \frac{\text{SALES}_{i \to j,t}}{\text{SALES}_{i,t}} \cdot \frac{\text{SALES}_{j \to G,t}}{\text{SALES}_{j,t}}}_{\text{Indirect Sales.}}$$

We report the time-average of $\boldsymbol{\gamma}_{1,t}$ in the fourth column of Table 1. Similarly, we construct direct, first and second order indirect sales to the government, shares of total output as:

$$\boldsymbol{\gamma}_{2,t} = \left(I_n + A_t + A_t^2\right) \cdot \boldsymbol{\gamma}_{0,t}.$$

We report the time-average values of $\boldsymbol{\gamma}_{2,t}$ in the fifth column of Table 1. Finally, we construct our industry weights θ_i as:

$$\theta_i := \frac{\mathbb{E}\left[\gamma_{2,i,t}\right]}{\max_i \mathbb{E}\left[\gamma_{2,i,t}\right]}$$

We report the weights in the last column of Table 1.

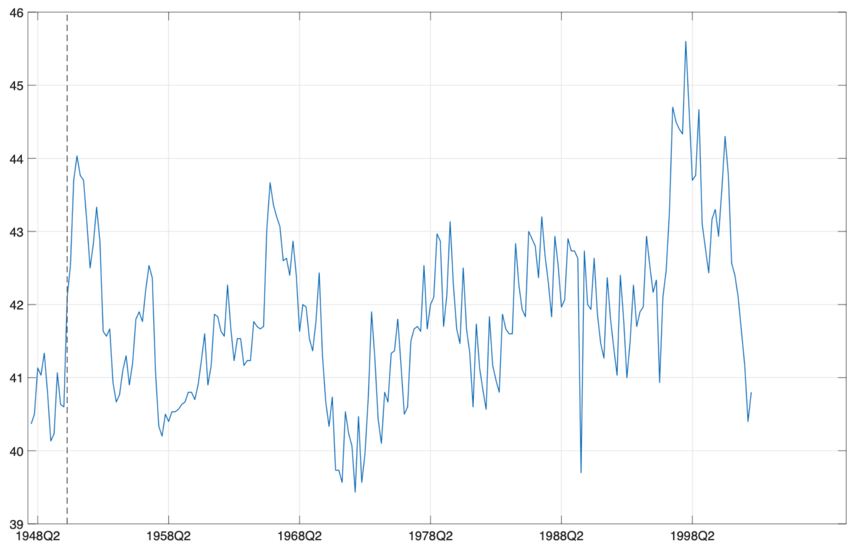
Sector	*Commodity Description*:	$\gamma_{0,i}$	$\gamma_{1,i}$	$\gamma_{2,i}$	θ_i
3364	Other transportation equipment	34.43%	42.00%	43.94%	1.00
334	Computer and electronic products	13.09%	17.04%	18.38%	0.42
323	Printing and related support activities	7.98%	9.35%	9.95%	0.23
332	Fabricated metal products	3.73%	4.78%	5.37%	0.12
3361	Motor vehicles, bodies and trailers, and parts	2.09%	3.70%	4.64%	0.11
339	Miscellaneous manufacturing	2.31%	3.80%	4.49%	0.10
333	Machinery	2.65%	3.84%	4.44%	0.10
335	Electrical equipment, appliances, and components	2.37%	3.66%	4.31%	0.10
325	Chemical products	1.91%	3.50%	4.27%	0.10
324	Petroleum and coal products	2.71%	3.50%	4.17%	0.09
326	Plastics and rubber products	1.13%	2.20%	2.89%	0.07
337	Furniture and related products	0.66%	1.63%	2.19%	0.05
331	Primary metals	0.54%	1.44%	2.06%	0.05
313	Textile mills and textile product mills	0.48%	1.31%	2.01%	0.05
315	Apparel and leather and allied products	0.57%	1.37%	1.98%	0.05
327	Nonmetallic mineral products	0.49%	1.35%	1.91%	0.04
322	Paper products	0.51%	1.25%	1.83%	0.04
311	Food and beverage and tobacco products	0.38%	1.16%	1.77%	0.04
321	Wood products	0.19%	0.91%	1.53%	0.03

Table 1: **Industry Weights.** Last column divides $\theta_{2,i}$ by the maximum value (i.e. the one of Other Transportation Equipment Manufacturing). In the paper, the weights θ_i that we use are the ones which include second order degree of connections, normalized (last column).

C.3 Tracking Defense Industrial Production

In Section II of the paper, we use use *Average Hours of Production Workers* of the *Aircraft industry* to keep track of the "*defense production machine*". We now explain the reasons behind that choice. Firstly, we plot the quarterly time series in Figure 6.

Figure 6: Average Hours of Production Workers in the Aircraft Industry



Aircraft Industry We choose the Aircraft industry for two reasons: (i) great data availability (monthly data from BLS discontinued series starting from 1939) and (ii) high dependency on government purchases (see Nekarda and Ramey (2011)).

Hours-per-Worker In general, there are no direct measures of industrial output. In the case of the aircraft industry, we do not observe the exact number of aircraft produced every month nor their percentage of completion. However, we have three variables which can proxy for industrial production: (i) average weekly hours of production workers, (ii) number of production workers (i.e., employment) and (iii) their product, namely total hours worked. The first one is a measure of intensity of production, while the other two are stock variables measuring the extensive margin of production.

In order to understand which one is more suitable to measure changes in production, we consider as an illustrative example the outbreak of the Korean War. During this period, defense manufacturers foresee a period of high demand of weapons by the government and adjust production accordingly. The first sensible thing is to increase production, given the predetermined level of capital and labor inputs. For instance, increasing production requires extra use of electricity to operate machinery in the assembly lines as well as a higher number of shifts with longer duration for production workers. By consequence, hours per worker increase immediately. Over time, contractors expand production by widening their stock of capital and workers, thus overcoming problems related to capital immobility (see e.g., Ramey and Shapiro (1998)) and labor market frictions. As contractors expand their production facilities and hire new production workers, intensity of production returns back to normal.

This example highlights two facts. Firstly, intensity of production of manufacturing industries is a good indicator of switches in the production regime. Secondly, intensity of production leads employment and other stock variables which tend to move more slowly. This intuition is consistent with Bils and Cho (1994), who find that hours per worker lead employment and the business cycle. Moreover, they emphasize how hours-per-worker co-moves with other relevant but unobserved measures of intensity of production.[1] Along these lines, Fernald (2012) suggest to use hours of production workers to proxy other unobserved measures of intensity of production. According to them, a cost-minimizing firm operates on all margins simultaneously, both observed (i.e., hours per worker) and unobserved (i.e., labor effort and workweek of capital).

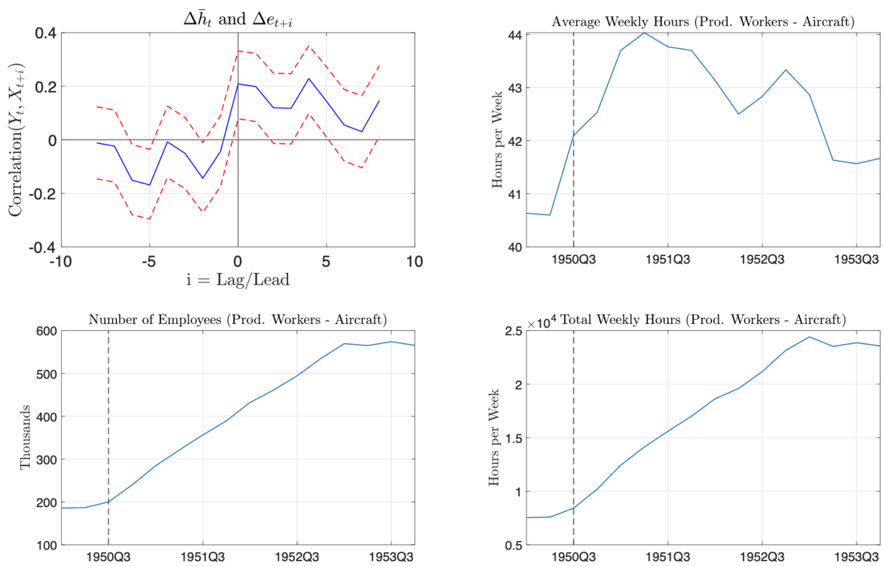
In what follows, we show that (i) hours-per-worker in the aircraft industry leads employment and (ii) employment drives the dynamics of total hours, overshadowing very informative lumpy changes in hours-per-worker. In light of all this, *hours-per-worker is the most suitable variable to timely measure changes in production*.

Hour per Worker, Employment and Total Hours in the Aircraft Industry Figure 7 shows in its top-left panel the lead-lag correlation map between changes in average hours of production workers and changes in the number of production workers in the Aircraft industry. Clockwise from the top-right panel we show the time series

[1] They find that (i) "looms hours" are strongly related to hours per worker in the US textile industry and (ii) electricity use of manufacturing industries and hours worked per week co-moves. On the contrary, they find that the relationship between their measures of capital utilization and the number of production workers is much weaker.

of average hours of production workers ($\bar{h}_t$), number of production workers (e_t) and total hours of production workers ($\bar{h}_t \cdot e_t$) around the onset of the Korean war for the Aircraft industry (i.e., 1950Q3), respectively.

Figure 7: Average Hours of Production Workers Vs Production Workers - Aircraft Industry



Firstly, from the lead-lag correlation map, we observe that average hours of production workers lead employment. This is consistent with the findings of Bils and Cho (1994). Secondly, notice that the dynamics of total hours is dominated by employment, and not by average hours per worker. Therefore, if we gauge industrial production by simply looking at the dynamics of total hours, we would conclude that the response of the Aircraft industry at the outbreak of the Korean war was mild and slow. On the contrary, average hours per production worker anticipated the peak response of employment and total hours of production, signaling that defense production had already fired up at the onset of the war.

We further clarify what is happening by breaking down the change in total hours into two components, one which accrues to changes in hours worked (intensive margin) and one which accrues to changes in number of workers (extensive margin):

$$H_t = \bar{h}_t \cdot e_t$$
$$\frac{\partial H_{t+h}}{\partial z_t} = \underbrace{\frac{\partial \bar{h}_{t+h}}{\partial z_t} \cdot e_{t+h}}_{\text{Intensive Margin}} + \underbrace{\frac{\partial e_{t+h}}{\partial z_t} \cdot \bar{h}_{t+h}}_{\text{Extensive Margin}}$$

where z_t is a defense news shock. We break down the dynamic response of total hours to the Korean War using the previous expression:

$$(H_{1950Q3+h} - H_{1950Q2}) = \underbrace{\left(\bar{h}_{1950Q3+h} - \bar{h}_{1950Q2}\right) \cdot e_{1050Q3+h}}_{\text{Intensive Margin}} + \underbrace{\left(e_{1950Q3+h} - e_{1950Q2}\right) \cdot \bar{h}_{1050Q3+h}}_{\text{Extensive Margin}}$$

with $h = 0, 1, ..., H$. We show this breakdown in Table 2:

Table 2: Breakdown Total Hours - Korean War

Date	$\bar{h}_t$	e_t	H_t	$H_{1950Q3+h} - H_{1950Q2}$	Int. Margin	Ext. Margin	Int. Margin (%)	Ext. Margin (%)
1950Q2	40.60	186.83	7585.43	0.00	0.0	0.0	-	-
1950Q3	42.10	200.00	8420.00	834.57	300.0	554.3	35.9%	66.4%
1950Q4	42.53	239.70	10195.24	2609.81	463.4	2248.6	17.8%	86.2%
1951Q1	43.70	284.57	12435.56	4850.13	882.2	4270.9	18.2%	88.1%
1951Q2	44.03	321.00	14134.70	6549.27	1102.1	5907.8	16.8%	90.2%
1951Q3	43.77	356.37	15596.98	8011.55	1128.5	7419.9	14.1%	92.6%
1951Q4	43.70	389.27	17010.95	9425.52	1206.7	8846.3	12.8%	93.9%
1952Q1	43.13	432.00	18633.60	11048.17	1094.4	10574.9	9.9%	95.7%
1952Q2	42.50	461.07	19595.33	12009.90	876.0	11654.9	7.3%	97.0%
1952Q3	42.83	494.30	21172.52	13587.08	1103.9	13169.8	8.1%	96.9%
1952Q4	43.33	534.37	23155.89	15570.46	1460.6	15059.8	9.4%	96.7%
1953Q1	42.87	569.43	24409.71	16824.28	1290.7	16400.8	7.7%	97.5%

Notice that the dynamic of Total hours, H_t is dominated by the extensive margin. Therefore, using total hours would overshadow the early change in hours-per-worker, which is a clear signal that contractors were already responding to the shock in the third quarter of 1950.

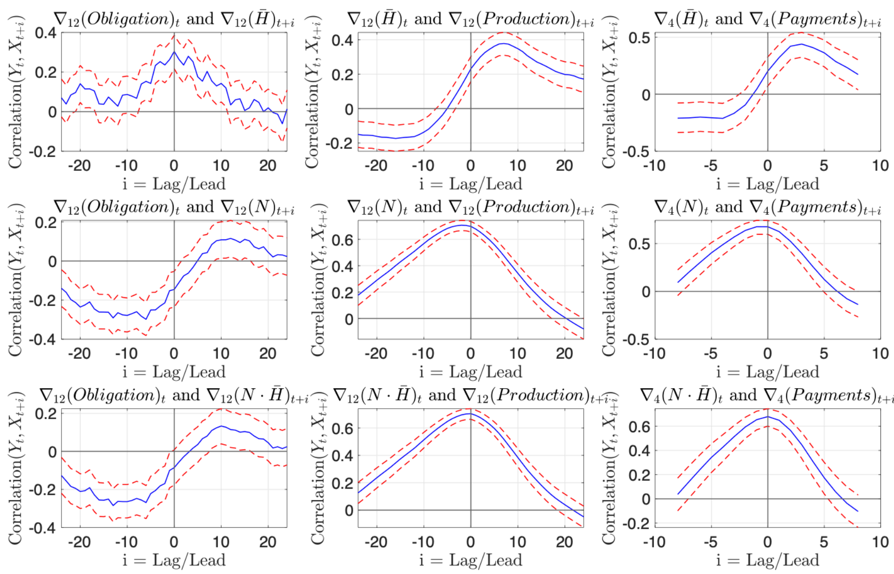
Delay in the FED's Defense Industrial Production Index Notice that the Board of Governors of Federal Reserve System constructs a monthly real index of industrial production of manufacturing equipment in defense industries.[2]

[2]Data is available from 1947 to present at monthly and quarterly frequency, both seasonally adjusted and not. It can be downloaded at this link. Detailed information on the Real Index of Industrial

The Fed makes clear that such defense production index is *mainly obtained from BLS data on production-hours (i.e., total hours). Hours are then used to infer output.* However, we have just seen that the dynamics of total hours worked are delayed relative to average hours worked. In fact, we now show that hours-per-worker in the Aircraft industry leads defense production as measured by the Fed.

In particular, we study the lead-lag correlation map between each labor margin and defense procurement obligations, production, and spending. Figure 8 plots the results.

Figure 8: Lead-Lag Correlation Graph - Defense Industrial Production



Defense procurement spending is constructed as discussed in the paper and therefore tracks payments to contractors (sample from 1947Q1). Defense procurement obligations come from the original series from Business Condition Digest, discussed in Appendix D.2 and track new contract awards (monthly data from 1951M1 to 1988M11). Defense Production is the monthly seasonally adjusted index constructed by the Fed (data available from 1947M1). Hours and employment data come from the BLS discontinued data series on production workers data (available from 1939M1 to 2003M12).

Firstly, looking at the first row, average hours of production workers in the Aircraft industry (intensive margin) appear to: (i) co-move with obligations, (ii) lead

Production of Manufacturing Equipment in Defense sector is available at this link. In particular, the underlying industries used for the construction of the series are discussed in these two tables: (i) market structure (Equipment); (ii) Industry Group (defense and space).

industrial output by 8 months (2 quarters), and (iii) lead payments by 4 quarters.

From the second row, we notice that the number of production workers (extensive margin) appear to: (i) lag behind obligations (the delay is about 3 quarters), (ii) co-move with the production index and (iii) co-move with payments.

Finally, the third row shows that total hours of production workers co-move with industrial production as measured by the Fed. This confirms the fact that the Federal Reserve adopts total hours to construct the defense production variable. Moreover, the maps of total hours and employment are basically identical, confirming our previous finding that the dynamics of employment drive movements in total hours.

To summarize, we show that the Fed measures defense production using total hours of production workers. However, the dynamics of total hours is dominated by employment, which is a delayed measure of production and overlooks the ability of producers to ramp-up production by using more intensively their input of production (i.e., capital utilization and average hours worked). Specifically, the Fed's measure lags behind defense procurement obligations but co-moves with spending. This confirms that the Fed's production index is subject to the same delays whichcharacterize employment. In light of this, we believe that using average hours of production workers in the Aircraft industry is best suited for capturing real-time changes in defense production.

D Details on Defense Procurement in the Data

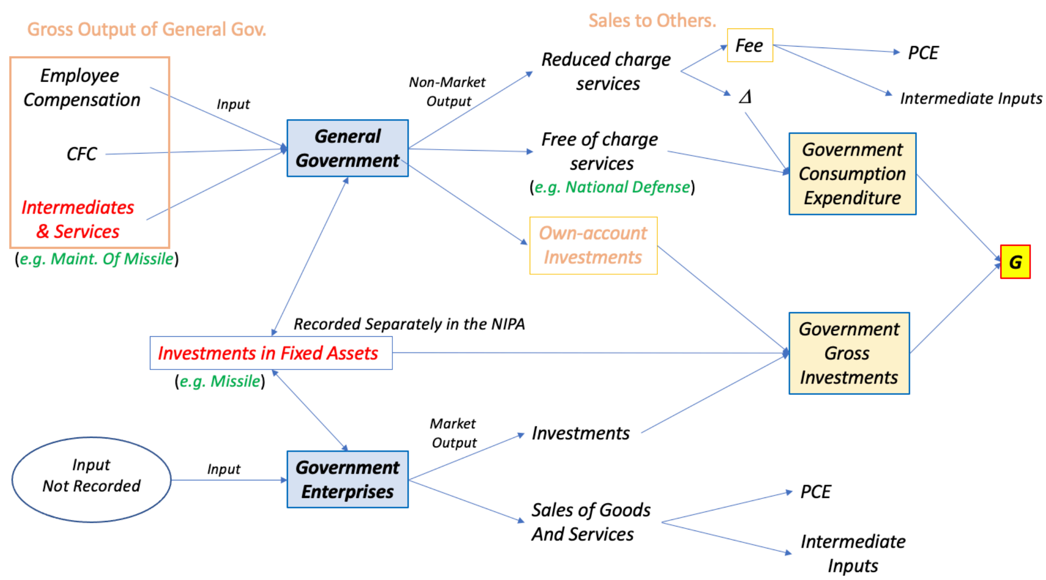
In this section, we outline the details about measurement of defense procurement spending.

Section D.1 clarifies the accounting origin in the NIPA of outlays which refer to the purchase of goods. Section D.2 shows how we calculate the 2 to 3 quarters delay between defense procurement obligations and spending. Section D.3 uses contract level data from the 2000 to rationalize the existence of a time delay and address the issue of partial delivery payments. Section D.4 illustrates how we construct the quarterly time series of defense procurement obligations. Section D.5 uses data from the 2000 on contracts' opportunities (i.e., contract level *solicitations*) to show that it is unlikely for contracts awards to be anticipated by more than one quarter.

D.1 Accounting Origin of Procurement in the NIPA

In this section, we provide further details on the accounting origin of public procurement contracts in the NIPA tables. Figure 9 summarizes the accounting of G, according to Chapter 9 of BEA (2017), which explains how the NIPA record all the entries of G. It highlights in red the two entries which contain public procurement spending: (i) Intermediate Goods and Services and (ii) Investment in Fixed Assets.

Figure 9: Accounting of G - Summary



CFC means "Cost of Fixed Capital" and measures depreciation of government assets. PCE means Personal Consumption Expenditure, the NIPA measure of Consumption which absorbs reduced charge services from the government (e.g. tuition fees from public universities). Own Account Investment is own resources reinvested in the public capital stock.

First of all, notice that G is made of two components, consumption and investments:

$$G = \underbrace{\text{Government Consumption Expenditure}}_{G^C} + \underbrace{\text{Government Gross Investments}}_{G^I}$$

Government Consumption Expenditure Government consumption originates from the gross output of the government after deducting (i) Sales to Other Sectors and (ii) Own-Account Investments:

$$G^C = \underbrace{\text{Compensations} + \text{CFC} + \text{Intermediates and Services Purchased}}_{\text{Gross Output of General Government}} - \ldots$$
$$- \text{Own Account Investments} - \text{Sales to Others}$$

When a general government entity (e.g., DoD) decides to purchase goods and/or services, they are mainly accounted as Intermediates, which eventually end up in G as government consumption.

Government Gross Investments The government also makes three types of investments. Firstly, the General Government makes Own-Account-Investments, which are deducted from the gross output of general government, in order to account them as investments. Secondly, both the General Government and Government Enterprises make investments in fixed assets. Investment in Fixed Assets contain other purchases from the private sector.

Example D.1 (Purchasing a Missile)**.** To clarify this point, consider the case of the government purchasing a new set of guided missiles:

1. The missile is accounted as Equipment in the Federal Defense category of Change in Government Fixed Assets and therefore contributes to G as part of Government Gross Investments.

2. Installation, Maintenance, Quality Control and other services related to the Missile are accounted as Intermediate Goods and Services Purchased (input of production).

3. The missiles and the related services are used to produce a non-market output of production, namely, national defense.

The production of the missile shows up in business inventories as long as the contractor supplying the missile delivers it to the government. Once delivered, inventories decrease and government investment increase. Notice that the reduction in inventories and the corresponding increase in G is a zero-sum game which does not increase GDP (recall that GDP in the US is constructed as the sum of final demand). GDP increases while production takes place and is recorded as inventories. In absence of time-to-build, inventories do not increase and the purchase of the item by the government directly shows up in G. For instance, this is the case of the Installation, Maintenance, Quality Control and other services related to the missile purchased by the Government.

Figure 10 provides an example of official accounting table of G, namely NIPA Table 3.10.5A, taken from BEA (2017).

Figure 10: NIPA Table 3.10.5A - Example

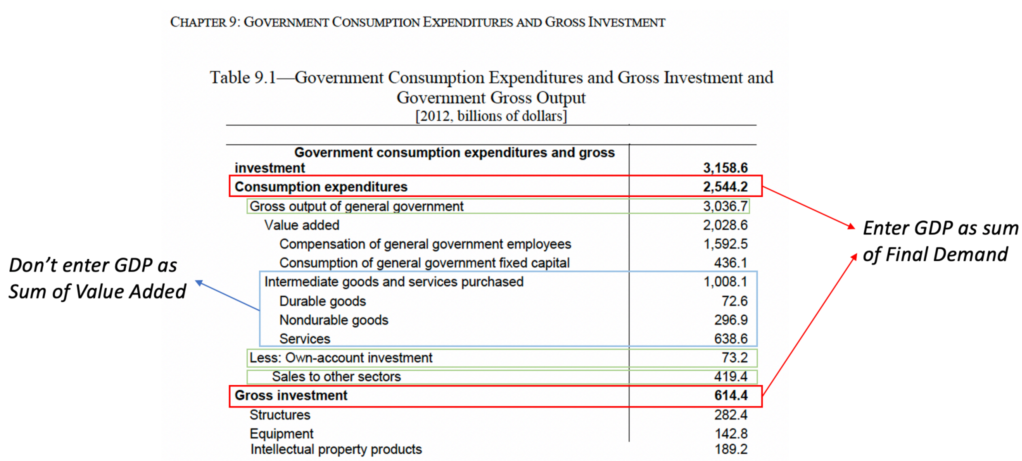

CHAPTER 9: GOVERNMENT CONSUMPTION EXPENDITURES AND GROSS INVESTMENT

Table 9.1—Government Consumption Expenditures and Gross Investment and Government Gross Output
[2012, billions of dollars]

Government consumption expenditures and gross investment	**3,158.6**
Consumption expenditures	**2,544.2**
Gross output of general government	3,036.7
Value added	2,028.6
Compensation of general government employees	1,592.5
Consumption of general government fixed capital	436.1
Intermediate goods and services purchased	1,008.1
Durable goods	72.6
Nondurable goods	296.9
Services	638.6
Less: Own-account investment	73.2
Sales to other sectors	419.4
Gross investment	**614.4**
Structures	282.4
Equipment	142.8
Intellectual property products	189.2

Finally, to clarify the timing, we provide a visual representation of the process in Figure 11.

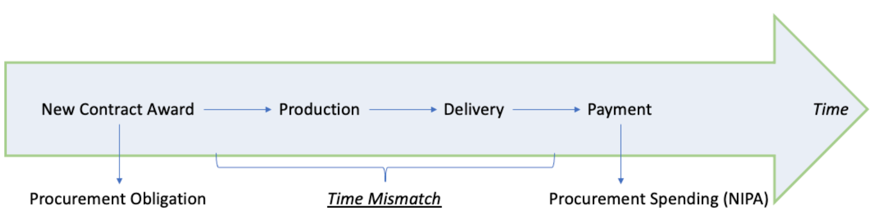


Figure 11: **Timeline of Procurement Contracts.** *The procurement timeline follows information from the Federal Acquisition Regulation (FAR) and the BEA's Concepts and Methods of NIPA.*

D.2 Time Mismatch Between Obligations and Payments

In Section D.2, we show how we construct a proxy for defense procurement spending using data from the NIPA. We now show how we construct the defense procurement obligation proxy. Recall that obligations arise when the DoD awards new contracts while spending reflect government outlays, that is, payment to contractors. We observe obligations through two data sources, discussed below.

Business Condition Digest The periodical *Business Conditions Digest*, available on Fraser at this link, provided Business Cycle Indicators, among which a list of Defense Indicators. The original source of the data was the Department of Defense, Office of the Assistant Secretary of Defense (seasonal adjustment implemented by BEA). In particular, we use Series 525, "*Defense Prime Contracts Awards*". This series was firstly collected by Valerie Ramey for her papers: Ramey (1989) and Ramey (1991). We are grateful to her for providing the data. The periodical was issued monthly from October 1961 until March 1990. However data is available from January 1951 to November 1988.

Business Condition Digest was discontinued in March 1990, and data on prime contracts is no longer recorded starting December 1988 (all year 1989 is missing). Most business indicators on *Business Condition Digest* were moved to another monthly periodical, namely the *Survey of Current Business*. Prime award contracts (series 525) was preserved and moved to Appendix C on *Business Cycle Indicators* (section 2.4: other important economic measures/government activities). Data is available in the form of scanned versions of the *Survey of Current Business* at this link. For some reason, data starting from 1991 does report values of prime contract awards for months in the fourth quarter (Q4) of every year. We believe this is a systematic omission, which results in less reliable data for this time period. Finally, due to reorganization of resources at the BEA, the *Business Cycle Indicators* section was discontinued, and prime award contracts were no longer disclosed to public, following the joint November-December 1995 issue. Therefore data is not available after this date.

To summarize, we obtain reliable monthly data on prime contract awards from January 1951 to November 1988. We plot defense prime contract awards versus defense procurement spending in the top-left panel of Figure 5 of the paper. Notice that in order to match the quarterly frequency of procurement spending, obligation data is aggregated by quarters. Moreover, since NIPA data are annualized (their quarterly averages return their yearly values), we do the same for obligation data to allow for a closer comparison between the two series.

We observe from the graph that obligations lead spending. Notice that obligation data tends to be more noisy than spending data. The main reason for this is that large contracts are often awarded and then terminated a few months later for convenience, or due to litigation with a losing offeror (this is also highlighted in Auerbach, Gorodnichenko, and Murphy (2020)). Moreover, obligations are more lumpy than payments which get smoothed over the duration of a contract. In order to account for this, we use a simple MA smoother (red line in the graph). We then provide a quantitative assessment of the delay by looking at the lead-lag correlation map between the growth rates of smoothed obligations and the growth rates of spending (see top-right panel).[3]

Overall, we find a positive correlation between the two series which increases when obligations are delayed (top-right quadrant of the lead-lag correlation map). In particular, correlation spikes when obligations are delayed by 2, 5 and 8 quarters. Results are robust to a different approach which looks at the lead-lag correlation between year-to-year quarterly changes ($\nabla_4 \, x_t = (1-L^4)x_t = x_t - x_{t-4}$) of original -i.e., not smoothed - obligations and spending. In this case, the spikes happen at 2 and 5 quarters.

Federal Procurement Data System Next Generation On September 26th 2006, the Federal Funding and Accountability Act is passed by congress as a first step towards a more transparent procurement system, which allows full disclosure of information involving federal contracts. The transparency effort by FFATA culminates in 2019 with the opening of a public website, USASpending.gov, which discloses information on all federal procurement contracts.[4] Data from USASPending.gov is pulled from FPDS-NG, the Federal Procurement Data System Next Generation,

[3] We look at growth rates ($\Delta_1 \, x_t = (1-L)^1 x_t = x_t - x_{t-1}$) to cope with the non-stationarity of the series.

[4] More information on the history of USASpending.gov can be found here.

which actually includes the whole universe of procurement contracts. FPDS is the system used by government contracting officers to officially input data on awarded contracts in the government-wide system. Data from FPDS can be downloaded from USASpending.gov. The data spans 2000Q4 to the present with a caveat: contract data awarded before the beginning of the construction of the database could have been lost or not recorded. We collect data on all defense procurement contracts on FPDS between 2000Q4-2020Q3.

We again compare obligations and spending in Figure 12. The top-right panel plots again the lead-lag correlation between the growth rates of (smoothed) obligations and the growth rates of spending. The highest correlation is recorded when obligations are delayed by 1 quarter. Once again, the results are robust to looking at the lead-lag correlation of year-to-year quarterly changes between original obligations and spending. In this case, the peak occurs from 0 to 2 quarters.

Figure 12: Accounting Mismatch - January 2000 onward

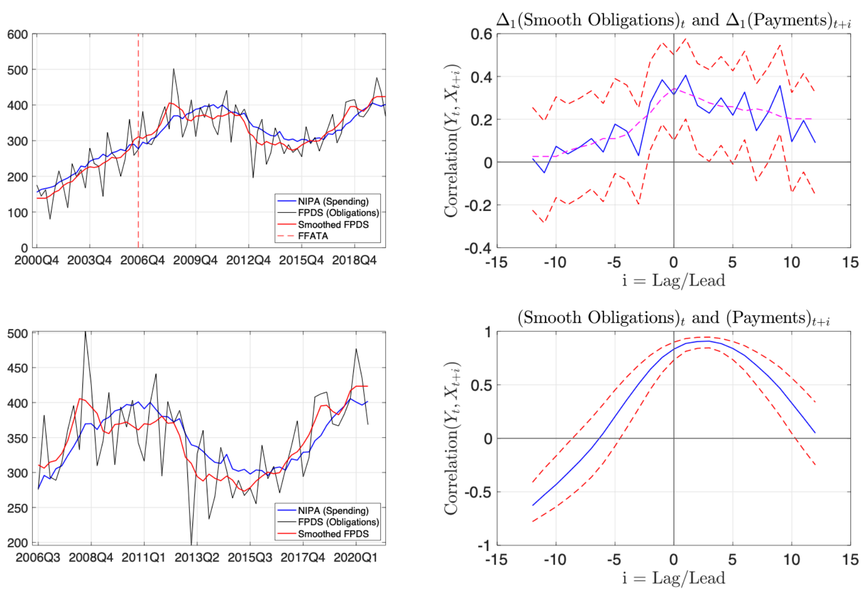


Figure 12's notes: the FPDS measure of obligation (blue line) is constructed by: (i) summing the daily data to obtain quarterly data; (ii) annualizing the data as done by NIPA; (iii) de-seasonalize data using Brockwell and Davis (1991)'s method (the Matlab code can be found here).

Before the signing of the FFATA, 2006, obligations seem under-reported relative to spending, thus inducing a downward bias in estimates of the accounting time-mismatch. We have two possible explanations for this counter-intuitive result, either this is a consequence of missing contract modifications awarded before the introduction of FPDS, or those modifications could have been classified before FFATA made most of contracts available to the public. In fact, FPDS-obligation data catches up and starts leading spending after the signing of the FFATA. Moreover, we show in Figure 13 that the share of large contracts (top 1%, 5% and 10%) out of all procurement spending stabilizes after 2006, indicating that large classified contracts are not showing up in FPDS.

We take this into account and we repeat the analysis only on those quarters following the signing of the FFATA (bottom panel of Figure 12). We observe a single clear spike in the lead-lag correlation, which indicates that obligations are delayed by 3 quarters relative to payments.[5]

Summary of Time Mismatch We summarize the time delay between obligations and spending in Table 3

Table 3: Summary of Time Mismatch Between Spneding and Obligations

Period	*Data Source*	*Correlation Spike Delay (Quarters)* Δ_1	∇_4
1951M1 to 1988M11	BCD	2-5	2-5
2000M10 to 2020M9	FPDS	1	2
2006M1 to 2020M9	FPDS	3	-

These results suggest that the accounting delay between beginning of production (award date) and the first payment (outlay) is on average between 2 to 3 quarters. Notice also that the time delay seems to shorten over time, when we use FPDS data.

[5]The peculiar non-trending sinusoidal-wave shape of the data referring this period allows us to directly look at the correlation between the two series in levels. The super-positioning of waves which happen when we shift one series back and forth in time, allows to observe a single clear spike which refers to the exact period when the two series overlap. The correlation spikes when obligations are delayed by 3 quarters.

Overall, our results are consistent with anecdotal evidence that government payments happen once every 180 days.[6]

D.3 Rationalizing the Time Mismatch

In this section, we rationalize the existence of an aggregate time-mismatch between defense procurement obligations and spending. In particular, we provide both theoretical and empirical micro-level evidence of the time mismatch.

Duration of Defense Procurement Contracts Firstly, a necessary condition for the existence of an accounting mismatch is the long duration of contracts. If contracts were less than 90 days in duration, then payments would be processed in the same quarter as the award date.

We use FPDS data pulled from USASpending.gov from 2000Q4 to 2020Q3 to construct the distribution of duration of defense government contracts. In this context, contracts have two main types: (i) single transaction and (ii) multiple transaction.[7] We calculate the duration of a single transaction contract from the award date to the end of work. The award date almost always indicates the start of work associated with a contract. To calculate the duration of multiple transaction contracts, we take the oldest contract modification end date and subtract from it the "new-action" award date.[8] Table 4 shows contract durations without distinguishing between single and multiple transaction contracts.

The median contract duration is 20 days and 90% of contracts have duration less than one year. These results are in line with the findings of Cox et al. (2021) and suggest that contracts have a short duration.[9] However, this measure does not take into account the size of contracts, as larger contracts might have longer duration. The right columns of Table 4 report the distribution of the contracts' (log)duration,

[6] We confirm this timeline in discussions with several federal procurement contractors.

[7] Transactions which refer to the same contracts are pooled together through a unique contract identifier field in FPDS: contract_unique_key_identifier.

[8] This is possible because FPDS reports both the beginning and the end of the PoP (Period of Performance).

[9] They use a sample from 2001 to 2018 and find a median duration of defense contracts of 26 days and 90% of them have duration less than a year.

Table 4: (Log)Duration of Defense Contracts

Stats		Unweighted Duration (days)	Unweighted Log-Duration	Weighted (by Obligation) Duration (days)	Weighted (by Obligation) Log-Duration
Percentiles	1%	0	0	0	0
	5%	0	0	46	3.85
	10%	0	0	193	5.27
	25%	3	1.39	514	6.24
	50%	20	3.04	1519	7.33
	75%	126	4.84	2962	7.99
	90%	377	5.93	4844	8.49
	95%	794	6.68	5464	8.61
	99%	2584	7.86	6887	8.84
Mean		173.03	3.09	1988.02	6.94
Std.		485.32	2.14	1746.81	1.57
Min.		0.00	0	0.00	0
Max.		7300.00	8.89	7300.00	8.89

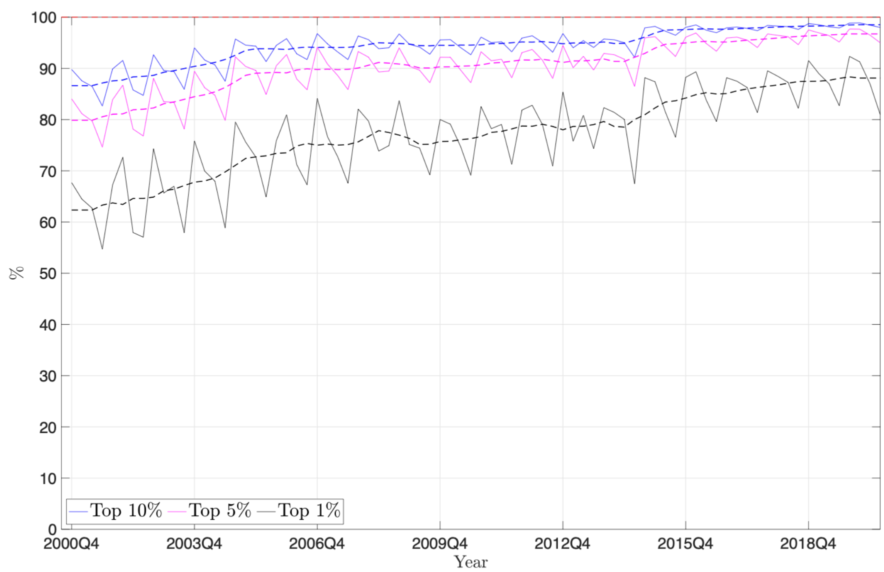
Table 4: defense contracts are identified by reporting DoD as funding/awarding agency. Data is taken from FPDS, all defense contracts from 2000Q1 to 2020Q1. Sample is restricted to those contracts for which the entire history of transactions (from the first new contract to the last modification) are available. Number of contracts in the sample is about 17 millions. Almost 5 thousands contracts with duration more than 20 years (7,300 days) are eliminated from the sample.

weighted by the total obligation amount. The weighted distribution can be interpreted as the duration distribution of a \$1 of spending in defense procurement. The following remark characterizes the mean and median of this distribution.

Remark D.1 (Median/Mean Duration of \$1)**.** The median duration of \$1 of defense procurement spending is 4.16 years. The mean duration of \$1 of defense procurement spending is 5.44 years.

Notice that after weighting, the shape of the distribution drastically changes. This suggests that procurement spending is characterized by a small number of large and long-duration contracts. We confirm this in Figure 13, which plots the share of total spending of the largest 1%, 5% and 10% of contracts. We find that the largest 10% of contracts account for 95% of total spending, on average. Similarly, the top 1% of contracts accounts for roughly 80% of total spending on average.

Figure 13: Large Contracts Share of Total Procurement Spending



To summarize the results of this section: (i) large contracts make the bulk of defense spending and (ii) large contracts have long duration.

Partial Delivery Payments Now, we want to rationalize the observed aggregate time delay. We do so by assuming there exists a "representative large contract" which follows a specific delayed payment schedule consistent with partial delivery payments.

Firstly, consider an example of a top 5% defense contract from FPDS. For instance, on December 22nd, 2015, the Department of Defense (DoD) awards a new "multi-transactions" contract to L-3 Communications Corporation.[10] The contract has a duration of two years and involves the reparation and maintenance of some aircraft components and accessories.[11] At the time of obligation, this contract has several components, denoted child contracts, and 24 contract modifications. Each

[10]See contract here.

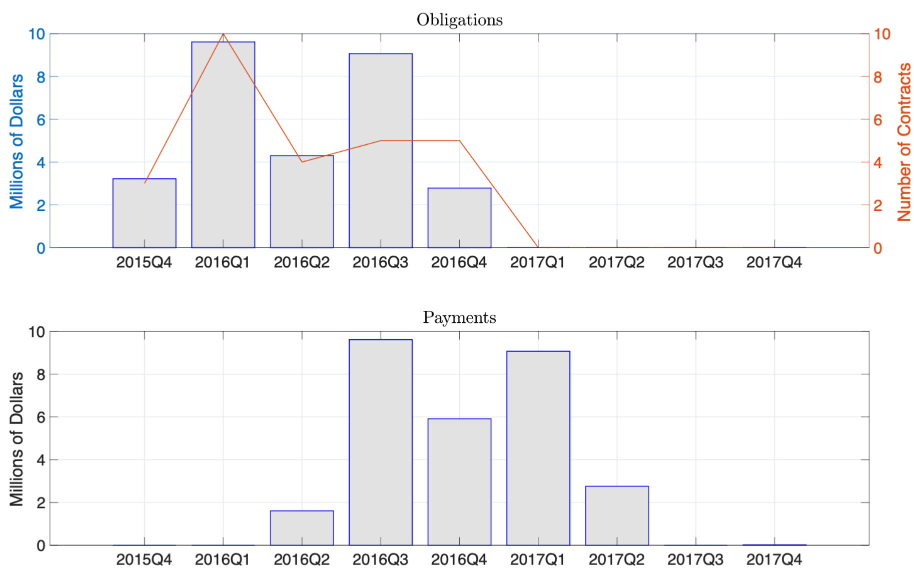
[11]Duration is measured as the number of days between the Period of Performance (PoP) end date and the PoP start date.

modification represents a new child contract with its own duration.[12]

In the top panel of Figure 14, we show on the left axis the amount of dollars obligated every quarter by this contract, and on the right axis the number of (child) contracts signed every quarter. The bottom panel shows the corresponding payment schedule which assumes that payments are disbursed once every 180 days, by uniformly spreading the initial amount of obligated funds over a contract duration.[13]

For instance, the first new child contract, signed in December 2015, lasts 375 days and obligates almost $3 million by the DoD. The payment schedule assumes that the contractors start producing the parts to be replaced immediately with partial delivery and partial reimbursement after 180 days, Therefore, the contractor is paid $1.5 million in June 2016. Finally, in December 2016, the period of performance ends and the DoD pays to the contractor the remaining half of obligated funds.

Figure 14: Example of a Contract's Obligation and Payment Schedule



Notice that payments look like a delayed version of obligations for this particu-

[12]Modifications can have two types: (i) uni-lateral (e.g., administrative actions which obligate new funds for the specific contract) or (ii) bi-lateral (e.g., change to the original orders or additional work).

[13]This assumption is also made in Auerbach, Gorodnichenko, and Murphy (2020).

lar contract. The choice of 180 days delay between payments is consistent with our estimates for the average time mismatch between defense obligations and payments found earlier. The assumption of uniform production and payments is standard and consistent with the work of Auerbach, Gorodnichenko, and Murphy (2020). In general, contractors are often incentivized to distribute production associated with an obligation throughout the whole duration of the contract.[14] In the data, cost-overruns and delays are common (see e.g., Gonzalez-Lira, Carril, and Walker (2021)).

Therefore, consider a representative contract with a structure similar to the one just analyzed: few new child contracts followed by several modifications. Overall, the contract lasts 48 months - consistent with the median weighted duration of defense contracts (see Table 4) and is characterized by payments disbursed once every 6 months (for a total of 8 payments). If we denote by P_t the total payments to contractors at time t and by O_t the amount of obligations, it is easy to show that the mapping between spending and obligations is given by the following equation:

$$P_t = \frac{1}{8} \cdot \sum_{j=1}^{8} O_{t-6 \cdot j}. \tag{1}$$

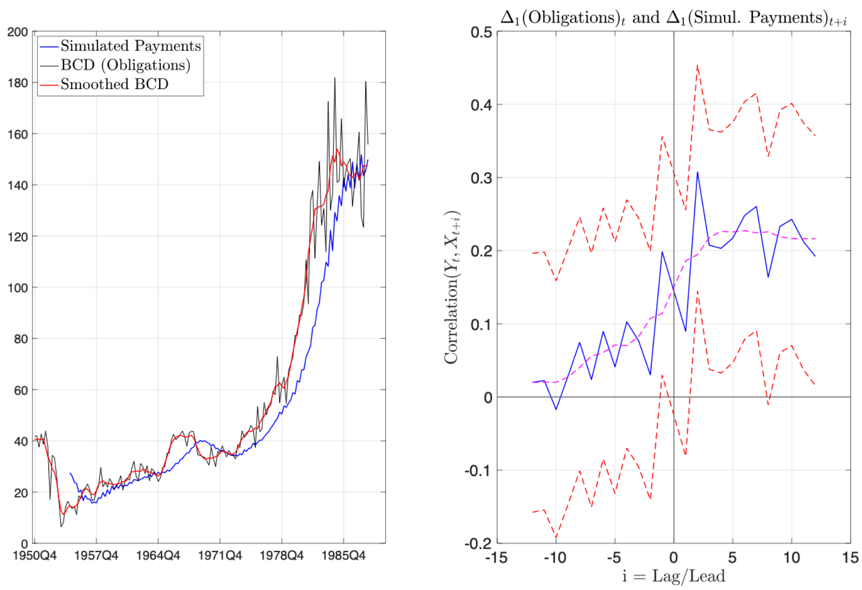
We take the obligation data from BCD and feed it into Equation (1) to construct a time series of simulated payments. The left panel of Figure 15 plots BCD defense obligations data and the so constructed payments.

Despite the simplicity of the payments data generating process given by Equation (1), the simulated payments data approximate quite well the actual ones shown in Figure 5 of the paper. Similarly, the right panel shows the lead-lag correlation map between the growth rates of (smoothed) obligations and simulated payments. Notice that the results are very similar to the ones obtained using real spending data.[15]

[14]Consider a simple firm optimization problem with convex adjustment costs.

[15]We highlight that by allowing time varying number of payments (here 8) and payments delays (here 6 months), we can improve by far the approximation to the actual data. Here, we preferred to keep things simple in the interest of brevity and clarity.

Figure 15: BCD Obligations and Simulated Payments



D.4 Construction of Quarterly Defense Obligation

We show here how we construct the time series of defense procurement obligations.

We face two main challenges: (i) we have obligations data only from 1951 to 1989 and from 2000 onward; (ii) obligations are very lumpy because contracts also get cancelled and we want to focus on obligations which turn into actual production.

i. We turn BCD and FPDS monthly data into quarterly annualized data (sum monthly observations within a quarter and multiply by 4).

ii. We apply the standard Brockwell and Davis (1991) filter to deaseasonalize the data.

iii. We construct a time trend which takes value of 1 in 1947Q1. Denote it by t.

iv. We predict obligations using 4 leads and lags and contemporaneous defense procurement spending, as well as time trends t and t^2.

v. We construct obligations from 1951Q1 to 1988Q4 using the predicted values from the previous regression. We use the estimated coefficients and the values of defense procurement spending from 1947 to 1951 to extrapolate obligations for those years.

vi. We predict obligations from year 2006 onward (FFATA introduction) in the same way. We use the predicted values to be our new series of obligations for those years. Since defense procurement (smoothed) obligations and spending overlap from 2000 to 2006, we use actual defense procurement spending for those years.

vii. From 1989 to 2000 we use defense procurement spending to proxy obligations which turn into actual production.

Figure 16 plots the so constructed defense procurement obligations variable (pink dash line) along with defense procurement spending (blue line) and original defense procurement obligations (dark solid line).

Figure 16: Quarterly Defense Obligation and Spending

D.5 What Goes On Before Contract Awards?

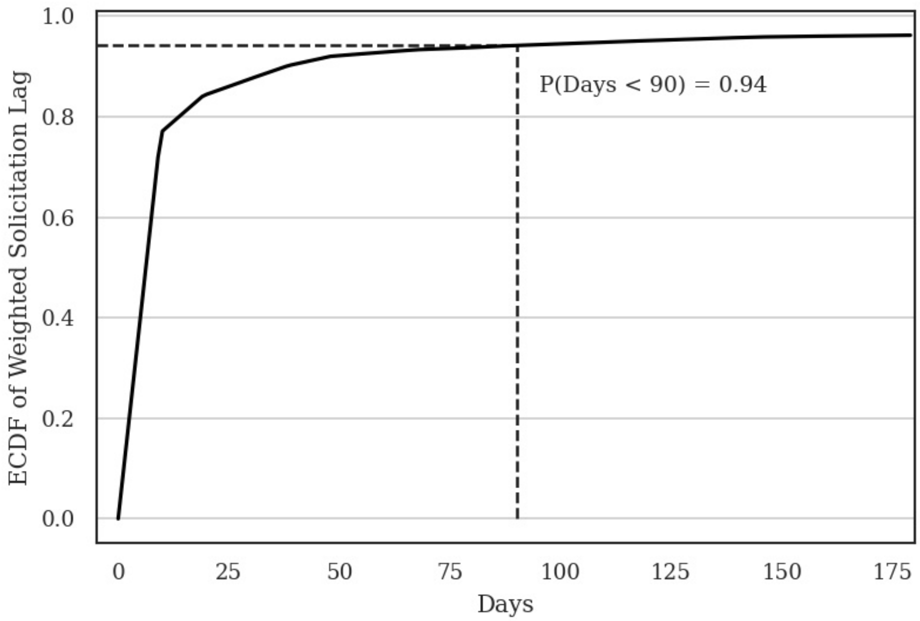
Although there is still uncertainty about the contract award when a pre-award notice is posted, firms might still take action in anticipation of the award. This might occur if a firm wants to become more competitive in the bidding process or predicts a contract win with a high probability. In addition, some pre-award notices justify the lack of competition in a sole-sourced contract proposal. In this case, the contractor might even predict a contract award with full certainty.

We argue from the data that any anticipatory behavior is likely to occur at a frequency higher than the frequency of aggregate analysis in this work. In other words, almost all information about contract opportunities is revealed to contractors within the quarter of the contract award. We summarize this finding by notice type in Table 5 and plot the distribution of pre-award notice lags in Figure 17.

Table 5: **Average Lag Between Pre-Award Notices and Award Date**
Based on matched notices between FPDS and Contract Opportunities.

Notice Type	*Avg Lag in Days*	*Proportion of Notices*
Justification / Fair Opportunity	87	1.2%
Other	54	62.5%
Special Notice	41	2.1%
Pre-Solicitation	28	14.6%
Sources Sought	21	4.1%
Solicitation/Contract Solicitation	16	15.5%
TOTAL	43	

Figure 17: Empirical CDF of (Weighted) Solicitation Lag



Weighted duration between Contract Solicitation and Award dates measured in days. Dark dashed line represents 1 quarter (90 days). The Empirical CDF is estimated using Gaussian Kernel Density.

Detailed Description of Solicitation Process: Although public procurement contracts are awarded at a highly decentralized level (i.e., by over 69 federal agencies, 209 sub-agencies), all contracting officers are required to abide by the guidelines proposed in the Federal Acquisition Regulation (FAR). The FAR is a set of principles and procedures intended to organize and guide the procurement process across all federal agencies. In this section, we focus on the publicizing requirements associated with procurement contracts, depicted in Figure 18.

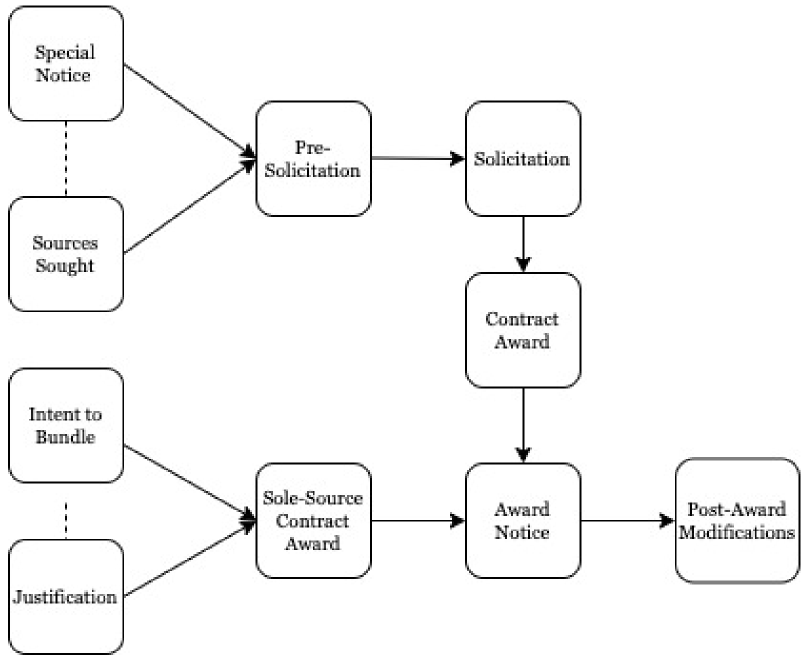


Figure 18: **Timeline of the Procurement Process**
Notice prior to contract award step occur on average within the quarter. Source: `beta.sam.gov` daily files.

In particular, FAR Part 5 (*Publicizing Contract Actions*) requires that contractors publicize contract opportunities with the goal of increasing competition, broadening industry participation, and assisting small businesses in obtaining contracts. Since October 1, 2001, contract actions with an expected value of over $25,000 must be publicized in an online and easy-to-access government platform, which we refer to as *Contract Opportunities*. Contract actions below the threshold might still be posted to increase visibility. On the other hand, FAR allows for exemptions to the requirement above the threshold when the posting might "compromise national security" or when the posting is "not in the government's interest". The result is that many contracts which are awarded are never solicited. When the regulation applies, Contract Opportunity notices are posted publicly at `beta.sam.gov` and include award notices such as solicitations, pre-solicitations, or other pre-award and post-award actions.

We describe the types of contract notices below.[16]

[16] Gonzalez-Lira, Carril, and Walker (2021) also provides a useful description and analysis of the

Special Notice Agencies use Special Notices to announce important pre-award events such as business fairs, long-run procurement forecasts, or pre-award conferences and meetings. Special Notices might also refer to "Requests for Information" (RFI) or draft solicitations.

Sources Sought Agencies post Sources Sought Notices in order to seek possible sources for a project. As discussed in FAR 7.3, the Sources Sought notice is not a solicitation for work or a request for proposal. Agencies typically use Sources Sought notices to collect industry feedback on key contracting strategy decisions and to perform market research on firm capabilities.

Pre-Solicitation Agencies post a pre-solicitation to notify vendors that a solicitation may follow. Potential vendors might then express interest in the contract by adding themselves to the Interested Vendors List. Government agencies use pre-solicitations to determine the number of qualified vendors to perform the desired work. Contracting officers can also use pre-solicitations to gather information on interested suppliers and determine if a set-aside for a small business might be applicable.

Intent to Bundle Requirements Agencies post "Intent to Bundle Requirements (DoD-Funded)" (ITB) whenever awarding actions are funded solely by the DoD. ITB supports the requirements in Section 820 of the Fiscal Year (FY) 2010 National Defense Authorization Act (NDAA) for contracting officers to post a notice of intent to use contract bundling procedures 30 days prior to releasing a solicitation or placing an order - if a solicitation is not required.

Solicitation Agencies post a solicitation to clearly define government requirements for a potential contract so that businesses can submit competitive bids. A

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publicizing requirements for Federal Procurement and the effects of information diffusion via public notices. We thank Andres Gonzales-Lira for directing us to the General Services Administration Technical Documentation for the FedBizOpps (FBO) website, whose information is now migrated to Contract Opportunities.

“Request for Proposal” (RFP) is the most common type of solicitation used by federal agencies. The solicitation also sets conditions and requirements for contractor proposals and includes the government’s plan for evaluating submissions for potential award.

Combined Synopsis/Solicitation Agencies post a combined synopsis/solicitation when a contract is open for bids from eligible vendors. The Synopsis/Solicitation includes specifications for the product or service requested and a due date for the proposal, as well as the bidding procedures associated with the solicitation.

Award Notice Agencies post an award notice when they award a contract in response to a solicitation. Federal agencies may choose to upload a notice of the award to make aware other interested vendors of the winning bid. Note that the requirement guidelines for posting the award notice vary based on the agency and the solicitation.

Justification Agencies are required to post a justification in order to obtain approval to award a contract without posting a solicitation as required by FAR 41 U.S.C. 253(c) and 10 U.S.C. 2304(c). Under certain conditions, agencies are authorized for contracting without full and open competition. The Department of Defense, Coast Guard, and National Aeronautics and Space Administration are subject to 10 U.S.C. 2304(c). Other executive agencies are subject to 41 U.S.C. 253(c). Contracting without providing for full and open competition or full and open competition after exclusion of sources is a violation, unless permitted by one of the exceptions in FAR 6.302.

Sale of Surplus Property Agencies post a sale of surplus property notice when they wish to sell federal real estate properties for public use. These properties are typically made available for public use to state and local governments, regional agencies, or nonprofit organizations to state and local governments. Public uses for properties are those that are accessible to and can be shared by all members of a community, and include community centers, schools and colleges, parks, municipal buildings and many more.

E Time-to-build or Production Smoothing?

We decompose the early response of inventories to a defense news shock into time-to-build and production smoothing. We already have contract level evidence of a long time-to-build, but at the onset of a military build-up, contractors should also presumably change their expectations about future government demand. Even if contractors lack resources to forecast government demand, federal agencies are required by the FAR to provide procurement forecasts each quarter.[17] If contractors anticipate winning future contracts, they might decide to increase production today to smooth convex adjustment costs or reduce future delivery times. We do not take a stance on the exact mechanism here. We consider a recent example of this type of behavior.

Example E.1 (Lockheed Martin in 2022)**.** In the context of an ongoing military conflict between Russia and Ukraine, new military tests in North Korea, and escalating tension in relationship between China and Taiwan, US-based contractors have modified expectations about future defense spending. In particular, the largest American defense contractor, Lockheed Martin, decided in October 2022 to increase production of HIMARS (High Mobility Artillery Rocket System). When asked about this decision, CEO Jim Taiclet responded as follows:[18]

"*The company has met with its long lead supply chain and spent $65 million — which will eventually be paid back by the US government — to fund parts in advance, shortening the time needed to manufacture the rocket system. That was without a contract or any other memo or whatnot back from the government. We just went ahead and did that because we expected it to happen. So those parts are already being manufactured now*".

In order to measure production smoothing, we first provide a formal definition.

Definition E.1 (Production Smoothing of Defense Industries)**.** We define production smoothing $\Delta(h)$ as the effect of a defense news shock on inventories, orthogonal to shocks to newly awarded contracts (i.e., defense procurement obligations).

[17] See e.g., Agency Recurring Procurement Forecasts.

[18] Find the associated article on *Breaking Defense*. here.

In particular, production smoothing is the impulse response of inventories to a defense news shock conditional on zero shocks to defense procurement obligations (i.e. orthogonalized IRF):

$$\Delta(h) = \mathbb{E}_t[\text{Invt}_{t+h}|Z_t = 1, \varepsilon_t^O = 0] - \mathbb{E}_t[\text{Invt}_{t+h}|Z_t = 0, \varepsilon_t^O = 0], \tag{2}$$

where Invt_t is changes in aggregate inventories as from the NIPA, Z_t is a defense news shock, and ε_t^O is a shock to defense procurement obligations.

We estimate production smoothing using the following tri-variate VAR using quarterly data from 1948Q1 to 2015Q4:

$$\begin{bmatrix} 1 & 0 & 0 \\ -\alpha & 1 & 0 \\ -\beta_{\text{News}} & -\beta_{\text{Oblg}} & 1 \end{bmatrix} \cdot \underbrace{\begin{bmatrix} Z_t \\ O_t \\ \text{Invt}_t \end{bmatrix}}_{\boldsymbol{X}_t^3} = \underset{3\times 3}{\boldsymbol{B}_3(L)} \cdot \boldsymbol{X}_t^3 + \boldsymbol{\varepsilon}_{3,t}$$

where $\mathbf{B}_3(L)$ is a polynomial in the lag operator. The parameter α captures the contemporaneous effect of a defense news shock on obligations, while β_{News} and β_{Oblg} capture the contemporaneous effect of shocks to news and obligations on inventories.

By including our aggregate series for defense procurement obligations O_t, we are able to calculate the effect of defense news shocks on inventories which is independent of the effect of shocks to newly awarded contracts. Figure 19 shows the impulse response function to a defense news shock estimated using the above tri-variate VAR as well as the total response of inventories estimated in a bi-variate VAR without obligations.

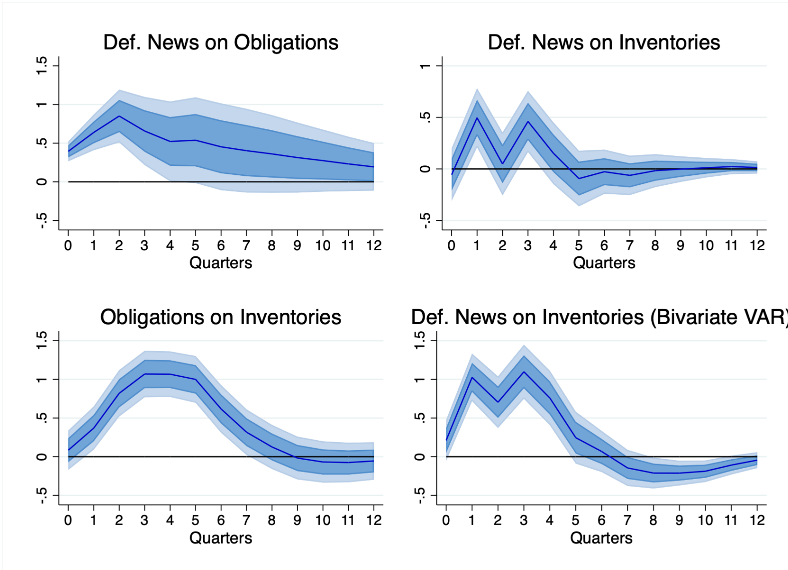

Figure 19: **(Orthogonalized) IRFs from Tri/Bi-Variate VARs.** *Variables are divided by potential GDP and include a linear time trend. Sample goes from 1948Q1 to 2015Q4. Confidence Bands are 68% and 90%. Values are rescaled by the peak response of Inventories to a defense news shock from the bivariate VAR which excludes defense procurement obligations.*

The top-left panel of Figure 19 shows the positive response of defense procurement obligations to a defense news shock. This indicates that new contracts start being awarded as soon as a defense news shock occurs. This confounds the effects of news (i.e., anticipation) with the effects of newly awarded contracts which show up in G with delay. In the bottom-left panel of the figure, we show the effect of shock to obligations ε_t^O, on inventories, orthogonal to defense news. The effect is positive and significant. Additionally, the top-right panel reports production smoothing, or the response of inventories to a defense news shock which is orthogonal to newly awarded contracts. The positive and significant estimates of $\Delta_(h)$ at horizons 1 and 3 suggest that production smoothing plays a role in the response of inventories. The bottom-right panel shows the IRF of inventories to a defense news shock without including obligations in the VAR, i.e. bivariate VAR.

For interpretability, we rescale the IRFs by the peak response of inventories to a defense news shock in the bivariate VAR occurring at horizon 1. Since the horizon 1 response of inventories to a defense news shock in the tri-variate VAR is slightly more than 0.4 it means that roughly 40% of the response of inventories at horizon 1 comes from production smoothing, while the residual part (gap between bottom-right and top-right responses) originates from the effects of newly awarded contracts, i.e. time-to-build production. Intuitively, this can be seen by shrinking the tri-variate VAR into a bivariate one by plugging obligations into the equation of inventories:

$$\begin{bmatrix} 1 & 0 \\ -\left(\beta_{\text{News}} + \alpha \cdot \beta_{\text{Oblg}}\right) & 1 \end{bmatrix} \cdot \underbrace{\begin{bmatrix} Z_t \\ \text{Invt}_t \end{bmatrix}}_{\boldsymbol{X}_t^2} = \underset{2\times 2}{\boldsymbol{B}_2(L)} \cdot \boldsymbol{X}_t^2 + \boldsymbol{\varepsilon}_{2,t}$$

Notice that the impact effect of a defense news shock on inventories is the combination of production smoothing (β_{News}) and the effect of a shock to new contracts on inventories triggered by the news ($\alpha \cdot \beta_{\text{Oblg}}$). Basically, without controlling for new contracts, defense news shock capture both production smoothing and the time-to-build, while augmenting the VAR with new contracts allows us to tell-apart the two effects.

F Robustness - Section IV in the paper

Firstly, we construct an index of cumulative excess returns similar to the Top3 index constructed in Fisher and Peters (2010). The variable is shown in Figure 20 along with red lines denoting the Ramey-Shapiro episodes.

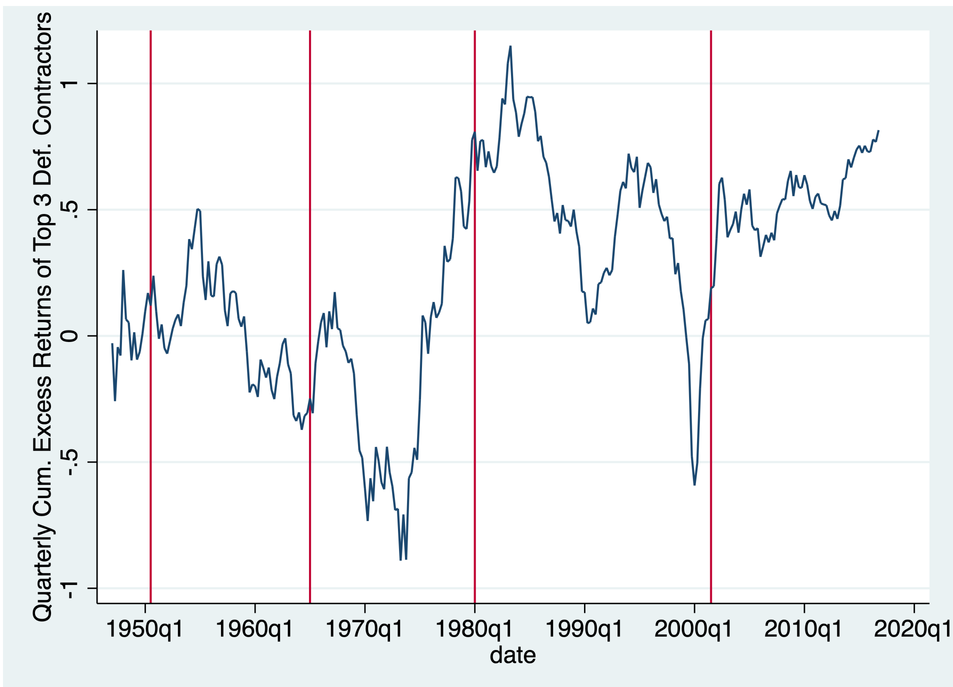

Figure 20: Top3 Defense Contractors Stock Price Index - (Cumulative Excess Returns)

Notes: Red solid lines are the Ramey-Shapiro episodes.

Similarly to Fisher and Peters (2010), the Top3 index onlr responds to the Vietnam war and 9/11, but not the Carter-Reagan military build-up nor the Korean war.

We construct shocks to this variable by ordering it first in the same VAR used in Section I in the paper. Furthermore, we complement the Granger Causality test in the paper by using these new shocks. Results are shown in table below.

Table 6: Predictability of Recursive Shocks via Obligations

Predicted	Predictor	F	Pvalue	Korea
Recursive Shocks	Top3	0.26	97.84%	Yes
Obligation Shocks	Top3	1.25	26.81%	Yes
Defense News Shocks	Top3	0.42	90.67%	Yes
Recursive Shocks	Top3	0.63	74.93%	No
Obligation Shocks	Top3	0.88	53.53%	No
Defense News Shocks	Top3	0.62	76.22%	No
Top3	Recursive Shocks	1.00	43.57%	Yes
Top3	Obligation Shocks	0.49	86.54%	Yes
Top3	Defense News Shocks	0.89	52.84%	Yes
Top3	Recursive Shocks	0.94	48.09%	No
Top3	Obligation Shocks	0.39	92.70%	No
Top3	Defense News Shocks	0.46	88.44%	No

Notes: Granger Causality test is a Wald test on the 8 lags of the predictor while controlling for 4 lags of the predicted variable.

It is clear from Table 6 that we find no significant predictability in either direction for the Top3 index.

Secondly, we replicate the bottom panel of Figure 4 in the paper, by excluding the Korean war from the sample. Results are shown in Figure 21.

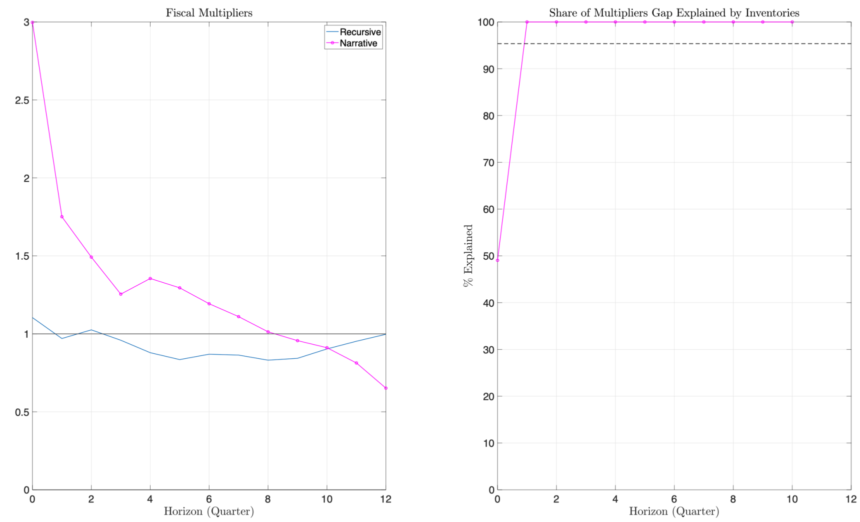

Figure 21: Cumulative Fiscal Multipliers and Multiplier-Gap (Robustness)

Notes: Sample goes from 1954Q1 to 2015Q4. All the rest is identical to Figure 7 in the Paper.

G Comparison of Multipliers with Brunet (2020)

Finally, we estimate multipliers using our new quarterly measure of defense procurement obligations. We compare our results to the recent estimates from Brunet (2020), who also uses a measure of government spending which is better aligned with the timing of obligated funds. In particular, Brunet (2020) estimates multipliers by regressing cumulative changes in GDP on cumulative changes of *Budget Authority*, which tracks defense spending when it is authorized, before funds are dispersed from the Treasury:

$$\sum_{k=0}^{H} \frac{GDP_{t+h} - GDP_{t-1}}{GDP_{t-1}} = \mathcal{M}(H) \cdot \sum_{k=0}^{H} \frac{BA_{t+h} - BA_{t-1}}{GDP_{t-1}} + lags + \varepsilon_{t+h}$$

where BA_t is Budget Authority in year t. We report these estimates in Table 7 for two post WWII samples which either include or do not include the Korean War.

Sample	Horizon (Years)	0	1	2	3	4
Post WWII Sample	Budget Authority	1.76 (4.08)	1.51 (2.73)	1.30 (1.63)	1.28 (1.29)	
	Def. Proc. Oblig.	4.84 (1.71)	3.96 (3.01)	1.61 (3.94)	1.27 (3.18)	1.17 (2.61)
Post Korean War	Budget Authority	1.83 (4.54)	1.84 (3.56)	1.72 (2.25)	1.67 (1.66)	
	Def. Proc. Oblig.	1.44 (2.85)	1.7 (2.46)	1.15 (1.99)	1.09 (2.04)	1.14 (2.09)

Table 7: **Multiplier Comparison:** t-statistics reported in parentheses below the multipliers' point estimates. Budget Authority samples go from 1948 to 2016 and from 1955 to 2016 (annual frequency). Samples using defense procurement obligations go from 1948Q1 to 2015Q4 and from 1954Q1 to 2015Q4 (quarterly frequency).

On the other hand, we estimate multipliers as suggested in Ramey (2016), instrumenting the cumulative change in the NIPA-measured government spending, G, with defense procurement obligations (one step LP-IV).[19] We plot our estimates of cumulative fiscal multipliers in Figure 22 for the two sample periods from Brunet

[19]Recall that this is equivalent in population to ordering defense procurement obligations first in a VAR.

(2020).

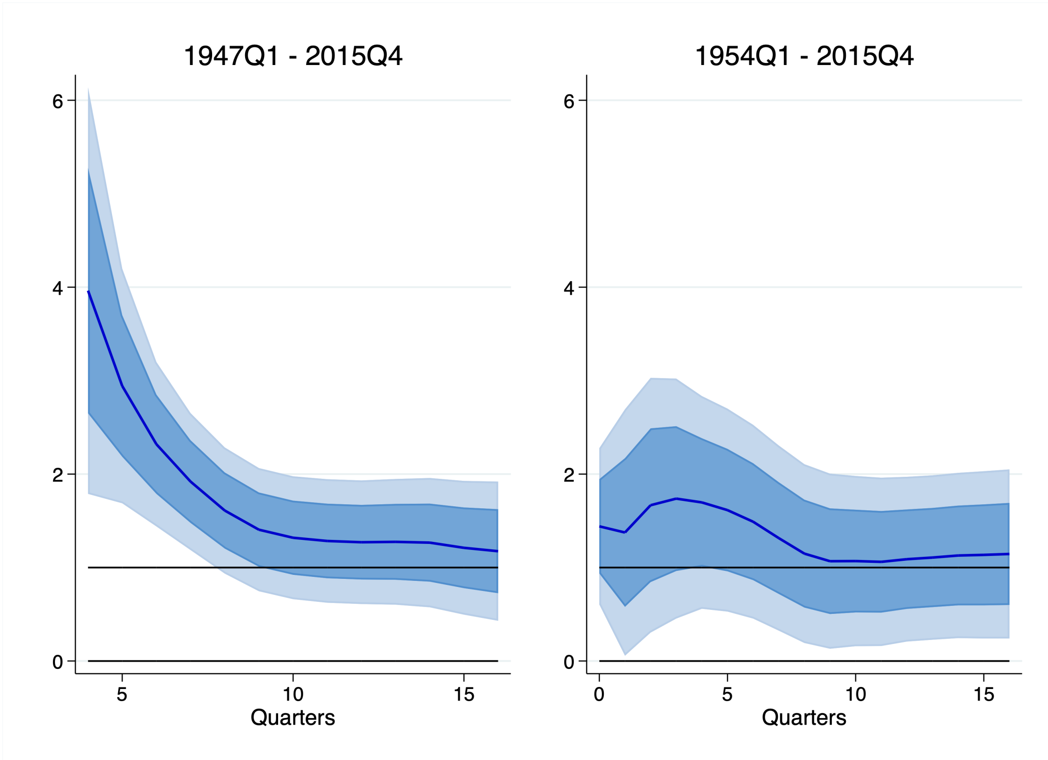

Figure 22: **Cumulative Fiscal Multipliers via Shocks to Defense Procurement Obligations.** *Standard errors are two-stage-least-squares robust standard errors and bands are the 68% and 90% confidence levels. Dark horizontal lines referring to the values of zero and one. Data are quarterly.*

Notice how in both sample periods, the multipliers are higher at short horizons and smaller at longer horizons. This is a consequence of anticipation effects: GDP increases even before G moves.[20] We also report the point estimates of the multipliers in Table 7 for different years. This is done to facilitate the comparison with the results of Brunet (2020).

In the top panel of the table, it is clear that analysis on both Post WWII samples deliver similar results, particularly at the three-year horizon. On the contrary, results slightly differ from each other when the Korean war is excluded from the sample. In fact, our point estimates are smaller than Brunet (2020), even if they both remain

[20] When the Korean war is in the sample, anticipation is so strong that the multiplier is infinite until horizon 4.

above one. Finally, our multipliers tend to be more statistically significant at longer horizons, which is likely due to the fact that our analysis is carried out at quarterly frequency rather than an annual frequency.

Despite minor discrepancies between our results and those of Brunet (2020), our obligations-based method also delivers point estimates for the multiplier which are greater than one. Nevertheless, we note three important differences in our methodology, without taking a stand on the relative effects of each. First of all, defense procurement obligations is a quarterly variable which captures the whole universe of newly awarded defense procurement contracts, while Budget Authority is an annual variable which captures authorizations for defense-spending and is broader than procurement spending. Secondly, our LP-IV multiplier is interpretable as the ratio of the IRFs of GDP and G following a shock to defense procurement obligations, and is therefore a spending multiplier. On the contrary, Brunet (2020) regresses cumulative changes of GDP on cumulative changes of Budget Authority. Since Budget Authority does not map directly to NIPA defense spending (i.e., changes in Budget Authority are not necessarily changes in NIPA G), their estimates cannot be directly interpreted as a spending multiplier. Thirdly, contemporaneous changes in non-defense spending are not captured in the Budget Authority measure.

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