Crowding-out Innovation*

Julian Atanassov[†] Vikram Nanda[‡]

This Version: June 2018

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Keywords: Government Borrowing, Government Spending, Defense spending, Taxes,

*Acknowledgements: We thank seminar participants at the Lundquist College of Business, University of Oregon, at the Ernest Scheller Jr. College of Business, Georgia Institute of Technology, the Midwest Finance Association in San Antonio and the Pacific Northwest Finance Conference at the University of Washington for their useful comments and suggestions.

[†]Department of Finance, College of Business Administration, University of Nebraska, Email: julian@unl.edu.

[‡]Department of Finance, Naveen Jindal School of Management, UT Dallas, 800 West Campbell Road, Richardson, TX 75080. Email: Vikram.Nanda@utdallas.edu.

Patents, Citations, Crowding out, Innovation, R&D, Productivity, Capital Structure, Financial Constraints, Multiplier

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Abstract

We document that exogenous shocks to federal government spending due unexpected military conflicts significantly impact the scale and novelty of corporate R&D output. We provide evidence of a possible financing channel: Higher government expenditures significantly increase government borrowing. There is a corresponding decrease in private borrowing, suggesting an indirect crowding-out that reduces R&D investment and innovation. We further support the borrowing channel by demonstrating that exogenous increases in federal taxes reduce government borrowing and increase R&D. We also show that firms with lower credit ratings and lower profitability are affected more adversely. Finally, we find that patterns are accentuated when the corporate bond risk premiums are higher and mitigated for military-related industries. Our results reveal the adverse effects of government spending on long-term economic growth through its impact on corporate innovation.

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I Introduction

Economists, at least since Keynes (1936), have debated government's role in influencing the real economy. Keynesians typically call for large and sudden fiscal interventions in the economy to boost aggregate demand and enhance economic activity. Neoclassical economists tend to oppose government intervention, arguing that such spending displaces private sector activity. Recent evidence suggests that an increase in government expenditures leads to a small increase in GDP (with a multiplier between 0.67 and 1.2) and a decrease in private consumption and investment, for an overall negative wealth effect (Barro and Redlick, 2011). The negative wealth effect is plausibly the result of government expenditures crowding out private consumption and investment (Cohen and Coval, 2011). While the short-term, cyclical effects of government spending and taxes are well documented, less well understood is their impact on longer-term productivity and economic growth.

In this paper we revisit the debate by examining the impact of federal government spending and taxes on corporate innovation and, thereby, on longer-term economic growth. Empirical studies indicate that the availability and nature of financing can strongly affect innovative activity (e.g., Atanassov, 2013, 2016, Hall et al. 2005, Brown, Martinsson, and Petersen, 2012, Seru, 2014). We contend that changes in federal government spending significantly increase government borrowing that could crowd out innovative firms from financial markets. If access to those markets is essential for financing R&D projects, we would expect to observe a decline in innovation, especially for firms that have weaker balance sheets, and cannot easily find alternative sources of financing. Further, reducing access to an important source of financing will curtail their financial flexibility. Such flexibility is essential for maintaining tolerance to experimentation, which according to Manso (2011) is an important key to innovation.

To test our hypotheses, we combine data on government spending and tax changes, patents and patent citations, government borrowing, and corporate credit ratings. We employ several distinct approaches to address endogeneity concerns that changes in fiscal policy and corporate innovation could both be driven by other factors such as macroeconomic conditions.[1] Our first approach is to use exogenous variations in government spending that are not related to the cyclical fluctuations in the economy. Ramey (2011) and Ramey and Shapiro (1998) develop a narrative approach that tracks unanticipated changes in government expenditures due to military buildups or rundowns. Ramey (2011) calculates the present value of unexpected changes in government defense spending by discounting the estimates obtained from Business Week and other major news sources. In an alternative specification, we also use an indicator variable, created by Ramey and Shapiro (1998), and Ramey (2011), for periods with unexpected substantial increases in defense related government expenditures. There are four such unexpected episodes - the Korean War in 1950, the unexpected escalation of the Vietnam war (1965), the Carter-Reagan military buildup after the Soviet invasion of Afghanistan (1980), and 9/11/2001.

Looking at the relationship between unexpected military conflicts, defense spending an innovation is also interesting on its own because it sheds some light in a long standing debate whether wars are beneficial or detrimental to innovation. There is plenty of anecdotal evidence that some of the most important technological discoveries such as the radar and the Turing machine were made during World War II, while the internet and GPS technologies were developed during the cold war (Ruttan, 2006). On the other hand, defense expenditures and the associated government borrowing could crowd out private innovation at a net loss. As a result, the net effect of military conflicts is not obvious. While this paper cannot settle the debate completely, it can provide large sample evidence that controls for endogeneity in

[1] We note that it is not obvious that innovation is pro-cyclical i.e., it declines during recessions and increases during booms (Barlevy, 2007). According to Schumpeter (1947) and his followers, R&D could be higher during recessions because firms shift resources from production to R&D.

several different ways.

Using the above approach, we find that higher unanticipated defense expenditures lead to lower innovation. Specifically, firms experience a significant decline in the number of patents and citations per patent from 1 to 4 years in the future. The results are economically significant: An increase in exogenous defense spending leads to a 23% and 20% decrease in the number of patents, and a 14% and 17% decrease in the number of citations per patent, respectively 3 and 4 years later. The finding is consistent with the view that defense expenditures crowd out innovation by pulling both financial and physical resources away from inventive activity (Griliches, 1990).

As a further test for the direction of causality, we conduct a dynamic test for whether there are significant changes in innovation activity before any of the four unanticipated military conflicts mentioned above that dramatically and unexpectedly increased defense spending. If this is the case, our relation could be spurious. We find no significant relation in the 5 years prior to the change in unexpected defense spending, the year of the change or even one year after the change. All of the impact comes two or more years after the exogenous change in defense spending. This is consistent with the notion that innovative projects take a long time to come to fruition and that firms tend to smooth their R&D spending over time, in order to avoid having to lay off knowledge workers (Hall and Lerner, 2010). This result provides further support for the hypothesis that changes in defense spending are causing the change in corporate innovation.

Our results are robust to different econometric specifications (Poisson and log-linear), and to controlling for numerous firm-specific, industry specific and macroeconomic time-varying factors that could influence our results. Specifically, we control for firm size, R&D expenditures, leverage, industry concentration, profitability, GDP and aggregate investment growth, the corporate bond risk premium, total real defense expenditures, and the size of the military. We also control for forward looking measures of performance and growth such as the total market capitalization. Following Petersen (2009), we cluster our standard errors by firm to control for serial correlation at the firm level over time, and for robustness, by year since our main explanatory variable only varies by year. We also confirm that our results are strongly significant if we only use a subsample of innovative firms.

Our next step is to investigate whether a specific channel, specifically the credit channel, plays an important role in the impact of government expenditures on corporate innovation. We employ a differences-in-differences methodology and compare a sample of weak balance sheet firms to a control group of strong balance sheet firms. Our main measure of balance sheet strength is a firm's credit rating because it provides a measure of the difficulty the firm faces in obtaining additional financing. We define our credit rating variable as 1 if the firm has a credit rating of B+ or higher (for robustness BBB and higher), and 0 otherwise. We find that the negative impact of unexpected defense expenditures is greater for firms with lower credit ratings. The results are economically significant. The negative impact of government spending on the number of citations per patent is 56.2% greater for firms with lower credit ratings. In another test, we find that less profitable firms are impacted more negatively by exogenous increases of government spending. The results suggest that weaker balance sheet firms are more severely affected by government borrowing. Finally, we find that the negative impact of government spending is especially severe when the corporate bond risk premium (defined as the difference of the corporate Baa bond rate and the T-bill rate) is higher. This result provides further support that the borrowing channel plays an important role in explaining our main findings.

We further investigate the credit channel by turning our attention to exogenous changes in federal tax revenues. If an increase in exogenous government spending requires the federal government to borrow more, we expect the opposite will be true if there is an increase in exogenous tax revenues, as the need to borrow will be lower. We would expect less crowding out of corporate borrowing and more innovation. For this part of our analysis, we rely on the exogenous variations in tax revenues constructed by Romer and Romer (2010). The authors use a narrative approach of Congressional legislation to construct measures of tax changes that are unrelated to current economic fluctuations. More specifically, they use exogenous changes in tax revenues resulting from dealing with inherited budget deficits, or for achieving some longer-run goal such as social fairness, or a smaller role of the government. Romer and Romer (2010) argue that these changes are exogenous because they do not directly target GDP.

Consistent with our main hypothesis, we find that an increase in exogenous tax revenues leads to more patents and citations per patent from 1 to 4 years into the future.[2] In our regressions we control for either contemporaneous or lagged GDP growth and aggregate investment growth. The results are economically significant. An increase in exogenous tax revenue leads to, respectively 3 and 4 years later, a 9% and 5% increase in the number of citations per patent when all exogenous taxes are involved, and 7% and 8% increase in the number of citations per patent when changes in tax revenues that affect only the deficit are involved. We also conduct a difference-in-difference analysis to study if there is a differential impact on firms. We demonstrate that the positive impact of tax revenues on innovation is greater for firms with weaker credit ratings. The positive impact of exogenous tax revenue on the number of citations per patent is 67% greater for firms with lower credit ratings.

Our next step is further investigate the borrowing channel of crowding out. Greenwood, Hanson, and Stein (2010) propose a gap-filling theory of corporate borrowing. They argue that if the government increases short-term borrowing, firms will switch to longer-term maturities. Firms with weaker balance sheets may not be able to borrow at longer maturities,

[2]For robustness, we exclude from the exogenous tax changes the ones that may directly affect corporate profits and investment, such as the 1993 tax increase, and obtain similar results.

however, and will reduce their borrowing. If our hypothesis is correct, we would expect crowding out to be more prevalent when the government finances its increased expenditures or reduced taxes by boosting the amount of short-term borrowing. The notion is that government borrowing crowds out firm borrowing by reducing the availability of credit and/or increasing the effective cost of capital to firms. In particular, we would expect that an increase in short-term borrowing by the government would impact firms that are more likely to engage in short-term borrowing and less able to substitute it with long-term borrowing.

We conduct an additional analysis of the crowding out hypothesis by employing a two-stage estimation. In the first stage, we demonstrate that unexpected government spending significantly increase, while unexpected federal tax revenues significantly decrease the amount of abnormal short-term government borrowing. In the second stage, we investigate the impact of predicted borrowing from the first stage on innovation. We find that greater exogenous abnormal government borrowing has a strong negative impact on future innovation. We also show that corporate borrowing declines significantly after an increase in exogenous government spending, especially for firms with lower credit ratings.

Our paper contributes to the macroeconomic debate between the New Keynesians and the neoclassical economists on the role of government in stimulating the real economy versus the crowding out of private sector investments. Our focus is on the financing channel whereby government borrowing displaces corporate financing and innovation. The financing channel is also related to a long-standing academic debate about the role of finance in spurring innovation and economic growth. Several studies have documented a positive relation between the availability of finance and economic growth. Less certain, however is the direction of causality. One school of thought (e.g., Schumpeter, 1947) argues that greater availability of finance leads to more innovation. Other scholars (Robinson, 1965) argue that where the real economy leads, finance follows. Our approach in the paper to use exogenous shocks to government borrowing and to show that the crowding out of private borrowing dampens corporate innovation.

The paper also relates to recent research on the role government in affecting innovative activity. For instance, Atanassov and Liu (2016) document that state corporate income taxes stifle corporate innovation by reducing firms' pledgeable income and its incentives to innovate. The role of corporate debt financing is shown to be significant in providing capital for innovative activities. In particular, an exogenous enhancement in the value of borrowers' patents, either through greater patent protection or creditor rights over collateral, results in cheaper loans (e.g., Chava et al. 2016). Our paper examines a different mechanism: crowding out of private borrowing by the federal government.

This paper also sheds light on the question of whether wars or other military conflicts can stimulate innovation. In our sample, we find that this is the case only for firms operating in industries related to the military. In the full sample, we find that wars are largely detrimental to innovation because they cause the government to borrow and spend, and thereby crowd out innovation in the private sector.

Our paper is closely related to the paper by Greenwood, Hanson, and Stein (2010) on the crowing out of corporate bonds by government borrowing. Somewhat related is the work that examines the effect of the supply of long and short-term government bonds, on the term structure of Treasury yields. In particular, Greenwood and Vayanos (2010) show that the relative supply of long-term and short-term Treasuries is related to the slope of the yield curve and the excess return on long-term over short-term Treasuries.

Our paper is organized as follows. Section II describes the data and the empirical methodology. Section III analyzes the impact of exogenous federal spending and taxes on the quality of innovative output and on corporate R&D investment. Section IV explores the credit channel of indirect crowding out. Section V concludes.

II Data and Variable Construction

The initial sample of companies examined in the paper includes 240,429 firm-years based on 21,488 firms that have publicly traded stock over the period 1950-2009. We combine innovation data from the NBER patent database assembled by Hall, et al. (2006) and Kogan et al. (2016) with financial data from Compustat. Government borrowing data is obtained from CRSP U.S. monthly treasury dataset. Data on credit ratings come from S&P Issuer (Entity) Credit Ratings database. Data on military expenditures are obtained from Ramey (2011), while tax revenue data are from Romer and Romer (2010).

After we combine the various datasets, we have 129,134 observations and 14,131 firms if the dependent variable is measured four years forward. The Poisson maximum-likelihood estimation omits observations that do not change during the sample period. Therefore, our final sample in the main specification consists of 72,722 observations. For some regressions we require that credit ratings data be available. This reduces the sample size to 41,891 observations based on 2,547 firms if the dependent variable citations per patent is measured one year forward, and to 34,836 observations based on 2,314 firms if the dependent variable is measured four years forward.

II.A Main Explanatory Variables: Exogenous Military Expenditures and Exogenous Changes in Tax Revenues

We use the variable *ExogDefenseExp* created by Ramey (2011) to measure the exogenous variation in government expenditures, which we show are closely positively related to the need for short-term government borrowing. Ramey (2011) uses news articles to estimate the present discounted value of unexpected exogenous future military expenditures for each year from 1939 to 2009. She uses a narrative approach by tracking Business Week articles that give detailed predictions of changes in government spending based on unexpected military events.

For data after 2001, Ramey relies more on newspaper sources because she considers Business Week to be less reliable in subsequent years. The variable *ExogDefenseExp* represents an approximation to the changes in expectations at the time of the news, and involves many judgment calls. In calculating present discounted values, Ramey uses the 3-year Treasury bond rate prevailing at the time.

For robustness, we also use the variable WarDummy, created by Ramey and Shapiro (1998), and Ramey (2011), which is an indicator variable equal to 1, if there is an unexpected substantial increase in government defense expenditures, and zero otherwise. There are four such unexpected episodes that Ramey (2011) discusses - the Korean War in 1950, the Vietnam war (1965), the Carter-Reagan military buildup after the Soviet invasion of Afghanistan (1980), and 9/11/2001.

We use two additional variables that affect government's need to borrow. The first one is provided by Romer and Romer (2010). They use sources such as Congressional reports to estimate significant tax changes based on federal legislation during the 1945-2007 period. As we document in our empirical section, higher exogenous tax revenues reduce government borrowing, while lower exogenous tax revenues increase government borrowing, especially in the short-term. Romer and Romer (2010) classify the motivation for each tax change into one of four categories: offsetting a change in government spending; offsetting some factor other than spending likely to affect output in the near future; dealing with an inherited budget deficit; and achieving some long-run goal, such as higher normal growth, increased fairness, or a smaller role of government. Romer and Romer (2010) argue the first two motivations are endogenous to GDP and other macroeconomic variables, while the third and the fourth motivations are exogenous. In Table VIII we use the variable *RomerExogTax* which is defined to be the sum of the last two types of tax changes divided by GDP. Because the fourth motivation for tax changes (i.e., achieving some long-run goal) could be related to future innovation, we re-estimate our results in Table IX using the variable *deficnrratio*, which is the third type of tax change (dealing with an inherited budget deficit) scaled by GDP.

For our measure of abnormal short-term government borrowing, *AbnSTGovBor*, we obtain data on US monthly Treasuries from CRSP. We follow Greenwood, Hanson, and Stein (2010) to calculate the total amount of debt outstanding at each maturity. For each outstanding issue we measure the principal and coupon repayments, adjusting the series each month for variation in the face value outstanding. For every month, we calculate the sum of payments due in the subsequent n periods, across all issues that are still outstanding. The government short-term debt is calculated as the sum of all payments due in one year or less, divided by total payments in all future periods. The abnormal level of government debt, *AbnSTGovBor*, is then calculated by subtracting the predicted value from a regression of the amount of government short term borrowing on a time trend from the actual value of short term government borrowing. After that, the monthly measures are averaged for each year to convert them to annual frequencies.

II.B Construction of the Dependent Variable

We use two main metrics, patents and patent citations, to measure a firm's innovative output. Patents and patent citations measure the output of the innovative process, which is the result of several inputs including physical capital, human capital, and the effort and creativity of managers and employees.[3] The number of citations received by a patent provide a measure of the importance and long-term value of the innovation. In comparison, R&D expenditures may not be a reliable indicator of innovative activity since higher R&D expenditures could, for instance, reflect managerial spending on pet projects that have no significant impact

[3] Using R&D expenditures instead of patents or patent citations (scaled by R&D expenditures) to measure innovation is akin to using total expenditures instead of profits, firm value or stock returns to measure firm performance.

of firm value. It should be noted that patents as a measure innovation output have the limitation that not all firms and industries patent their innovations. This is because some inventions do not meet the patentability criteria or because the inventor might rely on secrecy or other means to protect her innovation.[4]

The first innovation metric, *Patent*, is a simple patent count for each firm in each year. As is typical in the literature, the relevant year for the innovation is taken to be the patent application year, which is close to the actual innovation and well before the innovation is transformed into a finished product, ready for the market (Hall, Jaffee, and Trajtenberg, 2001). *Patent* is equal to the number of patents for each firm-year divided by the mean number of patents granted in the year. This weighting adjustment is made to correct for truncation bias in patent data. The bias results from the fact that there is on average a two-year lag from the date of patent application to grant date but that lag may differ for different patents. Additionally, some patents that have been applied for may not yet appear in the sample.[5]

The second metric, citations per patent, assesses the significance of a firm's innovative output. It is motivated by the recognition that a simple count of patents does not distinguish breakthrough innovations from those that are incremental. Pakes and Shankerman (1984), for instance, show that the distribution of the value of patents is extremely skewed, i.e., most of the value is concentrated in a small number of very important and highly cited patents. Since patents are required to cite prior patents that are technologically relevant, the citations garnered by a patent can provide a measure of its technological and economic significance. Hall et al. (2005) among others demonstrate that patent citations are a reliable indicator of

[4]In Table IIIB, we examine a sub-sample of firms operating in industries, in which patenting is important (citations per patent above the mean), and obtain similar results.

[5]Although we use the application year as the relevant year, the NBER patent dataset provides information only on successful patents, that is those that have been already granted. Therefore, only patents that have been already granted appear in the sample. The truncation bias is explained in greater detail in Appendix A.

the value of innovations.

Patent citations suffer from a truncation bias because citations are received for many years after the patent is applied for and granted. For instance, a patent granted in 1995 will have far more time to receive citations than a patent granted in 2006 because our sample of patent citations ends in 2009. Another potential concern is that different industries might have different propensities to cite patents. We correct for these biases by using two methods suggested by Hall, Jaffe and Trajtenberg (2001), the fixed effects method and the quasi-structural method. The fixed effects method corrects for these biases by dividing the number of patent citations by the average amount of patent citations in the cohort (year, technology class, or year-and-technology class) to which the patent belongs.[6] The quasi-structural method multiplies each patent citation by an index created by econometrically estimating the distribution of the citation lag (the time from the application of the patent until a citation is received).

We construct four dependent variables that measure the number of citations per patent for each firm in each year. The variable *Citations/Patent* uses the raw measure without correcting for truncation, $\textit{Citations/Patent}^{Time}$ corrects for year fixed-effects, $\textit{Citations/Patent}^{Time-Tech}$ corrects both for year and technology class fixed effects, and $\textit{Citations/Patent}^{Quasi}$ uses the quasi-structural method to correct for the truncation bias. Although due to space considerations we only report the results with the $\textit{Citations/Patent}^{Quasi}$ variable in the main tables, our findings are similar when we use the other three variables instead. The results using these alternative measures are provided in the Internet Appendix (Tables B1-B3).

Our sample period spans 1950-2009. We complement the NBER patent dataset available from 1976 to 2006 with data from Kogan et al. (2016). The NBER patent dataset, which

[6]A more detailed explanation of the construction of the dependent variable and the truncation bias in patent citations is provided in Appendix A.

includes annual information on patent assignee names, the number of patents, the number of citations received by each patent, the technology class of the patent, the year that the patent application is filed, and the year it is granted. As Hall, Jaffe, and Trajtenberg (2001) indicate, the match is not perfect because assignees obtain patents under a variety of names and the United States Patent and Trademark Office does not keep a unique identifier for each patenting organization from year to year. Hall, Jaffe, and Trajtenberg perform a cumbersome procedure to account for these idiosyncrasies and the matched firms in the patent dataset are identified by the Compustat GVKEY number if the assignee is a public corporation or is a subsidiary of a public corporation covered in the Compustat Industrial Annual database. Using these GVKEY numbers, we merge the financial data in Compustat with the NBER patent dataset.

We also augment the sample of firms with patents by including all the other firms in Compustat that do not have patents. We take the patent and citations per patent count to be zero for these firms. Including these firms alleviates sample selection concerns, since the sampling procedure is independent of whether the firms patent or not. We include firm (or industry) fixed effects in all regression models to address (time-invariant) heterogeneity between firms and/or industries in terms of their propensity to patent. Finally, we exclude industries such as financial services and utilities that operate under different regulatory rules from manufacturing firms.

II.C Other Explanatory Variables

The data on total assets, sales, R&D expenditures, debt, net property plant and equipment, EBITDA, come from CRSP/Compustat merged database. We follow Hall and Ziedonis (2001) and Aghion et al. (2005) among others and include *Log(Sales)* to control for firm size and the Herfindahl index (HI) at the 4-digit SIC level for industry concentration in our regression specifications. We also include the squared Herfindahl index to control for non-linear effects of industry concentration. All continuous variables are winsorized at the 1st and 99th percentiles to remove the influence of extreme outliers. To measure the quality of borrowers, we create an indicator variable *Crating* equal to 1, if the firm has a credit rating of B+ or above, and 0 if the firm has a credit rating lower than B+. To control for economy wide, time varying economic changes we include the variable *LnRealGDP* that measures the log of real GDP, and *LnRealInv* that measures the log of real aggregate investment. We also use the average Baa rate and the TB3 rate to measure the cost of corporate and government borrowing and construct the risk premium measure. The data comes from Ramey (2011) and the Bureau of Economic Analysis.

II.D Model Specification

In our main empirical specifications, we estimate the following model:

$$y_{i(t+n)} = \alpha_i + \beta GOV_t + \gamma X_{it} + \epsilon_{it}, \tag{1}$$

where i indexes firms, t indexes time, $y_{i(t+n)}$ is the dependent variable, which is Patent or Citations/Patent for the Poisson (count) specifications, and *RD/TA* (*R&D* scaled by total assets) in linear specifications. Here n is the number of years after the current time period t, and varies from 1 to 4. GOV_t is a variable that measures exogenous changes in government spending or taxes. We control for time invariant unobservable firm characteristics by using firm fixed effects α_i.

We investigate the channel through which government spending and taxes affect corporate innovation by modifying the above model. Specifically, we test for the indirect crowding out channel by using a difference-in-difference methodology. We estimate the following model:

$$y_{i(t+n)} = \alpha_i + \beta_1 GOV_t + \beta_2 BSheetStr_{it} + \beta_3 GOV_t BSheetStr_{it} + \gamma X_{it} + \epsilon_{it}, \qquad (2)$$

where i indexes firms, t indexes time, $y_{i(t+n)}$ is the dependent variable, which is Patent or Citations/Patent for the Poisson specifications, and *Log(1+Patent)* or *Log(1+*$\frac{Citations}{Patent}$*)*, for the log-linear specifications. As above, n is the number of years after the current time period t, and varies from 1 to 4. GOV_t is a variable that measures unexpected exogenous changes in government spending or taxes. $BSheetStr_{it}$ is a variable that measures the strength of balance sheet or firm creditworthiness, while α_i indicates firm fixed effects. The coefficient on the interaction term GOV_t*$BSheetStr_{it}$ represents the difference-in-difference estimate. The balance sheet measure that we use in our analysis is an indicator variable equal to 1 if a firm has a S&P credit rating of B+ or higher, and 0 otherwise. For robustness, we also use the standard classification assigning a value of 1 if a firm has a credit rating of BBB or higher (investment grade) and 0 otherwise (junk grade).

It is helpful to explain the test using an example. Suppose we want to estimate the effect of an increase in government spending on innovation in 1980. Economy wide shocks may occur at the same time and affect the number of innovations in 1980. To control for such factors, we calculate the change in innovation output for a treatment group of firms with high credit ratings (strong balance sheets) before and after the increase in government spending, and compare that to the change in innovation output for a control group of firms with low credit ratings (weak balance sheets) before and after the increase in government borrowing. The difference of these two differences represents the incremental effect of the increase in government spending on innovation output of the treated group. We expect this incremental effect to be positive, implying that firms with higher credit ratings will have an easier time financing their innovative projects from alternative sources, while firms with lower credit ratings will tend to be crowded out more, and suffer a greater decline in innovation.

II.E Summary Statistics

Table I presents a summary of the main variables. There are two panels. The first panel presents the results for the observations in which exogenous government spending is above its time-series mean, and the second panel is for observations with below mean exogenous government spending. Compared to the sub-sample with above-mean government spending, firm-years with government spending below the mean have 2.25 times more citations per patent four years later (0.41 vs. 0.32), 2.8 times more patents four years later (6.5 vs. 2.3), 42% less sales (975 mil. vs. 1682 mil.) and 14.7% less R&D expenditures to total assets two years later (0.029 vs. 0.034). To ensure that we are not picking up a trend, we normalize our dependent variable using the quasi-structural approach described in the previous section.

The firm-years with lower government spending are also 25% more profitable, have 11.11% more tangible assets, 20% less cash, and 4% higher leverage. When government spending is above the mean, Ln(GDP) is 1% higher, Ln(Real Aggregate Investment) is 3% higher, exogenous taxes are 74% lower and exogenous taxes to reduce the deficit are 20% higher.

The summary statistics indicate that there is an overall positive correlation between exogenous military expenditures and innovative output measured by patents and citations per patent. For better inference, we turn to multivariate analysis in the next section.

III The Impact of Exogenous Government Spending on Technological Innovation

The first step of our analysis is to show directly that exogenous increases in government spending reduce corporate innovation. To that end, we estimate the following model:

$$y_{i(t+n)} = \alpha_i + \beta ExogDefenseExp_t + \gamma X_{it} + \epsilon_{it}, \tag{3}$$

where i indexes firms, t indexes time, $y_{i(t+n)}$ is the dependent variable, which is Patents or Citations/Patent, and n is the number of years after the current time period t, and varies from 3 to 4. *ExogDefenseExp* is a variable that measures the exogenous government defense spending as described in Ramey (2011). It is equal to the present value of future military expenditures divided by real GDP. For robustness, as an alternative to *ExogDefenseExp*, we use a dummy variable measuring dramatic unexpected military escalations resulting in an exogenous increase in military expenditures, *WarDummy*. We control for time invariant unobservable firm characteristics by using firm fixed effects α_i. The vector X_{it} is a vector of control variables that account for size, profitability, the amount of tangible assets, the availability of cash and financial leverage. Since economic booms or recessions can be a third factor that influences both government spending and innovation, we also include the log of real GDP and the log of real aggregate investment in each regression specification.

Table II reports the results when the dependent variable is the number of patents. Columns (1) and (2) show a strong negative impact of *ExogDefenseExp* on the innovative output in terms of the number of patents. The results suggest that unexpected increases in government spending that are unrelated to the business cycle and to the change in aggregate demand and GDP, lead to a decline in corporate innovation. This finding is consistent with the hypothesis that government spending crowds out corporate investment and leads to lower innovation. Columns (3) and (4) show similar results for a sub-sample of innovative firm-years that have at least one patent.

In Table III, Panel A, we investigate the impact of government spending on the quality of innovative output measured by citations per patent, using the full set of publicly-traded firms from Compustat. It is possible that, although higher government spending decreases the number of patents, it leads to more novel innovations. We find that this is not the case. As indicated, the increase in exogenous defense expenditures leads to a lower number of citations per patent. The results are economically significant. An increase in exogenous defense spending leads to a 23% and 20% decrease in the number of patents and 14% and 17% decrease in the number of citations per patent, respectively 3 and 4 years later (columns (1) and (2)).

Interestingly, the estimated relation between real GDP growth and innovation and real aggregate investment growth and innovation is negative. A possible explanation might be, as argued in Schumpeter (1947), that companies use recessions (when demand is weak) to invest in R&D and eventually create high quality innovative output.

The results in Table III, Panel A also indicate the relation between the control variables and the number of citations per patent. The associations are worth noting even though they lack a causal interpretation. Firms with more tangible assets (measured by net property, plant and equipment divided by total assets) innovate more. Firms with more cash also innovate more. While this is consistent with the "deep pockets" theory, it can also mean that more innovative firms generate more cash. We also find that firms innovate less when the risk premium between corporate bonds and government bonds is higher, and when total real defense expenditures are higher. Finally, total stock market capitalization is positively related to future innovation suggesting that the stock market maybe forward looking and anticipate future innovations. This finding is consistent with Hall et al. (2005).

In Table III, Panel A, columns (3) and (4) we investigate if the presence of a large number of firms with zero patents or citations per patent affects our results. We do this by reestimating the regressions in Panel A for the sub-sample of innovative firms. We define innovative firms as those that have larger than the mean citations per patent in a given year. As reported, we still find a very strong negative impact of *ExogDefenseExp* on the quality of innovative output, even though the sample size is less than a half of the full sample. The results indicate that unexpected increases in government defense spending that are unrelated to the business cycle and to changes in aggregate demand and GDP, lead to a decline in corporate innovation. This finding again provides support for the hypothesis that government spending crowds out corporate investment and leads to lower innovation. In the internet appendix table B4, we use an alternative way to define innovative firms as firms that have at least one patent. We obtain similar results.

In Table III, Panel B, columns (1) and (2), we use the variable *ExogWar0* (Ramey and Shapiro, 1998, and Ramey, 2011) instead of *ExogDefenseExp* as our main explanatory variable. *ExogWar0* is a coarser measure of unexpected defense spending, but at the same time it identifies four episodes of truly unexpected military escalations that were followed by substantial exogenous increases in military spending. It is equal to 1 for 1950 (the Korean war), 1965 (the escalation of the Vietnam war), 1980 (the Soviet invasion of Afghanistan), and 2001 (9/11). Ramey (2011) argues that these wars were unexpected and therefore represent an exogenous shock to government expenditures. We find that the beginning of these unexpected conflicts has a negative impact of the quality of corporate innovation measured by the number of citations per patent.

In column (3) of Table III, Panel C, we provide the results of a dynamic test to further demonstrate that it is the exogenous shock to government expenditures that is causing innovation to drop and not the other way around . In particular, we establish that the decline in innovation occurs after the start of wars and that there is no declining trend in innovation in prior periods. We proceed by constructing several additional indicator variables: *ExogWarBefore1-5* is equal to 1 if it is 1, 2, 3 , 4 or 5 years before the wars started, *ExogWar0* is equal to 1 in the year of the war, while *ExogWarAfter1* and *ExogWarAfter2plus* are, respectively, equal to 1 one year and two or more years after the start of the unexpected military conflict. We find that the only significant coefficient is on *ExogWarAfter2plus.* This result indicates that the greatest impact on the number of citations per patent occurs 2 or more years after start of the war. The time pattern is also indicative of the relatively long time-frame over which innovation decisions are made and outcomes are realized.

In Table III, Panel D, we conduct further robustness checks. In particular, we use a log-linear specification instead of Poisson because of the concerns that the Poisson specification uses a non-linear maximum likelihood technique that drops observations that do not vary over the time period and therefore may constitute a loss of valuable information. We find that our results are similar in magnitude and statistical significance as the Poisson specification. Following Petersen (2009), we cluster the standard errors by firm in columns (1) and (2), and for robustness by year in columns 3 and 4. The latter specification is necessary to demonstrate that our results are unaffected by a potential serial correlation within a year, given that our main explanatory variable varies only by year. We find that even after clustering in this more stringent way, our results are still economically and statistically significant at the 1% level.

IV The Credit Channel

There are several possible channels through which government spending and taxes could crowd out private investment and reduce innovation. In this paper, we investigate crowding out that works through financial markets. The notion is that if government spending is financed through borrowing, it will increase the cost and difficulty of obtaining capital if lenders and investors substitute (even imperfectly) between government debt and private financing. If firms find it more difficult to finance their investment in R&D, or in other inputs necessary for the creation of high quality innovations, they will innovate less.

We hypothesize that if there is crowding out in credit markets, firms that find it more difficult to obtain financing (those with weaker balance sheets) will be disproportionately affected. We measure the strength of a firm's balance sheet by using several variables including credit ratings, profitability, size, and indebtedness. We report the results using credit ratings (Table IV, Panel A) and profitability and the risk premium between corporate and government bonds (Table IV, Panel B). Specifically, we estimate the following regression specification:

$$\begin{aligned} y_{i(t+n)} &= \alpha_i + \beta_1 ExogDefenseExp_t + \beta_2 Crating_{it} \\ &+\beta_3 ExogDefenseExp_t * Crating_{it} + \gamma X_{it} + \epsilon_{it}, \end{aligned} \quad (4)$$

where, as before, i indexes firms, t indexes time, $y_{i(t+n)}$ is the dependent variable, which is Patent or Citations/Patent, and n is the number of years after the current time period t, and varies from 1 to 4. In columns 1- 4 of Table IVA, we use *Crating1* is an indicator variable equal to one if the firm has S&P credit rating of B+ or higher, and zero if the credit rating is lower than B+. In columns 5 and 6 of Table IVA, we use *Crating2* is an indicator variable equal to one if the firm has S&P credit rating of BBB or higher (investment grade), and zero if the credit rating is lower than BBB (junk grade).The coefficient on the interaction term $ExogDefenseExp_t$*$Crating_{it}$ represents the difference-in-difference estimate described in the methodology section. In all regressions, we control for time invariant unobservable firm characteristics by using firm fixed effects α_i, and we cluster the standard errors by firm in columns 1-2 and 5-6, and by year in columns 3-4.

Table IV, Panel A reports the results. Similar to Table III, we find a strong negative impact of *ExogDefenseExp* on the quality of innovative output. The results again suggest that unexpected increases in government spending that are unrelated to the business cycle, lead to a decline in corporate innovation. Furthermore, the coefficient on the interaction term between *ExogDefenseExp* and *Crating* is positive and significant. This finding suggests that firms with better credit ratings, experience a smaller decline in innovation. Although having a good credit rating helps mitigate the negative impact of government spending, it cannot completely eliminate it. As a result, even high quality firms experience a decline in innovation. Firms with poorer credit ratings, however, experience a more dramatic decline in innovation of 58.2%, and 56.2% in years 3 to 4 in the future, respectively (columns 1 and 2). This finding is consistent with the hypothesis that government spending crowds out corporate investment because it decreases the availability of credit, which leads to lower innovation, especially for firms with weaker balance sheets.

In columns 3 and 4 of Table IV, Panel A, we use a log-linear OLS specification instead of the Poisson specification and find similar results. We also cluster our standard errors by year to demonstrate that serial correlation within the year does not affect the significance of our results. In columns 5 and 6, we define our credit ratings differently. The variable is equal to 1 if a firm has BBB or higher credit rating, and 0 otherwise. The results are qualitatively similar.

In Panel B of Table IV, we use two additional measures to test the credit channel. In columns 1 and 2, we interact the *ExogDefenseExp* with the corporate risk premium. The intuition is that the indirect crowding out will be more severe when the risk premium is higher and it is more costly for companies to issue debt because of the higher corporate Baa rate compared to the government rate. We find support for this hypothesis. The coefficient on the interaction term is negative and significant, suggesting that in times when the risk premium is higher, the negative impact of exogenous government spending on innovation is greater.

Columns 3 and 4 of Table IV, Panel B, document that more profitable firms are less impacted by the government borrowing. Profitability is measured by EBTDA divided by total assetsIn unreported tests, we employ several alternative measures of profitability and find similar results.. Presumably, more profitable firms have stronger balance sheets, and therefore more internal resources to finance R&D. As a result, these firms will be less reliant on external credit markets and less affected by the indirect crowding-out.

V The Impact of Exogenous Federal Taxes on the Quality of Innovative Output

In this section, we address a potential concern that military conflicts can themselves lead to recessions and decrease in innovation if more resources are directed to unproductive uses. We do this by exploiting two other measures of unexpected changes in the government fiscal policy that can similarly affect government's need to borrow, especially in the short-term, and crowd-out (or "crowd-in" if government's need to borrow is decreased) firms from the credit markets. Instead of expenditures, we now focus on exogenous changes in taxes. We estimate the following model:

$$y_{i(t+n)} = \alpha_i + \beta ExogenousTax_t + \gamma X_{it} + \epsilon_{it}, \tag{5}$$

where, as before, i indexes firms, t indexes time, $y_{i(t+n)}$ is the dependent variable, which is Citations/Patent for the Poisson specifications, and *log(1+Citations/Patent*^{Time}*)*, for the log-linear specifications, and n is the number of years after the current time period t, and varies from 1 to 4. *RomerExogTax* is a variable that measures the exogenous changes in taxes as described in Romer and Romer (2010). It is equal to the exogenous tax changes in a given year divided by real GDP. For robustness, we exclude changes in taxes that may directly affect corporate profits and investment, such as the 1993 tax increase, and obtain similar results. As a second test, we examine the impact of taxes aimed only at reducing an inherited budget deficit, *RomerExogDeficit*. The regressions include firm fixed effects α_i. The vector X_{it} is a vector of control variables that control for size, profitability, the amount of tangible assets, the availability of cash and financial leverage. Since changes in real GDP can be a third factor that may influence both tax changes and innovation, we also include the log of real GDP and the log of real aggregate investment in each regression specification.

We argue that an unexpected increase in tax revenues will reduce crowding out because the government will have more funds available and will not need to borrow as much from the financial markets and compete with the private sector. Additionally, if the tax revenues are used for the reduction of an inherited budget deficit, that could reduce future uncertainty about, for instance, the government's need to monetize public debt,[7] or to borrow even more to pay the interest. There is, however, an alternative hypothesis that by increasing taxes, the government takes productive resources away from the private sector. In that case, we would expect innovation to decline.

V.A The Impact of Exogenous Tax Changes on the Number of Citations per Patent

As noted earlier, Romer and Romer (2010) use a narrative approach of Congressional legislation that affects future tax revenues. They classify the motivation for each tax change into one of four categories, of which they argue that two can be taken as exogenous: (i) dealing with an inherited budget deficit; and (ii) achieving some long-run goal, such as higher normal growth, increased fairness, or a smaller role for government. The variable *RomerExogTax* is equal to the sum of these two types of tax changes divided by GDP.

Table V, columns 1 and 2 reports the results. We find a strong positive impact of *RomerExogTax* on the quality of innovative output. The results suggest that unexpected increases in exogenous taxes that are unrelated to the business cycle and to the change

[7]By increasing money supply and thus the likelihood of future inflation.

in aggregate demand and GDP, lead to an increase in corporate innovation. This finding is consistent with the hypothesis that government fiscal policy crowds out corporate investment and leads to lower innovation. The finding is inconsistent with the alternative hypotheses that exogenous increases in taxes will siphon resources away from the private sector, and thus reduce innovation.

We observe that tax changes that are motivated by some long-run goal (such as higher normal growth) could be related to future innovation for reasons other than crowding out of private investment. Hence, we re-estimate our regression models by using the variable *RomerExogDeficit*, which measures only tax changes dealing with an inherited budget deficit, divided by GDP. As reported in Table V, columns 3 and 4, we find a strong positive impact of *RomerExogDeficit* on the quality of innovative output 3 and 4 years after the exogenous tax change. The results suggest that unexpected increases in exogenous taxes that are aimed at reducing an inherited budget deficit, and are unrelated to the business cycle and to the change in aggregate demand and GDP, lead to an increase in corporate innovation. This finding provides strong support to the hypothesis that government fiscal policy affects corporate R&D investment and innovation.

The results are also economically significant. An increase in exogenous tax revenue leads to a 9% and 5% increase in the number of citations per patent, respectively 3 and 4 years later, when all exogenous taxes are involved, and 7% and 8% increase in the number of citations per patent when changes in tax revenues that affect the deficit only are involved.

V.B Exploring the Credit Channel

In this section, along the lines of Table IV, Panel A, we investigate whether exogenous tax changes affect innovation through the credit channel i.e., by reducing the availability of financing for innovative projects. We expect that when there is an increase in exogenous taxes, especially in those taxes used to reduce an inherited budget deficit, the need to borrow will decrease. As a result, there will be less crowding out via the credit channel and firms will find it easier to finance their R&D investments and innovate more. If that is the case, firms with weaker balance sheets (worse creditworthiness) would again be affected disproportionately.

Table VI, columns 1 and 2 reports the results using *RomerExogTax* to measure exogenous changes in taxes (Romer and Romer 2010). Similarly to Table V, Panel A, we find a strong positive impact of *RomerExogTax* on the quality of innovative output. The results again suggest that unexpected increases in taxes that are unrelated to the business cycle and to the change in aggregate demand and GDP, lead to an increase in corporate innovation. Furthermore, the coefficient on the interaction term between *RomerExogTax* and *Crating1* is negative and significant. This finding suggests that firms with better credit ratings, experience a smaller increase in innovation. Conversely, firms with poorer credit ratings experience a more dramatic increase in innovation. The results are also economically significant, the positive impact of exogenous tax increases on citations per patent are 64.7% and 67% greater for firms with lower credit ratings 3 and 4 years after the tax increase.

Table VI, columns 3 and 4 report the third set of results using *RomerExogDeficit* to measure exogenous changes in taxes aimed at reducing an inherited budget deficit (Romer and Romer 2010). We again find a strong positive impact of *RomerExogDeficit* on the quality of innovative output. The coefficient on the interaction term between *RomerExogDeficit* and *Crating* is negative and significant. This result implies that firms with poorer credit ratings experience a more dramatic increase in innovation after a tax increase aimed at reducing the budget deficit. The findings in Table VI are consistent with the hypothesis that increases in exogenous taxes, especially those that are targeted at reducing an inherited budget deficit, reduce the need of the government to borrow and alleviate the crowding out problem. As a result, firms find it easier to obtain financing and increase innovation. That effect is especially strong for firms with weaker balance sheets.

V.C Exogenous Federal Government Spending and Taxes and the R&D Expenditures

The above results in Tables II-VI suggest that government spending crowds out innovative output. The conjecture is that increased government spending crowds out firm borrowing and reduces investment. In particular, there is a decrease in research and development (R&D) investments that are a key input for innovations to occur. If the crowding out story is valid, we should see a decline in R&D expenditures.

Therefore, in Table VII, we estimate how R&D expenditures are affected by exogenous changes in government military expenditures (Ramey, 2011), and exogenous changes in tax revenues (Romer and Romer, 2010). We measure R&D expenditures as a proportion to total assets, and for robustness, as a proportion to sales. We find a negative impact of *ExogDefenseExp* on R&D expenditures, and positive impact of *RomerExogDeficit* on R&D expenditures. The results suggest that unexpected increases in government spending that are unrelated to the business cycle and to the change in aggregate demand and GDP, lead to a decline in R&D expenditures. Similarly, unexpected increases in taxes to reduce an inherited budged deficit lead to an increase in R&D expenditures. These findings are consistent with the hypothesis that government spending crowds out corporate investment in R&D.

VI The Credit Channel: An Instrumental Variable Approach

Overall, the findings in Tables IV and VI provide strong support for the credit channel of indirect crowding out. In this section, we go further and investigate directly if an increase in government military spending leads to an increase in short-term government borrowing, and if that increase reduces innovation. We also examine if exogenous increases in taxes, and especially those used to reduce an inherited budget deficit, reduce short-term government borrowing. We measure short-term government borrowing with the variable *AbnSTGovBor*, which is equal to the difference between the actual value of short term government debt minus the predicted value of short term government debt obtained from a regression of the amount of short term government debt on a time trend. In other words, *AbnSTGovBor* measures the deviation of the actual value from predicted value. Following Greenwood, Hanson, and Stein (2010), we set the amount of government short-term debt equal to the sum of all payments due in 1 year or less divided by total payments in all future periods.

Table VIII presents the results. We use Newey-West estimation techniques to control for autocorrelation in the time-series. Supportive of the proposed credit channel, we find that *AbnSTGovBor* is positively related to *ExogDefenseExp*, and negatively related to *RomerExogTax* and *RomerExogDeficit*. This finding is consistent with the hypothesis that an increase in exogenous government spending leads to more short-term government borrowing, while exogenous tax increases lead to less short-term government borrowing. As control variables, we also include variables that appear in the second stage of the estimation, such as log of GDP, real investment, total market capitalization and the risk premium of corporate bonds over government bonds.

We next investigate if the increase (decrease) in short-term government borrowing, caused by increased spending (lower tax revenues), impacts corporate innovation. We obtain the predicted values of *AbnSTGovBor* from Table VIII, and relate these values to citations per patent in Tables IX and X. We expect that an increase in short-term government borrowing caused by an exogenous increase in spending (Table IX) will crowd out private borrowing and reduce innovation. On the other hand, an increase in taxes (Table X) is expected to reduce government borrowing and crowding out and to enhance innovation.

Table IX reports results using the predicted values of *AbnSTGovBor* from regressing *AbnSTGovBor* on *ExogDefenseExp*. We find a strong negative impact of the exogenous increase of short-term government borrowing on the quality of innovative output. Table X reports results using the predicted values of *AbnSTGovBor* from regressing *AbnSTGovBor* on *RomerExogDeficit*. Similarly to Table IX, we find a strong negative impact of the exogenous increase of short-term government borrowing on the quality of innovative output. These findings are consistent with the hypothesis that government borrowing crowds out corporate investment and innovations because it decreases the availability of credit.

To further corroborate the crowding out hypothesis, we examine if corporate borrowing changes after an exogenous change in government spending. Greenwood, Hanson and Stein (2010) propose a gap-filling theory of corporate debt and argue that after an increase in short-term government borrowing, firms will try to switch to longer term maturities. Firms with weak balance sheets however may find it difficult (and expensive) to borrow at longer maturities, and consequently experience a decline in their short-term borrowing. Table XI documents a finding consistent with that prediction. We show that an increase in exogenous government spending has a negative effect on short-term borrowing, especially for firms with lower credit ratings. There is no such effect on long-term borrowing. The results support the conjecture that an increase in government spending crowds out firm borrowing especially for firms with weaker balance sheets. As a result, these firms may not have sufficient resources to finance their R&D activities at prior levels (i.e., before the increase in government borrowing), leading to a decline in innovative output.

VII Industry Analysis

In the sections above, we have documented that unexpected government military spending has a negative impact on innovation, especially for firms with weaker balance sheets. In this section, we investigate if there are specific industries that can potentially benefit from the increased military spending. An obvious candidate is an industry that could be sourced to provide the military with new technology, or that receives a greater amount of government subsidies or contracts. To this end, we look first at the differential impact of unexpected military spending on the industries related to the military. In particular, we consider the following industries: Transportation Equipment (SIC code 37), National Security and International Affairs (SIC code 97), Transportation by Air (SIC code 45) and Transportation Services (SIC code 47).

The results appear in Table XII, columns 1 and 2. We find that the interaction term on the military-related industry indicator variable with unexpected military spending is positive. This implies that the negative impact of military spending on innovation is mitigated for firms doing business with the military. However, in most regressions the overall impact is still negative. A Wald test with a statistic of 33.30 confirms that the coefficient on government military spending is significantly different from the coefficient on the interaction term of government military spending with the military-related industry dummy.

We pursue this result further by looking at total government industry procurement expenditures from 1990 until 2007. We collect data from the Federal Procurement Data System[8], and in Table XII, columns 3 and 4, we analyze whether unexpected military spending tends to affect innovation disproportionately for industries that rely more on government procurement. We use an indicator variable equal to 1 if in a given year an industry is above the median of government procurement expenditures, and zero otherwise.

We find that industries with greater reliance on government procurement experience a greater decline in innovation 3 or 4 years after the exogenous change in military spending. Intuitively, the industries that depend most on government spending may anticipate a decrease in funding due to a shift in government spending towards the military and respond by cutting back on innovation related activities. Another possible explanation is that the

[8] www.fpds.org

government might be expected to reduce future procurement spending in order to eventually pay down the debt accumulated due to the increased current military spending.

VIII Conclusion

This paper documents that unexpected exogenous shifts in federal government spending and taxes that increase its need for short term borrowing have unintended consequences by crowding out corporate borrowing. This, in turn, leads to reducing investment in R&D and the quality of innovative output. We verify that these effects are strong and not spurious by using an exogenous variation in government expenditures due to military buildups or run downs. We also use exogenous changes in taxes, especially those aimed at reducing an inherited budget deficit.

We suggest a credit or financial markets channel through which unexpected spending or taxes affect corporate investment and innovation. Specifically, we document that firms with poor credit ratings, that may have difficulty obtaining financing through alternative means, are affected more negatively by increases in government borrowing. Our findings suggest that government fiscal policy can have adverse effects not only in the short-run, but also on long-run economic growth through its impact on corporate innovation, especially for firms with weaker balance sheets.

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Table I, Panel A:
Summary Statistics for Years with Unexpected Defense Expenditures Greater than the Mean

This table reports summary statistics for years with unexpected defense expenditures greater than the mean. Data is for the period 1950 to 2009.

Variable	**Mean**	**Min**	**Max**
$Citations/Patent_{t+4}$	.12	0	98
$Patents_{t+4}$	2.3	0	1843
Sales	1682	0	25801
$R\&D/TA_{t+2}$	.034	0	.49
Profitability	.075	-1	.42
Tangibility	.27	0	.92
Cash/TA	.1	0	.74
Leverage	.23	0	.93
Ln(Real GDP)	-8.2	-9	-8
Ln(Real Investment)	-8.3	-9.5	-8
ExogDefenseExp	.0078	.0015	.02
RomerExogTax	-.047	-.29	.1
RomerExogDeficit	.024	0	.14

Table I, Panel B: Summary Statistics for for Years with Unexpected Defense Expenditures Smaller than the Mean

This table reports summary statistics for years with unexpected defense expenditures smaller than the mean. Data is for the period 1950 to 2009.

Variable	**Mean**	**Min**	**Max**
$Citations/Patent_{t+4}$	.27	0	43
$Patents_{t+4}$	6.5	0	4340
Sales	975	0	25801
$R\&D/TA_{t+2}$	.029	0	.49
Profitability	.094	-1	.42
Tangibility	.3	0	.92
Cash/TA	.08	0	.74
Leverage	.24	0	.93
Ln(Real GDP)	-8.3	-9.1	-8
Ln(Real Investment)	-8.6	-9.6	-8
ExogDefenseExp	-.0017	-.023	.0012
RomerExogTax	-.012	-.34	.15
RomerExogDeficit	.029	0	.2

Table II:
The Impact of Exogenous Defense Expenditures on the Number of Patents

This table reports the results relating the number of patents to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects Poisson model of $Patent_{it}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, RD/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). Columns 1 and 2 use the full sample, while columns 3 and 4 use a sample of innovative firm-years that have at least one patent. All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$Patent_{t+3}$	$Patent_{t+4}$	$Patent_{t+3}$	$Patent_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-51.329***	-43.736***	-34.796***	-29.038***
	(2.174)	(2.237)	(1.662)	(1.743)
LnSales	.653***	.622***	.655***	.617***
	(.064)	(.070)	(.063)	(.069)
RD/TA	3.213***	3.833***	2.975***	3.409***
	(.827)	(.928)	(.826)	(.937)
Profitability	-.070	.079	.175	.297
	(.319)	(.367)	(.357)	(.460)
Tangibility	.793	.723	.621	.569
	(.511)	(.540)	(.511)	(.561)
Cash	.566	.846**	.410	.724*
	(.367)	(.400)	(.380)	(.410)
Leverage	.249	.413	.399	.610*
	(.346)	(.341)	(.332)	(.346)
LogRealGDP	-.809	-1.871*	-1.375*	-3.523***
	(.899)	(1.058)	(.807)	(.843)
LogRealInv	-3.268***	-3.376***	-3.148***	-3.149***
	(.404)	(.418)	(.386)	(.401)
BudgetSurpl/GDP	-.005***	-.010***	.0009	-.008***
	(.001)	(.0009)	(.002)	(.001)
RiskPrem	-.105***	-.150***	-.115***	-.187***
	(.012)	(.011)	(.014)	(.013)
HI	3.374*	3.675**	2.998*	3.200*
	(1.735)	(1.841)	(1.633)	(1.728)
HI2	-3.830**	-4.178**	-3.357**	-3.546**
	(1.781)	(1.880)	(1.660)	(1.728)
RealDefExp	-.043***	-.032***	-.026***	-.017***
	(.004)	(.004)	(.003)	(.003)
LogTotMktCap	.974***	1.076***	.890***	1.198***
	(.072)	(.117)	(.079)	(.098)
Obs.	63157	57842	26440	24590
χ^2 statistic	1843.649	2161.451	1360.006	2082.09

Table III, Panel A: The Impact of Exogenous Defense Expenditures on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, R&D/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). Columns 1 and 2 use the full sample, while columns 3 and 4 use a sample of innovative firm-years that have above the mean citations per patent. All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-20.940***	-22.911***	-13.593***	-13.193***
	(1.591)	(1.927)	(1.303)	(1.335)
LnSales	-.012	.005	-.062***	-.047
	(.029)	(.032)	(.019)	(.032)
RD/TA	.194	.073	.339	.358
	(.345)	(.451)	(.296)	(.293)
Profitability	.033	.044	.151	.173
	(.059)	(.113)	(.113)	(.137)
Tangibility	.367**	.427**	.154	.235
	(.158)	(.171)	(.150)	(.164)
Cash	.316**	.339**	.101	.209
	(.141)	(.162)	(.140)	(.157)
Leverage	.014	-.062	.049	.066
	(.059)	(.100)	(.049)	(.093)
LogRealGDP	-2.632***	-2.648***	-1.481***	-2.562***
	(.572)	(.533)	(.404)	(.602)
LogRealInv	-.658***	-.703***	-.241	-.276
	(.178)	(.215)	(.177)	(.189)
BudgetSurpl/GDP	-.005***	-.009***	-.005***	-.010***
	(.002)	(.002)	(.001)	(.002)
RiskPrem	-.082***	-.080***	-.069***	-.102***
	(.026)	(.013)	(.012)	(.018)
HI	-.081	.160	.018	.650
	(.394)	(.429)	(.350)	(.460)
HI2	.049	-.146	.012	-.613
	(.362)	(.389)	(.321)	(.404)
RealDefExp	-.009***	-.008***	-.002**	-.002*
	(.001)	(.001)	(.001)	(.001)
LogTotMktCap	.515***	.487***	.226***	.424***
	(.087)	(.051)	(.051)	(.055)
Obs.	59094	53468	24161	22630
χ^2 statistic	436.966	614.874	377.127	443.138

Table III, Panel B:
The Impact of Unexpected Wars on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures proxied by an indicator variable for exogenous wars (ExogWar). Specifically, in Columns (1) and (2) we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogWar0, which is an indicator variable, equal to 1 for 1950 (the Korean war), 1965 (the escalation of the Vietnam war), 1980 (the Soviet invasion of Afghanistan), and 2001 (9/11), and zero otherwise. In Column (3), we construct several additional indicator variables: ExogWarBefore1-5 is equal to 1 if it is 1, 2, 3 , 4 or 5 years before the wars started, ExogWar0 is equal to 1 in the year of the war, ExogWarAfter1 is equal to 1 one year after the war began and ExogWarAfter2plus is equal to 1 if it is 2 or more years after the war started. Other controls include LnSales, R&D/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t}$
	(1)	(2)	(3)
ExogWarBefore1-5(t-1 to t-5)			.040
			(.025)
War0	-.143**	-.239**	-.021
	(.056)	(.099)	(.038)
Warafter1			-.016
			(.042)
Warafter2+			-.366***
			(.039)
LnSales	-.019	-.003	.014
	(.028)	(.032)	(.023)
RD/TA	.217	.101	.472
	(.343)	(.468)	(.311)
Profitability	.043	.063	.018
	(.060)	(.119)	(.030)
Tangibility	.453***	.516***	.243*
	(.160)	(.172)	(.129)
Cash	.355**	.381**	.299**
	(.146)	(.166)	(.122)
Leverage	.020	-.033	.021
	(.056)	(.100)	(.027)
LogRealGDP	-2.319***	-2.235***	-2.109***
	(.577)	(.493)	(.485)
LogRealInv	-.758***	-.848***	-.133
	(.182)	(.222)	(.179)
BudgetSurpl/GDP	-.004**	-.007***	.005***
	(.002)	(.002)	(.001)
RiskPrem	-.079***	-.079***	.047***
	(.025)	(.014)	(.010)
HI	-.159	.097	-.226
	(.401)	(.421)	(.335)
HI2	.068	-.144	.237
	(.368)	(.387)	(.321)
RealDefExp	-.004***	-.003***	.005***
	(.001)	(.001)	(.001)
LogTotMktCap	.441***	.406***	.181***
	(.084)	(.049)	(.058)
Obs.	59094	53468	74059
χ^2 statistic	387.764	464.195	304.742

Table III, Panel C: Alternative Specifications for the Impact of Defense Expenditures on the Number of Citations per Patent: OLS Regressions and Clustering by Year

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects OLS model of $Ln(1+Citations/Patent)_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, R&D/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level in columns (1) and (2) and at the year level in columns (3) and (4) following Petersen (2009). Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-2.461***	-2.220***	-2.461***	-2.220***
	(.144)	(.146)	(.867)	(.704)
LnSales	.001	.0009	.001	.0009
	(.002)	(.002)	(.002)	(.002)
RD/TA	.110***	.135***	.110**	.135***
	(.042)	(.047)	(.050)	(.049)
Profitability	.013**	.015***	.013***	.015***
	(.005)	(.006)	(.004)	(.005)
Tangibility	.058***	.066***	.058***	.066***
	(.012)	(.012)	(.014)	(.014)
Cash	.013	.014	.013	.014
	(.013)	(.014)	(.014)	(.016)
Leverage	-.008	-.010	-.008*	-.010***
	(.006)	(.007)	(.005)	(.004)
HI	-.025	-.017	-.025*	-.017
	(.021)	(.022)	(.014)	(.014)
HI2	.005	-8.31e-06	.005	-8.31e-06
	(.007)	(.009)	(.004)	(.007)
LogRealGDP	-.406***	-.362***	-.406**	-.362**
	(.037)	(.040)	(.166)	(.178)
LogRealInv	-.118***	-.155***	-.118	-.155*
	(.016)	(.017)	(.087)	(.092)
BudgSurpl/GDP	-.0002***	-.0008***	-.0002	-.0008*
	(.00008)	(.00008)	(.0004)	(.0004)
RiskPrem	-.007***	-.010***	-.007*	-.010**
	(.0007)	(.0007)	(.004)	(.004)
RealDefExp	-.0005***	-.0004***	-.0005	-.0004
	(.0001)	(.0001)	(.0006)	(.0006)
LogTotMktCap	.063***	.062***	.063***	.062***
	(.004)	(.005)	(.018)	(.020)
Obs.	147901	133748	147901	133748
R^2	.509	.513	.509	.513

Table IVA:
The Impact of Defense Expenditures and Credit Ratings on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures, and its interaction with corporate credit ratings. Specifically we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP, *Crating1* , which is a dummy variable equal to 1 if a firm has a credit rating of B+ or higher, and zero if the credit rating is lower than B+, and the interaction term ExogDefenseExp*Crating1 in columns (1) and (2). In column (3) and (4) we use a log-linear OLS specification. In columns (5) and (6) we use instead Crating2, which is equal to 1 if a firm has a credit rating of BBB or higher (investment grade), and zero if the credit rating is below BBB (junk grade). Other controls include LnSales, RD/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)	(5)	(6)
ExogDefenseExp	-45.814***	-39.292***	-5.347***	-4.205***	-26.672***	-22.951***
	(6.290)	(5.721)	(1.162)	(1.135)	(3.906)	(2.704)
Crating	.287***	.230**	.018**	.014*		
	(.102)	(.102)	(.007)	(.008)		
ExogDefenseExp*Crating	27.172***	23.327***	1.600**	1.174**		
	(6.343)	(5.704)	(.686)	(.553)		
Crating2					.048	.030
					(.073)	(.073)
ExogDefenseExp*Crating2					8.734**	7.694**
					(4.436)	(3.316)
LnSales	-.034	-.026	.015***	.014***	-.037	-.028
	(.037)	(.035)	(.003)	(.003)	(.039)	(.037)
RD/TA	1.629***	1.640**	.655***	.674***	1.554**	1.591**
	(.602)	(.649)	(.167)	(.159)	(.615)	(.661)
Profitability	-.057	.285	.008	.093***	-.054	.296
	(.071)	(.252)	(.025)	(.034)	(.070)	(.253)
Tangibility	.564**	.447	.083***	.071***	.555**	.439
	(.228)	(.278)	(.022)	(.021)	(.228)	(.278)
Cash	.053	-.248	-.137***	-.151***	.008	-.290
	(.421)	(.337)	(.051)	(.052)	(.430)	(.341)
Leverage	-.199	-.081	-.059***	-.052***	-.210	-.090
	(.134)	(.138)	(.012)	(.011)	(.136)	(.138)
LogRealGDP	-2.516***	-1.390***	-.779***	-.489**	-2.549***	-1.416***
	(.467)	(.514)	(.191)	(.209)	(.483)	(.526)
LogRealInv	-.381**	-.737***	-.090	-.180**	-.374**	-.728***
	(.180)	(.196)	(.068)	(.073)	(.180)	(.197)
HI	-.085	-.015	-.033	-.023	-.027	.039
	(.538)	(.532)	(.024)	(.026)	(.543)	(.537)
HI2	-.051	-.109	.002	-.006	-.087	-.144
	(.474)	(.476)	(.007)	(.013)	(.479)	(.481)
LogTotMktCap	.342***	.196***	.098***	.065**	.347***	.199***
	(.065)	(.066)	(.028)	(.031)	(.065)	(.067)
Obs.	20178	18953	38965	36772	20178	18953
χ^2 statistic	428.045	455.596			405.468	463.829

Table IVB:
Defense Expenditures, Risk Premium, Profitability and Innovation

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures, and its interaction with corporate bond risk premiums and firm profitability. Specifically we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP, *RiskPrem* , which is the difference between the average Baa corporate bond rate and the 3-month T-bill rate, and the interaction term ExogDefenseExp*RiskPrem in columns (1) and (2). We estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogDefenseExp, Profitability (EBTDA/TA) and the interaction term ExogDefenseExp*Profitability in columns (3) and (4). Other controls include LnSales, RD/TA, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-.868	-.778	-16.512***	-20.227***
	(5.541)	(4.592)	(1.757)	(1.885)
RiskPrem	-.048***	-.020**		
	(.018)	(.009)		
Profitability	.046	.042	.051	.157
	(.060)	(.112)	(.064)	(.127)
ExogDefenseExp*RiskPrem	-5.606**	-7.835***		
	(2.340)	(1.327)		
ExogDefenseExp*Profitability			-4.513	13.023**
			(6.947)	(5.168)
LnSales	-.011	.003	-.011	.003
	(.029)	(.032)	(.028)	(.032)
RD/TA	.268	.055	.240	.195
	(.346)	(.470)	(.353)	(.463)
Tangibility	.361**	.441***	.373**	.440***
	(.156)	(.170)	(.155)	(.169)
Cash	.279*	.280*	.310**	.281*
	(.146)	(.162)	(.140)	(.162)
Leverage	-.0009	-.107	.002	-.102
	(.064)	(.105)	(.064)	(.103)
LogRealGDP	-2.948***	-1.021***	-3.352***	-1.985***
	(.343)	(.367)	(.414)	(.334)
LogRealInv	-.447***	-1.123***	-.050	-.656***
	(.166)	(.184)	(.139)	(.139)
LogTotMktCap	.422***	.254***	.372***	.243***
	(.063)	(.049)	(.052)	(.048)
Obs.	59094	53468	59094	53468
χ^2 statistic	498.245	626.413	426.682	594.27

Table V:
The Impact of Exogenous Changes in Tax Revenue on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in tax revenue (Romer and Romer, 2010). Specifically we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable RomerExogTax (columns 1 and 2), which measures the exogenous changes in tax revenue (Romer and Romer, 2010), and RomerExogDeficit, which measures exogenous changes in tax revenue due to decreasing the budget deficit. Other controls include LnSales, RD/TA, profitability, tangibility, cash, LnRealGDP (measuring GDP growth), LnRealInv (measuring the growth rate of real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
RomerExogTax	.886***	.499**		
	(.180)	(.244)		
RomerExogDeficit			.929***	.517***
			(.165)	(.195)
LnSales	-.008	-.001	-.015	-.006
	(.028)	(.031)	(.028)	(.032)
RD/TA	.295	.139	.260	.122
	(.348)	(.456)	(.352)	(.471)
Profitability	.054	.067	.061	.079
	(.060)	(.117)	(.063)	(.120)
Tangibility	.380**	.505***	.360**	.494***
	(.156)	(.171)	(.157)	(.171)
Cash	.364**	.400**	.353**	.395**
	(.144)	(.163)	(.146)	(.165)
Leverage	.017	-.036	.019	-.028
	(.058)	(.099)	(.056)	(.098)
LogRealGDP	-2.221***	-2.838***	-1.358***	-2.285***
	(.547)	(.613)	(.519)	(.552)
LogRealnv	-.372*	-.515*	-.777***	-.754***
	(.199)	(.269)	(.177)	(.228)
BudgSurpl/GDP	-.001	-.008***	-.0001	-.007***
	(.001)	(.002)	(.002)	(.002)
RiskPrem	-.017	-.058***	-.041**	-.070***
	(.024)	(.015)	(.021)	(.013)
HI	-.199	.054	-.296	.0002
	(.398)	(.434)	(.399)	(.433)
HI2	.126	-.107	.205	-.064
	(.365)	(.396)	(.366)	(.395)
RealDefExp	-.002**	-.002**	-.003**	-.002**
	(.001)	(.001)	(.001)	(.001)
LogTotMktCap	.272***	.409***	.242***	.383***
	(.068)	(.053)	(.067)	(.050)
Obs.	58028	53343	58028	53343
χ^2 statistic	308.204	453.609	291.324	450.557

Table VI:
The Impact of Exogenous Changes in Tax Revenue and Credit Ratings on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in tax revenue (Romer and Romer, 2010), and its interaction with corporate credit ratings. Specifically we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable RomerExogTax, which measures the exogenous changes in tax revenue (Romer and Romer, 2010), Crating, which is a dummy variable equal to 1 if a firm has a credit rating of B+ or higher, and zero if the credit rating is lower than B+, and the interaction term RomerExogTax*Crating1 in columns (1) and (2) and the interaction term RomerExogDeficit*Crating1 in columns (3) and (4). Other controls include LnSales, RD/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring the growth rate of real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
RomerExogTax	1.625***	1.129**		
	(.388)	(.492)		
RomerExogDeficit			2.355***	2.908***
			(.747)	(.845)
Crating1	.258**	.210*	.287**	.255**
	(.106)	(.107)	(.114)	(.106)
RomerExogTax*Crating1	-.892**	-.640		
	(.413)	(.532)		
RomerExogDeficit*Crating1			-1.527**	-1.767**
			(.776)	(.893)
LnSales	-.031	-.027	-.035	-.032
	(.036)	(.035)	(.035)	(.035)
RD/TA	1.805***	1.792***	1.742***	1.778***
	(.575)	(.627)	(.566)	(.618)
Profitability	-.064	.226	-.034	.330
	(.081)	(.250)	(.063)	(.247)
Tangibility	.547**	.509*	.528**	.462
	(.233)	(.283)	(.235)	(.283)
Cash	.170	-.178	.205	-.105
	(.392)	(.337)	(.392)	(.329)
Leverage	-.108	-.027	-.108	-.003
	(.133)	(.140)	(.133)	(.138)
LnRealGDP	-.574*	-.343	-.456	-.350
	(.333)	(.362)	(.332)	(.363)
LnRealInv	-.524***	-.805***	-.550***	-.752***
	(.180)	(.204)	(.181)	(.200)
Observations	19733	18910	19733	18910
χ^2 statistic	318.381	292.02	258.726	293.175

Table VII: The Impact of Exogenous Government Spending and Taxes on R&D Expenditures

This table reports the results relating R&D expenditures to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects model of $Ln(1{+}Citations/Patent)_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP, and on RomerExogDeficit, which measures the exogenous changes in tax revenue targeting the budget deficit only (Romer and Romer, 2010). Other controls include LnSales, profitability, tangibility, cash, LnRealGDP (measuring gdp growth), LnRealInv (measuring the growth rate of real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	RD/TA_{t+1}	RD/TA_{t+2}	RD/TA_{t+1}	RD/TA_{t+2}
	(1)	(2)	(3)	(4)
ExogDefenseExp	-.026	-.046**		
	(.018)	(.018)		
RomerExogDeficit			.007***	.010***
			(.002)	(.002)
LnSales	-.003***	-.003***	-.003***	-.003***
	(.0004)	(.0004)	(.0004)	(.0004)
Profitability	-.012***	-.006***	-.011***	-.006***
	(.003)	(.002)	(.003)	(.002)
Tangibility	.013***	.005**	.013***	.005**
	(.002)	(.002)	(.002)	(.002)
Cash	.016***	.013***	.016***	.014***
	(.003)	(.003)	(.003)	(.003)
Leverage	-.002	-.002	-.002	-.002
	(.002)	(.001)	(.002)	(.001)
LogRealGDP	.032***	.016***	.031***	.015***
	(.005)	(.005)	(.005)	(.005)
LogRealInv	-.014***	-.012***	-.014***	-.013***
	(.002)	(.002)	(.002)	(.002)
BudgSurpl/GDP	-2.26e-06	-.00004***	4.93e-06	-.00002*
	(1.00e-05)	(1.00e-05)	(1.00e-05)	(1.00e-05)
RiskPrem	-.0004***	-.0008***	-.0004***	-.0007***
	(.0001)	(.0001)	(.0001)	(.0001)
HI	-.007**	-.007**	-.008**	-.008**
	(.003)	(.003)	(.003)	(.003)
HI2	.002**	.002**	.003**	.003**
	(.001)	(.001)	(.001)	(.001)
RealDefExp	-.00006***	-.00003*	-.00006***	-.00002
	(.00002)	(.00002)	(.00002)	(.00002)
LogTotMktCap	.001***	.003***	.002***	.003***
	(.0005)	(.0005)	(.0006)	(.0006)
Obs.	175145	161722	170662	157566
R^2	.819	.823	.819	.823

Table VIII:
The Impact of Exogenous Defense Spending and Tax Changes on Abnormal Short-Term Government Borrowing

This table reports the results relating Exogenous Defense Spending and Tax Changes to short term government borrowing. Specifically we estimate a Newey-West model of AbnSTGovBor, which measures the abnormal level of short term (1 year) government borrowing on ExogDefenseExp (columns 1, 3 and 4), which is the present discounted value of exogenous changes in military expenditures divided by real GDP, and RomerExogDeficit (columns 2, 3 and 4), which measures the exogenous changes in tax revenue targeting the budget deficit only (Romer and Romer, 2010). The model controls for autocorrelation over time with one lag in columns (1) - (3) and 2 lags in column (4). Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% levels respectively.

	AbnSTGovBor	AbnSTGovBor	AbnSTGovBor	AbnSTGovBor
	(1)	(2)	(3)	(4)
ExogDefenseExp	2.352***		2.167***	2.167***
	(.804)		(.718)	(.718)
RomerExogDeficit		-.370***	-.346***	-.346***
		(.126)	(.122)	(.122)
LogRealInv	.135	.131	.107	.107
	(.146)	(.140)	(.138)	(.138)
LogRealGDP	-.295	-.294	-.216	-.216
	(.238)	(.238)	(.228)	(.228)
LogTotMktCap	-.034	-.033	-.043*	-.043*
	(.027)	(.026)	(.026)	(.026)
RiskPrem	-.005	-.004	-.004	-.004
	(.008)	(.008)	(.007)	(.007)
Obs.	57	57	57	57
F statistic	46.345	38.964	43.641	43.641

Table IX:
The Impact of Short-term Government Borrowing on the Number of Citations per Patent: Instrumental Variable Approach using Exogenous Defense Expenditures

This table reports the results relating the number of citations per patent to short term government borrowing, using exogenous changes in military expenditures as an instrument. In the first stage in Table VIII column (1), we regress abnormal short-term government borrowing on exogenous defense spending, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. We then estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable AbnSTGovBorPred. Other controls include LnSales, RD/TA, profitability, tangibility, cash, LnRealGDP (measuring gdp growth), LnRealInv (measuring the growth rate of real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
AbnSTGovBorPredExp	-8.903***	-9.741***		
	(.676)	(.819)		
AbnSTGovBorPredTax			-2.513***	-1.398***
			(.447)	(.526)
LnSales	-.012	.005	-.015	-.006
	(.029)	(.032)	(.028)	(.032)
RD/TA	.194	.073	.260	.122
	(.345)	(.451)	(.352)	(.471)
Profitability	.033	.044	.061	.079
	(.059)	(.113)	(.063)	(.120)
Tangibility	.367**	.427**	.360**	.494***
	(.158)	(.171)	(.157)	(.171)
Cash	.316**	.339**	.353**	.395**
	(.141)	(.162)	(.146)	(.165)
Leverage	.014	-.062	.019	-.028
	(.059)	(.100)	(.056)	(.098)
LogRealGDP	-5.258***	-5.521***	-2.096***	-2.696***
	(.640)	(.631)	(.486)	(.494)
LogRealInv	.544***	.611**	-.447***	-.570***
	(.195)	(.267)	(.167)	(.208)
BudgSurpl/GDP	-.005***	-.009***	-.0001	-.007***
	(.002)	(.002)	(.002)	(.002)
RiskPrem	-.130***	-.132***	-.051**	-.076***
	(.027)	(.014)	(.020)	(.013)
HI	-.081	.160	-.296	.0002
	(.394)	(.429)	(.399)	(.433)
HI2	.049	-.146	.205	-.064
	(.362)	(.389)	(.366)	(.395)
RealDefExp	-.009***	-.008***	-.003**	-.002**
	(.001)	(.001)	(.001)	(.001)
LogTotMktCap	.216**	.160***	.160**	.337***
	(.087)	(.052)	(.071)	(.056)
Obs.	59094	53468	58028	53343
χ^2 statistic	436.967	614.873	291.323	450.557

Table X:
The Impact of Defense Expenditures and Credit Ratings on Short-term and Long-term Corporate Debt

This table reports the results relating short term and long term corporate debt to exogenous changes in military expenditures, and its interaction with corporate credit ratings. Specifically we estimate a firm-fixed effects OLS model of *StCorpDebt* in column (1) and *LtCorpDebtit* in column (2) on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP, *Crating1*, which is a dummy variable equal to 1 if a firm has a credit rating of B+ or higher, and zero if the credit rating is lower than B+, and the interaction term ExogDefenseExp**Crating1*. Other controls include LnSales, profitability, tangibility, cash, LnRealGDP, and LnRealInv (measuring real aggregate investment). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	StCorpDebt	LtCorpDebt
	(1)	(2)
ExogDefenseExp	-.343***	.155
	(.122)	(.319)
Crating1	-.016***	-.024***
	(.001)	(.003)
ExogDefenseExp*Crating1	.315**	-.383
	(.129)	(.338)
LnSales	-.002***	.009***
	(.0004)	(.001)
Profitability	-.036***	-.072***
	(.003)	(.005)
Tangibility	-.003	.180***
	(.003)	(.008)
Cash	-.022***	-.177***
	(.004)	(.011)
LnRealGDP	.025***	-.063***
	(.005)	(.014)
LnRealInv	-.005	.083***
	(.003)	(.008)
Observations	39786	43379
R^2	.011	.046

Table XI: The Impact of Defense Expenditures on the Number of Citations per Patent for Firms in Industries Related to the Military and in Industries Dependent on Government Procurement

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures, and its interaction with military industry dummy (Columns 1 and 2), and its interaction with government industry procurement expenses (Columns 3 and 4). Specifically, in Columns 1 and 2 we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Time}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP, MilInd, which is a dummy variable equal to 1 if a firm has an industry SIC code related to the military (37, 97, 45 and 47), and the interaction term ExogDefenseExp*MilInd. In Columns 3 and 4, we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP, ProcExpDum, which is a dummy variable equal to 1 if an industry is receives above the median amount of government procurement expenses, and the interaction term ExogDefense-Exp*ProcExpDum. Other controls include LnSales, RD/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-14.931***	-17.711***	-17.253***	-14.344***
	(1.524)	(1.720)	(1.631)	(1.547)
ExogDefenseExp*MilInd	2.742	9.219**		
	(4.545)	(3.643)		
ProcExpDum			.532***	.311***
			(.050)	(.045)
ExogDefenseExp*ProcExpDum			-61.103***	-83.315***
			(10.735)	(8.196)
LnSales	.0005	.006	-.008	-.002
	(.027)	(.029)	(.028)	(.031)
RD/TA	.184	.116	.108	.089
	(.348)	(.449)	(.343)	(.397)
Profitability	-.003	.042	-.015	.028
	(.058)	(.105)	(.055)	(.101)
Tangibility	.404***	.418**	.424***	.444***
	(.149)	(.166)	(.149)	(.170)
Cash	.352***	.242	.292**	.269*
	(.136)	(.161)	(.137)	(.157)
Leverage	.020	-.112	.035	-.072
	(.056)	(.099)	(.052)	(.095)
LnRealGDP	-1.806***	-.862***	-3.095***	-1.790***
	(.292)	(.270)	(.319)	(.278)
LnRealInv	.118	-.605***	.704***	-.063
	(.149)	(.140)	(.141)	(.153)
Observations	60703	55042	60703	55042
χ^2 statistic	360.14	438.743	577.585	671.191

Internet Appendix B

Table B1:
The Impact of Defense Expenditures on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects Poisson model where the dependent variable is $Citations/Patent_{it}$, which, unlike Table IIIA, is the raw measure, not corrected for truncation. The main explanatory variable is ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, R&D/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+1}$	$\frac{Citations}{Patent}_{t+2}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-19.307***	-21.243***	-19.993***	-22.397***
	(1.259)	(1.234)	(1.155)	(1.277)
LnSales	.020	.006	-.011	-.016
	(.021)	(.019)	(.021)	(.020)
RD/TA	.875***	.892***	.761***	.431
	(.253)	(.267)	(.290)	(.301)
Profitability	.190**	.184**	.212**	.137**
	(.077)	(.074)	(.102)	(.059)
Tangibility	.787***	.679***	.526***	.581***
	(.151)	(.151)	(.151)	(.154)
Cash	.349***	.080	.240*	.095
	(.115)	(.122)	(.132)	(.146)
Leverage	-.318***	-.352***	-.108	-.348***
	(.107)	(.097)	(.204)	(.128)
LnRealGDP	1.592***	2.004***	2.287***	2.513***
	(.202)	(.205)	(.213)	(.221)
LnRealInv	-1.894***	-2.450***	-2.921***	-3.346***
	(.105)	(.110)	(.114)	(.117)
Observations	68547	65277	61812	58125
χ^2 statistic	1132.172	1749.373	2323.47	2925.134

Table B2:
The Impact of Defense Expenditures on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects Poisson model where the dependent variable is $Citations/Patent_{it}^{Time}$, which, unlike Table IIIA, is corrected for truncation using the fixed-effects approach and compares patents only to other patents in the same year. The main explanatory variable is ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, R&D/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+1}$	$\frac{Citations}{Patent}_{t+2}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-11.191***	-14.605***	-15.783***	-20.026***
	(1.379)	(1.488)	(1.506)	(1.246)
LnSales	.010	.004	-.013	-.0002
	(.022)	(.022)	(.024)	(.025)
RD/TA	.652***	.732***	.625**	.420
	(.229)	(.249)	(.273)	(.300)
Profitability	.127**	.119**	.166**	.126**
	(.054)	(.055)	(.076)	(.062)
Tangibility	.611***	.570***	.487***	.519***
	(.140)	(.141)	(.145)	(.154)
Cash	.391***	.222*	.371***	.305**
	(.110)	(.120)	(.132)	(.144)
Leverage	-.182*	-.225**	-.019	-.269**
	(.108)	(.100)	(.124)	(.111)
LnRealGDP	-.525**	-.942***	-1.251***	-1.316***
	(.209)	(.238)	(.254)	(.259)
LnRealInv	-.407***	-.411***	-.455***	-.728***
	(.104)	(.111)	(.119)	(.132)
Observations	68547	65277	61812	58125
χ^2 statistic	285.721	451.123	568.729	883.879

Table B3:
The Impact of Defense Expenditures on the Number of Citations per Patent

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures. Specifically we estimate a firm-fixed effects Poisson model where the dependent variable is $Citations/Patent_{it}^{Time-Tech}$, which, unlike Table IIIA, is corrected for truncation using the fixed-effects approach and compares patents only to other patents in the same year and technology class. The main explanatory variable is ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, R&D/TA, profitability, tangibility, cash, LnRealGDP, LnRealInv (measuring real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+1}$	$\frac{Citations}{Patent}_{t+2}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-10.454***	-14.038***	-16.616***	-19.268***
	(1.335)	(1.463)	(1.536)	(1.154)
LnSales	.004	-.003	-.017	.0009
	(.024)	(.022)	(.024)	(.025)
RD/TA	.637***	.838***	.700***	.469*
	(.221)	(.233)	(.271)	(.282)
Profitability	.130**	.132**	.175**	.144**
	(.054)	(.060)	(.074)	(.066)
Tangibility	.672***	.617***	.592***	.570***
	(.140)	(.140)	(.141)	(.148)
Cash	.286**	.188	.353**	.317**
	(.115)	(.127)	(.137)	(.144)
Leverage	-.170	-.224**	-.068	-.276***
	(.107)	(.101)	(.163)	(.104)
LnRealGDP	-.464**	-.816***	-1.060***	-1.001***
	(.202)	(.231)	(.243)	(.249)
LnRealInv	-.300***	-.349***	-.450***	-.826***
	(.101)	(.107)	(.114)	(.129)
Observations	68547	65277	61812	58125
χ^2 statistic	241.121	426.53	554.155	881.815

Table B4:
The Impact of Defense Expenditures on the Number of Citations per Patent: Innovative Firms Only

This table reports the results relating the number of citations per patent to exogenous changes in military expenditures for innovative firms only. Innovative firms, unlike the definition in Table IIIB, are those that have at least one patent in a given year. Specifically we estimate a firm-fixed effects Poisson model of $Citations/Patent_{it}^{Quasi}$ on a variable ExogDefenseExp, which is the present discounted value of exogenous changes in military expenditures divided by real GDP. Other controls include LnSales, lnrd, profitability, tangibility, cash, LnRealGDP (measuring gdp growth), LnRealInv (measuring the growth rate of real aggregate investment), and leverage (equal to total debt divided by total assets). All regressions are estimated with firm fixed effects, and the standard errors reported in the parentheses are corrected for the panel in all the models and are clustered at the firm level. Data is for the period 1950 to 2009. ***, ** and * denote significance at 1%, 5% and 10% respectively.

	$\frac{Citations}{Patent}_{t+1}$	$\frac{Citations}{Patent}_{t+2}$	$\frac{Citations}{Patent}_{t+3}$	$\frac{Citations}{Patent}_{t+4}$
	(1)	(2)	(3)	(4)
ExogDefenseExp	-6.974***	-10.753***	-12.232***	-14.081***
	(1.310)	(1.654)	(1.876)	(1.254)
LnSales	-.081***	-.064***	-.074***	-.059*
	(.023)	(.024)	(.026)	(.031)
RD/TA	-.044	.546**	.585*	.695**
	(.243)	(.243)	(.304)	(.317)
Profitability	.007	.149	.273***	.266**
	(.081)	(.093)	(.088)	(.123)
Tangibility	.294**	.343**	.396***	.396**
	(.143)	(.140)	(.148)	(.173)
Cash	.182	.226*	.184	.111
	(.116)	(.123)	(.130)	(.158)
Leverage	-.063	-.077**	.077	.007
	(.049)	(.038)	(.048)	(.105)
LnRealGDP	-.388*	-.889***	-1.119***	-1.209***
	(.205)	(.250)	(.265)	(.262)
LnRealInv	-.233**	-.176*	-.184	-.287**
	(.099)	(.106)	(.112)	(.132)
Observations	28906	27033	24934	22758
χ^2 statistic	217.145	329.816	450.47	482.343