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Emi Nakamura
Jón Steinsson

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ABSTRACT

We use rich historical data on military procurement spending across U.S. regions to estimate the effects of government spending in a monetary union. Aggregate military build-ups and draw-downs have differential effects across regions. We use this variation to estimate an "open economy relative multiplier" of approximately 1.5. We develop a framework for interpreting this estimate and relating it to estimates of the standard closed economy aggregate multiplier. The closed economy aggregate multiplier is highly sensitive to how strongly aggregate monetary and tax policy "leans against the wind." In contrast, our estimate "differences out" these effects because different regions in the union share a common monetary and tax policy. Our estimate provides evidence in favor of models in which demand shocks can have large effects on output.

Emi Nakamura
Columbia Business School
3022 Broadway, Uris Hall 820
New York, NY 10027
and NBER
enakamura@columbia.edu

Jón Steinsson
Department of Economics
Columbia University
1026 International Affairs Building
420 West 118th Street
New York, NY 10027
and NBER
jsteinsson@columbia.edu

1 Introduction

The effect of government spending on output is often summarized by a multiplier—the percentage increase in output that results when government spending is increased by 1% of GDP. There is a wide range of views about this statistic in the literature. On the one hand, the recent American Recovery and Reinvestment Act (ARRA)—perhaps the largest fiscal stimulus plan in U.S. history—was motivated by a relatively high estimate of the multiplier of 1.6 (Romer and Bernstein, 2009). Other studies argue that the multiplier is substantially smaller and potentially close to zero. In particular, if the determination of output is dominated by supply-side factors, an increase in government purchases to a large extent "crowds out" private sector consumption and investment.

The wide range of views on the multiplier arises in part from the difficulty of measuring it. Changes in government spending are rarely exogenous, leading to a range of estimates depending on the estimation approach.[1] Two main approaches have been used to estimate the multiplier in the academic literature. The first is to study the output effects of increases in military spending associated with wars, which are plausibly unrelated to prevailing macroeconomic conditions (Ramey and Shapiro, 1998; Edelberg, Eichenbaum and Fisher, 1999; Burnside, Eichenbaum and Fisher, 2004; Ramey, 2010; Barro and Redlick, 2011; Fisher and Peters, 2010). This approach faces the challenge that large wars are relatively infrequent. Another challenge is confounding variation associated with tax increases, price controls, patriotism, and other macroeconomic shocks.[2] The second main approach used to identify the multiplier is the structural VAR approach (Blanchard and Perotti, 2002; Perotti, 2007; Mountford and Uhlig, 2008; Ilzetzki, Mendoza and Vegh, 2010). This approach relies on structural assumptions about output and fiscal policy dynamics to estimate the multiplier.

The wide range of views on the multiplier also results from a lack of clear predictions in the theoretical literature. The government spending multiplier is not a deep structural parameter like the elasticity of labor supply or the intertemporal elasticity of substitution. Different models, therefore, differ in their implications about the multiplier depending on what is assumed about preferences, technology, government policy and various "frictions." Simple versions of the Neoclassical model generally imply a small multiplier, typically smaller than 0.5 (see, e.g., Baxter and King, 1993). The multiplier is sensitive to how the spending is financed—smaller if it is financed by distortionary taxes

[1]For surveys of the existing evidence, see for example Perotti (2007), Hall (2009), Alesina and Ardagna (2009) and Cogan et al. (2010).

[2]Most of the evidence from this approach derives from the U.S. experience during WWII and the Korean War, when changes in U.S. military spending were largest and most abrupt as a fraction of total output. Hall (2009) and Barro and Redlick (2011) emphasize that it is not possible to draw meaningful inference using aggregate data on military spending after 1955 because there is insufficient variation in military spending in this period.

than lump sum taxes.[3] In New Keynesian models, the size of the multiplier depends critically on the extent to which monetary policy "leans against the wind." Strongly counter-cyclical monetary policy—such as that commonly estimated for the Volcker-Greenspan period—can generate quite low multipliers—comparable to those for the Neoclassical model. However, when monetary policy is less responsive—e.g., at the zero lower bound—the multiplier can exceed two.[4] Clearly, there is no "single" government spending multiplier. All estimates of the government spending multiplier depend on the policy regime in place. This is likely one contributing factor for the wide range of empirical estimates of the multiplier discussed above.

We analyze the effects of government spending in a monetary and fiscal union—the United States. In this setting, we estimate the effect that an increase in government spending in one region of the union relative to another has on relative output and employment. We refer to this as the "open economy relative multiplier." Studying a monetary union has the unique advantage that the relative monetary policy is precisely pinned down by the fact that the nominal interest rate is common across different regions (and the exchange rate fixed across regions). This implies that increased spending in one region relative to another cannot lead to tighter monetary policy in that region relative to the other. Also, federal spending is financed by federal taxes levied in the same way across regions. An increase in federal spending in one region relative another, therefore, does not increase current or future tax rates in that region relative to other regions. We show that an important advantage of the open economy relative multiplier that arises from being able to precisely specify relative policy across regions, is that we can more easily distinguish between different models of how government spending affects the economy.

We use regional variation in military spending to estimate the multiplier. Military spending is notoriously political and thus likely to be endogenous to regional economic conditions (see, e.g., Mintz, 1992). We use an instrumental variables approach to identify an exogenous component of regional variation in military spending. Our instruments are based on two characteristics of military spending. First, national military spending is dominated by geopolitical events. Second, when national military spending rises by 1 percentage point of GDP, it rises on average by more than 3 percentage points in states that receive a disproportionate amount of military spending—such as California and Connecticut—but by less than one-half of one percent in states that don't—

[3]See, e.g., Baxter and King (1993), Ohanian (1997), Corsetti et al., 2009, and Drautzburg and Uhlig (2011).

[4]Intuitively, at the zero lower bound, monetary policy is rendered impotent and a fiscal expansion is particularly effective since it lowers real interest rates by raising inflation (Eggertsson, 2010; Christiano, Eichenbaum, and Rebelo, 2011).

such as Illinois. We use this heterogeneity in the response of regional spending to national military build-ups and draw-downs to identify the effects of government spending on output. Our identifying assumption is that the U.S. does not embark on military buildups—such as those associated with the Vietnam war and the Soviet invasion of Afghanistan—because states that receive a disproportionate amount of military spending are doing poorly relative to other states. This assumption is similar—but weaker than—the common identifying assumption in the empirical literature on the effects of national military spending, that variation in national military spending is exogenous to the U.S. business cycle. By including time fixed effects, we control for aggregate shocks and policy that affect all states at a particular point in time—such as changes in distortionary taxes and aggregate monetary policy.[5]

We estimate the "open economy relative multiplier" to be roughly 1.5. In other words, when relative per-capita government purchases in a region rises by 1% of regional output, relative per-capita output in that region rises by roughly 1.5%. This open economy relative multiplier differs from the "closed economy aggregate multiplier" one might estimate using aggregate U.S. data. We develop a theoretical framework to help us interpret our multiplier estimate and assess how it relates to the closed economy aggregate multiplier for the United States. Our main conclusion is that our estimate favors models in which demand shocks can have large effects on output. Our estimate lines up well with the multiplier implied by an open economy New Keynesian model in which consumption and labor are complements.[6] The "plain-vanilla" Neoclassical model, however, yields a substantially lower open economy relative multiplier.

We show that in the New Keynesian model, the open economy relative multiplier is larger than the closed economy aggregate multiplier if monetary policy is of the type seen in the U.S. in recent decades (under Volcker and Greenspan). The reason is that the relative monetary policy across regions—fixed relative nominal rate and exchange rate—is more accommodative than "normal" monetary policy in the U.S.—which raises the real interest rate substantially in response to inflationary shocks such as government spending shocks. Our open economy relative multiplier is thus akin to a closed economy aggregate multiplier for a more accommodative monetary policy than the

[5]Since regional variation in military procurement is much larger than aggregate variation, this approach allows us to overturn the conclusion from the literature that focuses on aggregate data that little can be learned about fiscal multipliers from the post-1960 data. Data from this period may be more informative about the size of the fiscal multiplier for "normal times" and "normal purchases" than data from WWII and the Korean war. Several authors suggest that the multiplier may be different for military versus non-military spending, but these findings rely heavily on the WWII and Korean War experiences when variation in military spending was associated with price controls, rationing, patriotism and large changes in taxes (e.g., Perotti 2007; Auerbach and Gorodnichenko, 2010).

[6]Another potential approach to matching our multiplier estimate would be to consider a model with "hand-to-mouth" consumers as in Gali, Lopez-Salido, and Valles (2007).

one seen in the U.S. under Volcker and Greenspan. The New Keynesian model, therefore, implies that our estimate of 1.5 for the open economy relative multiplier is perfectly consistent with much lower existing estimates of the closed economy aggregate multiplier (e.g., those of Barro and Redlick, 2011).

Since the nominal interest rate is fixed across regions in our setting, one might think that our open economy relative multiplier would be akin to the closed economy aggregate multiplier when nominal interest rates are fixed at the zero lower bound, in which case the New Keynesian model generates large multipliers (Eggertsson, 2010; Christiano, Eichenbaum and Rebelo, 2011). We show that this is not the case. This simple intuition ignores a crucial dynamic aspect of price responses in a monetary union. Since transitory demand shocks do not lead to permanent changes in relative prices across regions and the exchange rate is fixed within the monetary union, any increase in prices in the short run in one region relative to the other must eventually be reversed in the long run. This implies that even though relative short-term real interest rates fall in response to government spending shocks in our model, relative *long-term* real interest rates don't (in contrast to the zero lower bound setting). It is the fall in long-term real interest rates that generates a high multiplier in the zero lower bound setting. The absence of such a fall in our setting explains why the open economy relative multiplier generated by the New Keynesian model is much lower than the closed economy aggregate multiplier at the zero lower bound.

The intuition for why the open economy relative multiplier is larger than the closed economy aggregate multiplier for normal monetary policy is similar to the intuition for why the government spending multiplier is larger under a fixed than a flexible exchange rate in the Mundell-Fleming model. In fact, we show that the open economy relative multiplier is exactly the same as the aggregate multiplier in a small open economy with a fixed exchange rate. Our estimate can, therefore, be compared with other estimates of multipliers in open economies with fixed exchange rates. Based on data from 44 countries, Ilzetzki, Mendoza, and Vegh (2010) estimate a multiplier of 1.5 for countries that operate a fixed exchange rate regime, but a much lower multiplier for countries operating a flexible exchange rate regime.[7]

An important difference between our open economy relative multiplier and the closed economy aggregate multiplier is that the regions that receive spending don't have to pay for it. Could this perhaps explain the "large" relative multiplier we estimate? In the Neoclassical model, negative

[7] Kraay (2011) estimates a government spending multiplier of about 0.5 for 29 aid-dependent developing countries using variation in World Bank lending.

wealth effects actually *raise* the fiscal multiplier (since leisure is a normal good). The absence of this effect in our setting, thus, lowers the open economy relative multiplier. Moreover, in our setting, agents are getting paid to produce goods and services that are used for defense of the union as a whole. If labor and product markets were competitive, they would be indifferent at the margin as to whether they get more or less such work. Our open economy relative multiplier is, therefore, quite different from a "windfall" or "manna from heaven" multiplier. The model we develop captures these features.

The theoretical framework we describe helps to interpret recent and ongoing research on the effects of other forms of local government spending (Acconcia et al., 2011; Chodorow-Reich et al., 2011; Clemens and Miran, 2010; Cohen et al., 2010; Fishback and Kachanovskaya, 2010; Serrato and Wingender, 2010; Shoag, 2010; Wilson, 2011). In general, these studies appear to estimate open economy relative multipliers of a similar magnitude as we do. There are, however, a few potentially important differences between our study and these. Some of these studies focus on windfall transfers rather than purchases. One advantage of our focus on military purchases is that it seems reasonable to assume that they are separable from other forms of consumption, as is typically assumed in macroeconomic models.

Our empirical approach builds on previous work by Davis, Loungani, and Mahidhara (1997), who study several drivers of regional economic fluctuations, including military procurement.[8] Several other studies on the impact of regional defense spending are surveyed in Braddon (1995). The most important difference in our empirical methodology relative to these studies is our use of variation in aggregate military spending in creating instruments to account for potential endogeneity of local procurement spending. Our work is also related to Canova and Pappa (2007), who study the price effects of fiscal shocks in a monetary union. Our theoretical analysis is related to earlier work on monetary and fiscal policy in a monetary union by Benigno and Benigno (2003) and Gali and Monacelli (2008).

The remainder of the paper is organized as follows. Section 2 described the data we use. Section 3 presents our empirical results. Section 4 presents the model we use to interpret these empirical results. Section 5 presents our theoretical results. Section 6 concludes.

[8]Similarly, Hooker and Knetter (1997) estimate the effects of military procurement on subsequent employment growth using a somewhat different specification.

2 Data

Relative to other forms of federal government spending, the geographical distribution of military spending is remarkably well documented, perhaps because of the intense political scrutiny surrounding these purchases. Our main source for military spending data is the electronic database of DD-350 military procurement forms available from the US Department of Defense. These forms document military purchases of everything from repairs of military facilities to the purchase of aircraft carriers. They cover purchases greater than $10,000 up to 1983 and greater than $25,000 thereafter.[9] These data are for the federal government fiscal year.[10] We have used the DD-350 database to compile data on total military procurement by state and year for 1966-2006.[11]

The DD-350 forms list prime contractors and provide information on the location where the majority of the work was performed. An important concern is the extent of inter-state subcontracting. To help assess the extent of such subcontracting, we have compiled a new dataset on shipments to the government from defense oriented industries. The source of these data are the *Annual Survey of Shipments by Defense-Oriented Industries* conducted by the US Census Bureau from 1963 through 1983. In section 3.2, we compare variation in procurement spending with these shipments data.

Our primary measure of state output is the GDP by state measure constructed by the U.S. Bureau of Economic Analysis (BEA), which is available since 1963. We also make use of analogous data by major SIC/NAICS grouping.[12] We use the Bureau of Labor Statistics (BLS) payroll survey from the Current Employment Statistics (CES) program to measure state-level employment. We also present results for the BEA measure of state employment which is available since 1969. We obtain state population data from the Census Bureau.[13]

Finally, to analyze price effects, we construct state and regional inflation measures from several sources. Before 1995, we rely on state-level inflation series constructed by Marco Del Negro (1998)

[9] Purchases reported on DD-350 forms account for 90% of military purchases. DD-1057 forms are used to summarize smaller transactions but do not give the identity of individual sellers. Our analysis of census shipment data in section 3 suggests DD-350 purchases account for almost all of the time-series variation in total military procurement.

[10] Since 1976, this has been from October 1st to September 30th. Prior to 1976, it was from July 1st to June 30th.

[11] The electronic military prime contract data file was created in the mid-1960's and records individual military prime contracts since 1966. This occurred around the time Robert McNamara was making sweeping changes to the procurement process of the U.S. Department of Defense. Aggregate statistics before this point do not appear to be a reliable source of information on military purchases since large discrepancies arise between actual outlays and procurement for the earlier period, particularly at the time of the Korean war. See the Department of Defense *Greenbook* for aggregate historical series of procurement and outlays.

[12] The data are organized by SIC code before 1997 and NAICS code after 1997. BEA publishes the data for both systems in 1997, allowing the growth rate series to be smoothly pasted together.

[13] Between census years, population is estimated using a variety of administrative data sources including birth and death records, IRS data, Medicare data and data from the Department of Defense. Since 1970, we are also able to obtain population by age group, which allows us to construct estimates of the working age population.

for the period 1969-1995 using a combination of BLS regional inflation data and cost of living estimates from the American Chamber of Commerce Realtors Association (ACCRA).[14] After 1995, we construct state-level price indexes by multiplying a population-weighted average of cost of living indexes from the American Chamber of Commerce Realtors Association (ACCRA) for each region with the US aggregate Consumer Price Index. Reliable annual consumption data are unfortunately not available at the state level for most of the time period or regions we consider.[15]

3 Measurement of the Open Economy Relative Multiplier

3.1 Empirical Specification and Identification

We use variation in military procurement spending across states and regions to identify the effects of government spending on output. Our empirical specification is

$$\frac{Y_{it} - Y_{it-2}}{Y_{it-2}} = \alpha_i + \gamma_t + \beta \frac{G_{it} - G_{it-2}}{Y_{it-2}} + \epsilon_{it}, \quad (1)$$

where Y_{it} is per-capita output in region i in year t, G_{it} is per-capita military procurement spending in region i in year t, and α_i and γ_t represent state and year fixed effects.[16] The inclusion of state fixed effects implies that we are allowing for state specific time trends in output and military procurement spending. The inclusion of time fixed effects allows us to control for aggregate shocks and aggregate policy—such as changes in distortionary taxes and aggregate monetary policy. All variables in the regression are measured in per capita terms. We run the regression on biannual data, as a crude way of capturing dynamics in the relationship between government spending and output.[17] We use panel data on state and regional output and spending for 1966-2006. The regional data are constructed by aggregating state-level data within Census divisions. We make one adjustment to the Census divisions. This is to divide the "South Atlantic" division into two parts because of its large size.[18]

[14] See Appendix A of Del Negro (1998) for the details of this procedure.

[15] Retail sales estimates from *Sales and Marketing Management Survey of Buying Power* have sometimes been used as a proxy for state-level annual consumption. However, these data are constructed by using employment data to impute retail sales between census years, rendering them inappropriate for our purposes. Fishback, Horrace, and Kantor (2004) study the longer run effects of New Deal spending on retail sales using Census data.

[16] We deflate both regional output and military procurement spending using the national CPI for the United States.

[17] An alternative approach would be to run the regression on annual data and include lags (and possibly also leads) of government spending on the right hand side. We have explored this and found that our biannual regression captures the bulk of the dynamics in a parsimonious way. We find small positive coefficients on further leads and lags. This suggests that we are likely slightly underestimating the multiplier.

[18] We place Delaware, Maryland, Washington DC, Virginia and West Virginia in one region, and North Carolina, South Carolina, Georgia and Florida in the other.

This yields ten regions made up of contiguous states. Our interest focuses on the coefficient β in regression (1), which we refer to as the "open economy relative multiplier."

An important challenge to identifying the effect of government spending is that government spending is potentially endogenous since military spending is notoriously political.[19] We therefore estimate equation (1) using an instrumental variables approach. Our instruments are based on two characteristics of the evolution of military spending. Figure 1 plots the evolution of military procurement spending relative to output for California and Illinois as well as for the U.S. as a whole. First, notice that most of the variation in national military spending is driven by geopolitical events—such as the Vietnam war, Soviet invasion of Afghanistan and 9/11. Second, it is clear from the figure that military spending in California is systematically more sensitive to movements in national military spending than military spending in Illinois. The 1966-1971 Vietnam war draw-down illustrates this. Over this period, military procurement in California fell by 2.5 percentage points (almost twice the national average), while military procurement in Illinois fell by only about 1 percentage point (about 2/3 the national average). We use this variation in the sensitivity of military spending across regions to national military build-ups and draw-downs to identify the effects of government spending shocks. Our identifying assumption is that the U.S. does not embark on a military build-up because states that receive a disproportionate amount of military spending are doing poorly relative to other states. This assumption is similar—but weaker than—the common identifying assumption in the empirical literature on the effects of national military spending, that variation in national military spending is exogenous to the U.S. business cycle.

We employ two separate approaches to constructing instruments that capture the differential sensitivity of military spending across regions to national military build-ups and draw-downs. Our baseline approach is to instrument for state or region military procurement using total national procurement interacted with a state or region dummy. The "first stage" in the two-stage least squares interpretation of this procedure is to regress state spending on aggregate spending and fixed effects allowing for different sensitivities across different states. This yields scaled versions of national spending as fitted values for each state. Table 1 lists the states for which state procurement spending is most sensitive to variation in national procurement spending. We also employ a simpler "Bartik" approach to constructing instruments (Bartik, 1991). In this case, we scale national spending for each state by the average level of spending in that state relative to state output in the first five

[19]See Mintz (1992) for a discussion of political issues related to the allocation of military procurement spending.

years of our sample.[20]

We estimate the effects of military spending on employment and inflation using an analogous approach. For employment, the regression is analogous to equation (1) except that the left-hand side variable is $(L_{it} - L_{it-2})/L_{it-2}$—where L_{it} is the employment rate (employment divided by population). For the inflation regression, the left-hand side variable is $(P_{it} - P_{it-2})/P_{it-2}$, where P_{it} is the price level.

U.S. states and regions are much more open economies than the U.S. as a whole. Using data from the U.S. Commodity Flow Survey and National Income and Product Accounts, we estimate that roughly 30% of the consumption basket of the typical region we use in our analysis is imported from other regions (see section 4.4 for details). Even though a large majority of goods are imported, the overall level of openness of U.S. regions is not higher than 30% because services account for a large fraction of output and are much more local. This estimate suggests that our regions are comparable in openness to mid-sized European countries such as Spain or Portugal.

3.2 Subcontracting of Prime Military Contracts

An important question with regard to the use of prime military contract data is to what extent the interpretation of these data might be affected by subcontracting to firms in other states. Fortunately, a second source of data exists on actual shipments to the government from defense oriented industries. These data were gathered by the Census Bureau over the period 1963-1983 as an appendage to the Annual Survey of Manufacturers. They have rarely been used, perhaps because no electronic version has existed. We digitized these data from microfilm.

Figure 2 illustrates the close relationship between these shipment data and the military procurement data for several states over this period—giving us confidence in the prime military contract data as a measure of the timing and magnitude of regional military production. To summarize this relationship, we estimate the following regression of shipments from a particular state on military procurement,

$$MS_{it} = \alpha_i + \beta MPS_{it} + \epsilon_{it}, \qquad (2)$$

where MS_t is the value of shipments from the Census Bureau data and MPS_{it} is military procurement spending. This regression yields a point estimate of $\beta = 0.96$, indicating that military

[20] Nekarda and Ramey (2011) use a similar approach to instrument for government purchases from particular industries. They use data at 5 year intervals to estimate the share of aggregate government spending from different industries.

procurement moves on average one-for-one with the value of shipments. The small differences between the two series probably indicates that they both measure regional production with some error. As we discuss below, one advantage of the instrumental variables approach we adopt is that it helps adjust for this type of measurement error.

3.3 Effects of Government Spending Shocks

The first row of Table 2 reports the open economy relative multiplier β in regression (1) for our baseline instruments. Standard errors are in parentheses and are clustered by regions or states.[21] In the second row of Table 2, we present an analogous set of results using a broader measure of military spending that combines military procurement spending with compensation of military employees for each state or region. We present results for output both deflated by national CPI and our measure of state CPI.

The point estimates of β for the output regression range from 1.4 to 1.9, while the point estimates of β for the employment regression range from 1.3 to 1.8. The estimates using regional data are, in general, slightly larger than those based on state data, though the differences are small and statistically insignificant. The point estimates of the effects of military spending on consumer prices are statistically insignificantly different from zero, ranging from small positive to small negative numbers.

These results control for short-term movements in population associated with government spending by running the regressions on per-capita variables. The last column of Table 2 looks directly at population movements by estimating an analogous specification to equation (1) where the left-hand side variable is $(Pop_{it} - Pop_{it-2})/Pop_{it-2}$ and the right-hand side government spending variable is constructed from the level of government spending and output rather than per-capita government spending and output. We find that the population responses to government spending shocks are small and cannot be distinguished from zero for the two year time horizon we consider.[22]

Figure 3 gives a visual representation of our main specification for output. The figure plots averages of changes in output against predicted military spending (based on our first-stage regression), grouped by 30 quantiles of the predicted military spending variable. Both variables are demeaned by year and state fixed effects. The vast majority of points in the figure are located in the NE and

[21] Our standard errors thus allow for arbitrary correlation over time in the error term for a given state. They also allow for heteroskedasticity.

[22] Our estimates appear consistent with existing estimates of regional population dynamics. Blanchard and Katz (1992) show that population dynamics are important in determining the dynamics of unemployment over longer horizons.

SW quadrants, leading to a positive coefficient in our IV regression. To assess the robustness of our results to outliers, we have experimented with dropping states and regions with especially large or small estimated sensitivity of spending to national spending and this slightly raises the estimated multiplier.[23]

In Table 3, we report results for the simpler "Bartik" approach to constructing instruments. For output, this approach yields a multiplier of roughly 2.5 for the states and 2.8 for the regions. For employment, this approach also yields larger multipliers than our baseline specification—1.8 for states and 2.5 for regions. Our estimates using the Bartik instruments are somewhat less precise than those using our baseline instruments. This arises because in constructing this instrument, we use the level of spending in each state as a proxy for the sensitivity of state spending to national spending—but it is an imperfect proxy.

Table 3 also reports a number of alternative specifications for the effects of military procurement on output and employment designed to evaluate the robustness of our results. We report the output multiplier when per-capita output is constructed using a measure of the working age population as opposed to the total population.[24] We add the price of oil interacted with state dummies as controls to our baseline regression. We add the real interest rate interacted with state dummies as controls to our baseline regression. We estimate the employment regression using the BEA's employment series (available from 1969) instead of BLS payroll employment. Table 3 shows that these specifications all yield similar results to our baseline estimates.

We have extensively investigated the small-sample properties of our estimation approach using Monte Carlo simulations. These simulations indicate that neither the regional regressions nor the regressions using the Bartik instruments suffer from bias associated with weak or many instruments. However, our estimates of the state regressions using our baseline instruments are likely to be conservative in the sense of underestimating the fiscal multiplier for states by roughly 10% (implying that the true state-level multiplier is 1.65 rather than 1.43). Intuitively, this downward bias arises because instrumental variables does not fully correct for endogeneity in small samples when instruments are weak or when many instruments are used—i.e., IV is biased in the direction of OLS.[25]

[23]MO and CT have substantially higher estimated sensitivity of spending to national spending than other states and ND has a substantially negative estimated sensitivity (alone among the states). Dropping any combination of these states from our baseline regression slightly raises the our multiplier estimate. Dropping all three yields 1.88 (0.57).

[24]State-level measures of population by age-group are available from the Census Bureau starting in 1970. We define the working age population as the population between the ages of 19 and 64.

[25]See Stock, Wright, and Yogo (2002) for an overview of this issue. The concern is that the first-stage of the IV procedure may pick up some of the endogenous variation in the explanatory variable in the presence of a large number of instruments. In contrast to the canonical examples discussed in Stock, Wright, and Yogo (2002), this

Table 3 also reports results using the LIML estimator, which is not affected by the presence of many instruments. This yields an output multiplier of roughly 2.0.[26] Our Monte Carlo simulation also allows us to assess the small sample properties of the standard errors we report. Our simulations imply that the asymptotic standard errors for the region regressions are slightly smaller than their small-sample counterparts: the standard 95% confidence interval based on the standard errors reported in Table 2 is in fact a 90% confidence interval. This adjustment arises from the well-known small-sample bias in clustered standard errors in the presence of a small number of clusters. This does not apply to the state-level regressions for which the asymptotic standard errors almost exactly replicate the small sample results from our simulations.

A potential concern with interpreting our results would arise if states receiving large amounts of military spending were more cyclically sensitive than other states. We have compared the cyclical sensitivity of state that receive large and small amounts of military spending. The standard deviation of output growth is the same for states and regions with above-median military spending as below median (4.7% for regions and 6.1% for states), indicating that a difference in overall cyclical sensitivity is not driving our results.[27]

Ramey (2011) argues that news about military spending leads actual spending by several quarters and that this has important implications for the estimation of fiscal multipliers. When we add future spending as a regressor in regression (1), the coefficient on this variable is positive and the sum of the coefficients on the government spending rises somewhat. This suggests that our baseline specification somewhat underestimates the multiplier by ignoring output effects associated with anticipated future spending.

Table 3 also presents OLS estimates of our baseline specification for output. The OLS estimates

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actually biases us *away* from finding a statistically significant result in small samples, since the OLS estimates in our case are close to zero. Our Monte Carlo analysis is roughly consistent with the asymptotic results reported in Stock and Yogo (2005). The partial R-squared of the excluded instruments, a statistic frequently used to gauge the "strength" of instruments is 12% for the state regressions and 18% for the region regressions. However, because we use a large number of instruments in our baseline case—one for each state or region—the Cragg-Donald (1993) first stage F-statistic suggested by Stock and Yogo (2005) is roughly 5 for our baseline specification of the state-level regressions and 8 for the region-level regressions. It is 48 for the simpler Bartik instrument specification. Our Monte Carlo analysis indicates that while the large number of instruments in the state-level specification leads to a slight downward-bias in the coefficient on government spending, the standard error on this coefficient is unbiased because of the high R-squared of our instruments taken as a whole. We thank Marcelo Moreira, James Stock and Motohiro Yogo for generous advice on this issue.

[26] See Stock and Yogo (2005) for a discussion of the LIML estimator's properties in settings with many instruments. The disadvantage of LIML is that its distribution has fat tails and, thus, yields large standard errors.

[27] Furthermore, suppose we regress state output growth ΔY_{it} on scaled national output growth $s_i \Delta Y_t$, where the scaling factor s_i is the average level of military spending in each state relative to state output, as well as state and time fixed effects. If state with high s_i are more cyclically sensitive, this regression should yield a positive coefficient on $s_i \Delta Y_t$. In fact, the coefficient is slightly negative in our data. In contrast, when $s_i \Delta Y_t$ is replaced with $s_i \Delta G_t$, this regression yields a large positive coefficient.

are substantially lower than our instrumental variables estimates. A natural explanation for this is that states' elected officials may find it easier to argue for spending at times when their states are having trouble economically. Our instruments also likely correct for measurement error in the data on state-level prime military contracts that does not arise at the national level. Such measurement error causes an "attenuation bias" in the OLS coefficient toward zero.[28]

Table 4 presents the results for equation (1) estimated separately by major SIC/NAICS groupings. An important point evident from Table 4 is that increases in government sector output contribute negligibly to the overall effects we estimate. The table also shows that increases in relative procurement spending are not associated with increases in other forms of military output. Statistically significant output responses occur in the construction, manufacturing, retail and services sectors. Effects on measured output in the government sector are less easily interpretable than effects on output in the private sector since much of government output is measured using input costs. Transfers associated with increases in public sector wages are therefore difficult to distinguish from changes in actual output.

3.4 Government Spending at High Versus Low Unemployment Rates

We next investigate whether the effects of government spending on the economy are larger in periods when the unemployment rate is already high. There are a variety of reasons why this could be the case. Most often cited is the idea that in an economy with greater slack, expansionary government spending is less likely to crowd out private consumption or investment.[29] A second potential source of such differences is the differential response of monetary policy—central bankers may have less incentive to "lean against the wind" to counteract the effects of government spending increases if unemployment is high. We show in section 5, however, that this second effect does not affect the size of the open economy relative multiplier since aggregate policy is "differenced out."

To investigate these issues, we estimate the following regression,

$$\frac{Y_{it}-Y_{it-2}}{Y_{it-2}} = \alpha_i + \gamma_t + \beta_h \frac{G_{it}-G_{it-2}}{Y_{it-2}} + (\beta_l - \beta_h) I_l \frac{G_{it}-G_{it-2}}{Y_{it-2}} + \epsilon_{it}, \tag{3}$$

[28]In section 3.2 below, we describe an alternative source of data on military procurement based on shipments to the government from defense oriented industries. Despite the close correspondence between the prime military contract data and the shipments data, small differences remain in the growth rates for the two series. Viewing these as independent (but noisy) measures on the magnitude of spending, we can adjust for measurement error by using one variable as an instrument for the other. We find that this significantly raises the multiplier relative to the OLS estimates.

[29]This might arise, for example, if unemployment leads to a higher labor supply elasticity (Hall, 2009) or because of tighter capacity constraints in booms (Gordon and Krenn, 2010).

where I_l is an indicator for a period of low economic slack, and the effects of government spending in high and low slack periods are given by β_h and β_l respectively. We define high and low slack periods in terms of the unemployment rate at the start of the interval over which the government spending occurs. Specifically, period t is defined as a high slack period if U_{t-2} is above its median value over our sample period.[30]

Table 5 presents our estimates of equation (3). The point estimates support the view that the effects of government spending are larger when unemployment is high. Depending on the specification, the government spending multiplier lies between 2 and 3.5 in the high slackness periods, substantially above our estimates for the time period as a whole. Given the limited number of business cycles in our sample, we are not, however, able to estimate these effects with much statistical precision. The difference in the multiplier in the high and low spending periods is moderately statistically significant (with a P-value of 0.06) only in the case of the state-level output regression.

4 A Model of Government Spending in a Monetary Union

In this section, we develop a framework to help us interpret the "open economy relative multiplier" that we estimate in section 3, and relate is to the "closed economy aggregate multiplier," which has been the focus of most earlier work on government spending multipliers. Many of the issues that arise in interpreting the open economy relative multiplier also arise in the international economics literature. The model we develop, therefore, draws heavily on earlier work on open economy business cycle models (Obstfeld and Rogoff, 1995; Chari, Kehoe and McGrattan, 2002), and, in particular, the literature on monetary unions (Benigno and Benigno, 2003; Gali and Monacelli, 2008).

The model consists of two regions that belong to a monetary and fiscal union. We refer to the regions as "home" and "foreign." Think of the home region as the region in which the government spending shock occurs – a U.S. state or small group of states – and the foreign region as the rest of the economy. The population of the entire economy is normalized to one. The population of the home region is denoted by n. Household preferences, market structure and firm behavior take the same form in both regions. Below, we describe the economy of the home region.

[30]The high slack years t according to this measure are: 1966, 1967, 1972-1974, 1976-1988, 1993, 1994, 2004 and 2005. We have also considered defining high slack years based on regional unemployment rates relative to their median values. This yields very similar results.

4.1 Households

The home region has a continuum of household types indexed by x. A household's type indicates the type of labor supplied by that household. Home households of type x seek to maximize their utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, L_t(x)), \tag{4}$$

where β denotes the household's subjective discount factor, C_t denotes household consumption of a composite consumption good, $L_t(x)$ denotes household supply of differentiated labor input x. There are an equal (large) number of households of each type.

The composite consumption good in expression (4) is an index given by

$$C_t = \left[\phi_H^{\frac{1}{\eta}} C_{Ht}^{\frac{\eta-1}{\eta}} + \phi_F^{\frac{1}{\eta}} C_{Ft}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{5}$$

where C_{Ht} and C_{Ft} denote the consumption of composites of home and foreign produced goods, respectively. The parameter $\eta > 0$ denotes the elasticity of substitution between home and foreign goods and ϕ_H and ϕ_F are preference parameters that determine the household's relative preference for home and foreign goods. It is analytically convenient to normalize $\phi_H + \phi_F = 1$. If $\phi_H > n$, household preferences are biased toward home produced goods.

The subindices, C_{Ht} and C_{Ft}, are given by

$$C_{Ht} = \left[\int_0^1 c_{ht}(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \quad \text{and} \quad C_{Ft} = \left[\int_0^1 c_{ft}(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \tag{6}$$

where $c_{ht}(z)$ and $c_{ft}(z)$ denote consumption of variety z of home and foreign produced goods, respectively. There is a continuum of measure one of varieties in each region. The parameter $\theta > 1$ denotes the elasticity of substitution between different varieties.

Goods markets are completely integrated across regions. Home and foreign households thus face the same prices for each of the differentiated goods produced in the economy. We denote these prices by $p_{ht}(z)$ for home produced goods and $p_{ft}(z)$ for foreign produced goods. All prices are denominated in a common currency called "dollars."

Households have access to complete financial markets. There are no impediments to trade in financial securities across regions. Home households of type x face a flow budget constraint given by

$$P_t C_t + E_t[M_{t,t+1} B_{t+1}(x)] \leq B_t(x) + (1 - \tau_t) W_t(x) L_t(x) + \int_0^1 \Xi_{ht}(z) dz - T_t, \tag{7}$$

where P_t is a price index that gives the minimum price of a unit of the consumption good C_t, $B_{t+1}(x)$ is a random variable that denotes the state contingent payoff of the portfolio of financial securities held by households of type x at the beginning of period $t+1$, $M_{t,t+1}$ is the stochastic discount factor that prices these payoffs in period t, τ_t denotes a labor income tax levied by the government in period t, $W_t(x)$ denotes the wage rate received by home households of type x in period t, $\Xi_{ht}(z)$ is the profit of home firm z in period t and T_t denotes lump sum taxes.[31] To rule out Ponzi schemes, household debt cannot exceed the present value of future income in any state of the world.

Households face a decision in each period about how much to spend on consumption, how many hours of labor to supply, how much to consume of each differentiated good produced in the economy and what portfolio of assets to purchase. Optimal choice regarding the trade-off between current consumption and consumption in different states in the future yields the following consumption Euler equation:

$$\frac{u_c(C_{t+j}, L_{t+j}(x))}{u_c(C_t, L_t(x))} = \frac{M_{t,t+j}}{\beta^j}\frac{P_{t+j}}{P_t} \tag{8}$$

as well as a standard transversality condition. Subscripts on the function u denote partial derivatives. Equation (8) holds state-by-state for all $j > 0$. Optimal choice regarding the intratemporal trade-off between current consumption and current labor supply yields a labor supply equation:

$$\frac{u_\ell(C_t, L_t(x))}{u_c(C_t, L_t(x))} = (1-\tau_t)\frac{W_t(x)}{P_t}. \tag{9}$$

Households optimally choose to minimize the cost of attaining the level of consumption C_t. This implies the following demand curves for home and foreign goods and for each of the differentiated products produced in the economy:

$$C_{H,t} = \phi_H C_t \left(\tfrac{P_{Ht}}{P_t}\right)^{-\eta} \quad \text{and} \quad C_{F,t} = \phi_F C_t \left(\tfrac{P_{Ft}}{P_t}\right)^{-\eta}, \tag{10}$$

$$c_{ht}(z) = C_{Ht} \left(\tfrac{p_t(z)}{P_{Ht}}\right)^{-\theta} \quad \text{and} \quad c_{ft}(z) = C_{Ft} \left(\tfrac{p_t(z)}{P_{Ft}}\right)^{-\theta}, \tag{11}$$

where

$$P_{Ht} = \left[\int_0^1 p_t(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \quad \text{and} \quad P^*_{Ft} = \left[\int_0^1 p^*_t(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}}, \tag{12}$$

and

$$P_t = \left[\phi_H P_{Ht}^{1-\eta} + \phi_F P_{Ft}^{1-\eta}\right]^{\frac{1}{1-\eta}}. \tag{13}$$

As we noted above, the problem of the foreign household is analogous. We therefore refrain from describing it in detail here. It is, however, useful to note that combining the home and foreign

[31] The stochastic discount factor $M_{t,t+1}$ is a random variable over states in period $t+1$. For each such state it equals the price of the Arrow-Debreu asset that pays off in that state divided by the conditional probability of that state. See Cochrane (2005) for a detailed discussion.

consumption Euler equations to eliminate the common stochastic discount factor yields

$$\frac{u_c(C_t^*, L_t^*(x))}{u_c(C_t, L_t(x))} = Q_t, \tag{14}$$

where $Q_t = P_t^*/P_t$ is the real exchange rate. This is the "Backus-Smith" condition that describes optimal risk-sharing between home and foreign households (Backus and Smith, 1993). For simplicity, we assume that all households—in both regions—initially have an equal amount of financial wealth.

4.2 The Government

The economy has a federal government that conducts fiscal and monetary policy. Total government spending in the home and foreign region follow exogenous AR(1) processes. Let G_{Ht} denote government spending per capita in the home region. Total government spending in the home region is then nG_{Ht}. For simplicity, we assume that government demand for the differentiated products produced in each region takes the same CES form as private demand. In other words, we assume that

$$g_{ht}(z) = G_{Ht}\left(\frac{p_{ht}(z)}{P_{Ht}}\right)^{-\theta} \quad \text{and} \quad g_{ft}(z) = G_{Ft}\left(\frac{p_{ft}(z)}{P_{Ft}}\right)^{-\theta}. \tag{15}$$

The government levies both labor income and lump-sum taxes to pay for its purchases of goods. Our assumption of perfect financial markets implies that any risk associated with variation in lump-sum taxes and transfers across the two regions is undone through risk-sharing. Ricardian equivalence holds in our model. We describe the policy for labor income taxes in section 5.

The federal government operates a common monetary policy for the two regions. This policy consists of the following augmented Taylor-rule for the economy-wide nominal interest rate:

$$\hat{r}_t^n = \rho_r \hat{r}_{t-1}^n + (1-\rho_i)(\phi_\pi \hat{\pi}_t^{ag} + \phi_y \hat{y}_t^{ag} + \phi_g \hat{g}_t^{ag}), \tag{16}$$

where hatted variables denote percentage deviations from steady state. The nominal interest rate is denoted $\hat{r}_t^n$. It responds to variation in the weighted average of consumer price inflation in the two regions $\hat{\pi}_t^{ag} = n\hat{\pi}_t + (1-n)\hat{\pi}_t^*$, where $\hat{\pi}_t$ is consumer price inflation in the home region and $\hat{\pi}_t^*$ is consumer price inflation in the foreign region. It also responds to variation in the weighted average of output in the two regions $\hat{y}_t^{ag} = n\hat{y}_t + (1-n)\hat{y}_t^*$. Finally, it may respond directly to the weighted average of the government spending shock in the two regions $\hat{g}_t^{ag} = n\hat{g}_t + (1-n)\hat{g}_t^*$.

4.3 Firms

There is a continuum of firms indexed by z in the home region. Firm z specializes in the production of differentiated good z, the output of which we denote $y_t(z)$. In our baseline model, labor is the only variable factor of production used by firms. Each firm is endowed with a fixed, non-depreciating stock of capital.[32] The production function of firm z is

$$y_t(z) = f(L_t(z)). \tag{17}$$

The function f is increasing and concave. It is concave because there are diminishing marginal returns to labor given the fixed amount of other inputs employed at the firm. Labor is immobile across regions. Our model yields very similar results to a model in which labor and capital are assumed to be equally mobile and the government spending shock is to per capita spending.[33] We follow Woodford (2003) in assuming that each firm belongs to an industry x and that there are many firms in each industry. The goods in industry x are produced using labor of type x and all firms in industry x change prices at the same time.

Firm z acts to maximize its value,

$$E_t \sum_{j=0}^{\infty} M_{t,t+j}[p_{t+j}(z)y_{t+j}(z) - W_{t+j}(x)L_{t+j}(z)]. \tag{18}$$

Firm z must satisfy demand for its product. The demand for firm z's product comes from three sources: home consumers, foreign consumers and the government. It is given by

$$y_t(z) = (nC_{Ht} + (1-n)C^*_{Ht} + nG_{Ht}) \left(\frac{p_{ht}(z)}{P_{Ht}} \right)^{-\theta}. \tag{19}$$

Firm z is therefore subject to the following constraint:

$$(nC_{Ht} + (1-n)C^*_{Ht} + nG_{Ht}) \left(\frac{p_{ht}(z)}{P_{Ht}} \right)^{-\theta} \leq f(L_t(z)). \tag{20}$$

Firm z takes its industry wage $W_t(x)$ as given. Optimal choice of labor demand by the firm is given by

$$W_t(x) = f_\ell(L_t(z))S_t(z), \tag{21}$$

where $S_t(z)$ denotes the firm's nominal marginal cost (the Lagrange multiplier on equation (20) in the firm's constrained optimization problem).

[32] Appendix B develops an extension of our baseline model with investment.

[33] If labor and capital are equally mobile, factor movements simply affect the relative size of the regions. For example, a positive shock to the home region causes inward migration of both labor and capital and this makes the home region larger. But in per capita terms the model is identical to a model without factor mobility (save a slight change in home bias) as long as the government spending shock is defined in per-capita terms and the open economy relative multiplier is thus virtually identical. In contrast, if labor is more mobile then capital, inward migration in response to a positive government spending shock will lower the labor-capital ratio in the home region and through this channel lower the per-capita government spending multiplier (and vice versa if capital is more mobile than labor).

Firm z can reoptimize its price with probability $1-\alpha$ as in Calvo (1983). With probability α it must keep its price unchanged. Optimal price setting by firm z in periods when it can change its price implies

$$p_t(z) = \frac{\theta}{\theta-1} E_t \sum_{j=0}^{\infty} \frac{\alpha^j M_{t,t+j}(nC_{Ht+j} + (1-n)C_{Ft+j} + nG_{Ht+j})P_{Ht+j}^{\theta}}{E_t \sum_{k=0}^{\infty} \alpha^k M_{t,t+k}(nC_{Ht+l} + (1-n)C_{Ft+k} + nG_{Ht+k})P_{Ht+k}^{\theta}} S_{t+j}(z). \qquad (22)$$

Intuitively, the firm sets its price equal to a constant markup over a weighted average of current and expected future marginal cost.

4.4 Calibration of Preferences and Technology

We consider the following two forms for the utility function:

$$u(C_t, L_t(x)) = \frac{C_t^{1-\sigma^{-1}}}{1-\sigma^{-1}} - \chi \frac{L_t(x)^{1+\nu^{-1}}}{1+\nu^{-1}}, \qquad (23)$$

$$u(C_t, L_t(x)) = \frac{(C_t - \chi L_t(x)^{1-\nu^{-1}}/(1-\nu^{-1}))^{1-\sigma^{-1}}}{1-\sigma^{-1}}. \qquad (24)$$

In the first utility specification, consumption and labor enter separably. They are therefore neither complements nor substitutes. The second utility function is adopted from Greenwood, Hercowitz, and Huffman (1988). We refer to this utility function as representing GHH preferences. Consumption and labor are complements for households with GHH preferences. Recently, Monacelli and Perotti (2008), Bilbiie (2011), and Hall (2009) have emphasized the implications of consumption-labor complementarities for the government spending multiplier.

For both specifications of utility, we must specify values for σ and ν (χ is irrelevant when utility is separable and determined by other parameters in the GHH case). In both cases, ν is the Frisch-elasticity of labor supply. We set $\nu = 1$. This value is somewhat higher than values estimated in microeconomic studies of employed workers, but relatively standard in macroeconomics. The higher value is meant to capture variation in labor on the extensive margin—such as variation in unemployment and retirement (Hall, 2009; Chetty, et al., 2011). As Hall (2009) emphasizes, assuming a high labor supply elasticity raises the government spending multiplier. For the separable utility specification, σ denotes the intertemporal elasticity of substitution (IES). There is little agreement within the macroeconomics literature on the appropriate values for the IES. Hall (1988) estimates the IES to be close to zero, while Bansal and Yaron (2004), Gruber (2006) and Nakamura, et al. (2011) argue for values above 1. We set $\sigma = 1$, which yields balanced growth for the model with separable preferences, $\sigma = 1$. We set the subjective discount factor equal to $\beta = 0.99$, the elasticity of substitution across varieties equal to $\theta = 7$ and the elasticity of substitution between home and foreign goods to $\eta = 2$.[34] Larger values of η yield more expenditure switching between regions in response to regional shocks and thus lower open economy relative multipliers.

We assume the production function $f(L_t(z)) = L_t(z)^a$ and set $a = 2/3$. Regarding the frequency with which firms can change their prices, we consider two cases: $\alpha = 0$ (i.e., fully flexible prices) and $\alpha = 0.75$ (which implies that firms reoptimize there prices on average once a year). Rigid prices imply that relative prices across regions respond sluggishly to regional shocks. We set the size of the home region to $n = 0.1$. This roughly corresponds to the size of the average region in our regional regressions (where we divide the U.S. into 10 regions). We set the steady state value of government purchases as a fraction of output to 0.2. We log-linearize the equilibrium conditions of the model and use the methods of Sims (2001) to find the unique bounded equilibrium.

We use data from the U.S. Commodity Flow Survey (CFS) and the U.S. National Income and Product Accounts (NIPA) to set the home-bias parameter ϕ_H. The CFS reports data on shipments of goods within and between states in the U.S. It covers shipments between establishments in the mining, manufacturing, wholesale and retail sectors. For the average state in 2002, 38% of shipments were within state and 50% of shipments were within region. However, roughly 40% of all shipments in the CFS are from wholesalers to retailers and the results of Hillberry and Hummels (2003) suggest that a large majority of these are likely to be within region. Since the relevant shipments for our model are those from manufacturers to wholesalers, we assume that 83% of these are from another region (50 of the remaining 60 percent of shipments).

To calculate the degree of home bias, we must account for the fact that a substantial fraction of output is services, which are not measured in the CFS. NIPA data indicate that goods represent roughly 30% of U.S. GDP. If all inter-region trade were in goods—i.e., all services were local—imports from other regions would amount to 25% of total consumption (30*0.83 = 25). However, for the U.S. as a whole, services represent roughly 20% of international trade. Assuming that services represent the same fraction of cross-border trade for regions, total inter-region trade is 31% of region GDP (25/0.8 = 31). We therefore set $\phi_H = 0.69$. This makes our regions slightly more open than Spain and slightly less open than Portugal. We set ϕ_{H^*} so that overall demand for home products as a fraction of overall demand for all products is equal to the size of the home population relative to the total population of the economy. This implies that $\phi_{H^*} = (n/(1-n))\phi_F$.

[34] This is the same value for η as is used by Obstfeld and Rogoff (2005), and only slightly higher than the values used by Backus, Kehoe, and Kydland (1994) and Chari, Kehoe, and McGrattan (2002).

We have so far calibrated the "fundamentals"—i.e., preferences and technology—for our model economy. We leave the detailed description of government policy to the next section. We wish to draw a clear distinction between fundamentals and government policy. The former determine constraints on the potential effects of government policy. In contrast, monetary and fiscal policy are under the government's control and therefore "choice variables" from the perspective of an optimizing government, making it relevant to consider not only the policies that have persisted in the past but also the potential effects of alternative government policies.

5 Theoretical Results

In this section, we analyze the effects of government spending shocks in the model presented in section 4. We consider several different specification for the economy's "fundamentals" (separable vs. GHH preferences, flexible vs. sticky prices) as well as different specifications for aggregate monetary and tax policy. In the Neoclassical (flexible price) versions of the model, money is neutral implying that the specification of monetary policy is irrelevant. Tax policy is, however, important and we consider two specifications for tax policy described below. In the New Keynesian (sticky price) versions of the model, monetary policy is important and we consider three specifications of monetary policy within the class of interest rate rules described by equation (16).

The monetary policies we consider are: 1) a "Volcker-Greenspan" policy, 2) a" fixed real-rate" policy and 3) a "fixed nominal-rate" policy. These policies are designed to imply successively less "leaning against the wind" by the central bank in response to inflationary government spending shocks. The "Volcker-Greenspan" policy is meant to mimic the policy of the U.S. Federal Reserve during the Volcker-Greenspan period. For this case, we set the parameters in equation (16) to $\rho = 0.8$, $\phi_\pi = 1.5$, $\phi_y = 0.5$ and $\phi_g = 0$.[35] This specification of monetary policy implies that the monetary authority aggressively raises the real interest rate to curtail the inflationary effects of a government spending shock.

Under the "fixed real-rate" policy, the central bank maintains a fixed real interest rate in response to government spending shocks. However, to guarantee price-level determinacy, the central bank responds aggressively to the inflationary effects of all other shocks. Under the "fixed nominal-rate policy," central bank maintains a fixed nominal interest rate in response to government spending shocks. But as with the fixed real-rate policy, it responds aggressively to the inflationary effects of

[35] Many recent papers have estimated monetary rules similar to the one we adopt for the Volcker-Greenspan period (see, e.g., Taylor, 1993 and 1999; Clarida, Gali and Gertler, 2000).

all other shocks. We describe the details of how the fixed real-rate and fixed nominal-rate policies are implemented in appendix A. The fixed nominal-rate policy is a close cousin of the zero lower bound scenario analyzed in detail in Eggertsson (2010), Christiano, Eichenbaum, and Rebelo (2011), and Mertens and Ravn (2010). It is, in a sense, the opposite of the aggressive "leaning against the wind" embodied in the Volcker-Greenspan policy because an inflationary shock generates a fall in real interest rates (since nominal rates are held constant). The fixed real-rate policy charts a middle ground.

We consider two specifications for tax policy. Our baseline tax policy is one in which government spending shocks are financed completely by lump sum taxes. Under this policy, all distortionary taxes remain fixed in response to the government spending shock. The second tax policy we consider is a "balanced budget" tax policy. Under this policy, labor income taxes vary in response to government spending shocks such that the government's budget remains balanced throughout:

$$nP_{Ht}G_{Ht} + (1-n)P_{Ft}G_{Ft} = \tau_t \int W_t(x)L_t(x)dx, \tag{25}$$

This policy implies that an increase in government spending is associated with an increase in distortionary taxes. We focus on the case of government spending shocks chosen to have roughly the same persistence as aggregate military procurement spending, for which a linear model implies a half-life of 2 years (i.e., an AR(1) coefficient of $0.5^{1/8} \approx 0.917$). We also in some cases consider the implications of more transitory government spending shocks.

We present results for both the closed economy aggregate multiplier that has been studied in much of the previous literature and the open economy relative multiplier that we provide estimates for in section 3 and has been the focus of much recent work using sub-regional data (Acconcia et al., 2011; Chodorow-Reich et al., 2011; Clemens and Miran, 2010; Cohen et al., 2010; Fishback and Kachanovskaya, 2010; Serrato and Wingender, 2010; Shoag, 2010; Wilson, 2011). We begin in sections 5.1 and 5.2 by describing results for the case of additively separable preferences. We then consider the case of GHH preferences in section 5.3. Finally, in section 5.4, we consider an extension of our model that incorporates investment and variable capital utilization.

5.1 The Closed Economy Aggregate Multiplier

We define the closed economy aggregate multiplier analogously to the previous literature on multipliers (e.g., Barro and Redlick, 2011) as the response of total output (combining home and foreign production) to total government spending, i.e., β in the regression,

$$\frac{Y_t^{agg} - Y_{t-2}^{agg}}{Y_{t-2}^{agg}} = \alpha + \beta \frac{G_t^{agg} - G_{t-2}^{agg}}{Y_{t-2}^{agg}} + \epsilon_t, \tag{26}$$

where Y_t^{agg} denotes aggregate output and G_t^{agg} denotes aggregate government spending. This regression is identical to the one we use to measure the open economy relative multiplier—equation (1)—except that we are using aggregate variables and have dropped the time fixed effects. We calculate this object by simulating quarterly data from the model described in section 4, time-aggregating it up to an annual frequency, and running the regression (26) on this data.

The first column of table 6 reports results on the closed economy aggregate multiplier. These results clearly indicate that the closed economy aggregate multiplier is highly sensitive to aggregate monetary and tax policy. In the New Keynesian model with a Volcker-Greenspan monetary policy, it is quite low—only 0.22. The low multiplier arises because the monetary authority reacts to the inflationary effects of the increase in government spending by raising real interest rates. This counteracts the expansionary effects of the spending shock. The closed economy aggregate multiplier under Volcker-Greenspan policy is quite close to its value of 0.39 under flexible prices (and constant labor income tax rates). This should come as no surprise. "Good" monetary policy strives to replicate the behavior of a flexible price economy.

For monetary policies that respond less aggressively to inflationary shocks, the closed economy multiplier can be substantially larger. For the constant real-rate policy, the multiplier is one (Woodford, 2010). Intuitively, since the real interest rate remains constant rather than rising when spending increases there is no "crowding out" of consumption, implying that output rises one-for-one with government spending. For the constant nominal-rate policy, the multiplier is 1.70 if the government spending shock is relatively transient (half-life of one-year, $\rho_g = 0.85$), but -0.39 for the case of a more persistent government spending shock (half-life of two-years, $\rho_g = 0.917$). The sensitivity of the closed economy aggregate multiplier under fixed nominal-rate policy to the persistence of government spending is closely related to issues discussed in Mertens and Ravn (2010). Intuitively, if the government spending shock is inflationary, it will lower the real interest rate (since the nominal rate is constant) and this will boost the multiplier. However, the government spending shock has both inflationary effects (it increases aggregate demand at a given interest rate) and deflationary effects (labor supply shifts out since households are poorer). For relatively transitory government spending shocks, the overall effect is inflationary and the multiplier is large. For sufficiently persistent government spending shocks, however, the overall effect can be deflationary, leading to low multipliers.

The second panel of Table 6 presents results for the Neoclassical model. These results clearly indicate that the closed economy aggregate multiplier also depends on the extent to which the government spending is financed by contemporaneous distortionary taxes. If the spending is financed by an increase in distortionary taxes in such a way as to maintain a balanced budget period-by-period (as opposed to by lump sum taxes), the multiplier falls by about a fourth to 0.30. If distortionary taxes are reduced in concert with an increase in government spending the aggregate multiplier can be substantially higher (though we do not report this in the table).

It is useful to pause for a moment to consider why price rigidity—what distinguishes the New Keynesian and Neoclassical models we consider—matters so much in determining effects of government spending. For concreteness, consider a transitory shock to government spending at the zero lower bound. This shock puts pressure on prices to rise. In the Neoclassical, prices immediately jumping up and begin falling. This implies that the real interest rate rises on impact (because prices are falling) and crowds out private spending. In the New Keynesian model, however, prices rise only gradually since many are rigid in the short run. This implies that the real interest rate falls on impact and thus boosts private spending. It is this difference in the response of the real interest rate to government spending shocks—caused by a difference in the flexibility of prices—that explains the difference in the multiplier across these models.

The sensitivity of the closed economy aggregate multiplier to aggregate monetary and tax policy probably explains some of the wide range of estimates in the empirical literature. Most economists agree that the extent to which the Federal Reserve has "leaned against the wind" has varied substantially over the last century, as illustrated for example by the different policy response during the 2007-2009 financial crisis than the Great Depression (see also Clarida et al., 2000). This sensitivity carries over to other variables. Much recent work on the effects of fiscal policy has focused on consumption, real wages and markups (Ramey, 2010; Perotti, 2007). In our New Keynesian model with Volcker-Greenspan monetary policy, the closed economy aggregate multiplier is negative for all three of these variables, while it is positive for more accommodative monetary policy.

The enormous variation in possible values for the closed economy aggregate multiplier depending on the policy environment underscores the difficulty of using the closed economy aggregate multiplier to distinguish among alternative views of how government spending affects the economy. Under "normal" monetary policy (i.e., the Volcker-Greenspan policy), it may be exceedingly difficult to distinguish between the Neoclassical and New Keynesian models. Both frameworks predict little effect of government spending on output. Yet this does not imply that the models have similar implications overall. While the Neoclassical model continues to generate a low aggregate multiplier in the fixed nominal-rate scenario that we use to proxy for the zero lower bound, the New Keynesian model can generate extremely large multipliers in this environment. In the next section, we illustrate that the open economy relative multiplier has important advantages when it comes to distinguishing between different views of how government spending affects the economy, because it is not sensitive to the specification of aggregate monetary and tax policy but rather to the relative policies across regions—which are precisely pinned down in a monetary and fiscal union.

5.2 The Open Economy Relative Multiplier

Contrast the wide range of different closed economy aggregate multipliers produced by our model for different monetary policies with the complete stability of the open economy relative multiplier reported in the second column of Table 6. The open economy relative multiplier is calculated by estimating equation (1) using the regional data from the model—the same specification we use in our empirical analysis. For all three specifications of monetary policy we consider, the open economy relative multiplier is 0.85. Furthermore, the fifth and sixth row of Table 6 present result for the different specifications of tax policy in the Neoclassical model and illustrate that the open economy relative multiplier is also completely insensitive to aggregate tax policy. The open economy relative multiplier *is* sensitive to economic fundamentals (e.g., the degree of price rigidity) and to region-specific policies (e.g., the persistence of the regional government spending shock) as we discuss below.

Intuitively, the open economy relative multiplier is independent of aggregate policy because we "difference out" aggregate shocks and aggregate policy by including time fixed effects in the regression. In a monetary union, the monetary authority cannot respond to a shock in one region by making monetary policy tighter in that region alone. The relative monetary policy between the two regions is, therefore, held fixed by the monetary union in a very precise way, regardless of the stance of aggregate monetary policy. In this sense, the open economy relative multiplier is akin to the closed economy aggregate multiplier for a relatively accommodative aggregate monetary policy—more accommodative than U.S. monetary policy under Volcker and Greenspan.

Since the relative nominal interest rate is constant in response to a regional government spending shock, it is tempting to think that this situation is analogous to the zero lower bound, where the nominal interest rate is fixed at zero in response to government spending shocks. As in the zero lower bound case, an increase in relative government spending in the home region can raise expected inflation, lowering relative short-term real interest rates. However, unlike the zero lower bound case, the relative *long-term* real interest rate does not fall in response to a fiscal shock. The fiscal shock leads to an immediate rise in relative prices and expectations of further increases in the short term. This lowers the relative short term real interest rate. However, since a transitory shock to spending does not lead to a permanent change in relative prices and the exchange rate is fixed within the monetary union, any short term increase in prices in one region relative to the other region must be undone by a fall in relative prices in that region later on.[36] In fact, after their initial jump, relative prices are anticipated to fall more in the long run than they are anticipated to rise further in the short run. This implies that the relative long-term real interest rate actually rises slightly in the home region in response to an increase in government spending.[37]

To more clearly see the intuition for this result, Figure 4 presents the impulse response of the price level and the real interest rate in the home region relative to the foreign region after a government spending shock in our model. The home price level rises for several periods, but then falls back to its original level. This movement in prices implies that the real interest rate in the home region initially falls, but then rises above its steady state level for a prolonged period. Figure 5 shows what happens to consumption in the home region relative to the foreign region after a government spending shock. Despite the short-run fall in the real interest rate, consumption falls. This is because households anticipate high real rates in the future—equivalently, they face a high current long-term real interest rate—and therefore cut their consumption.

Since the relevant interest rate for consumption decisions—the long-term real interest rate—actually rises slightly in response to an increase in government spending irrespective of the persistence of the shock and other parameters, the fixed relative nominal interest rate policy in a monetary union is fundamentally different from a zero lower bound setting in a closed economy in which the long-term real interest rate may fall in response to a government spending shock. The response of relative long-term real interest rates in our setting is closest to the fixed *real* interest rate case in the closed economy setting. Table 6 shows that the open economy relative multiplier is, in fact, 0.85 for our baseline parameter values. This is far below the zero lower bound multipliers emphasized by Eggertsson (2010) and Christiano, Eichenbaum, and Rebelo (2011), but just slightly lower than

[36] Parsley and Wei (1996) present evidence for rapid convergence of relative prices following regional shocks using data for U.S. regions.

[37] Corsetti et al. (2011) show that the same logic holds for the case of a small open economy with a fixed exchange rate.

the closed economy aggregate multiplier for a fixed real rate monetary policy.

5.3 Model with GHH Preferences

The models we have considered so far have generated predictions for the open economy relative multiplier substantially below the point estimate of roughly 1.5 that we obtained in section 3. We next consider a model with GHH preferences that is capable of fitting this feature of our empirical estimates.[38] GHH preferences imply that consumption and labor are complements. This complementarity is intended to represent the extra consumption on food away from home, clothing, gas and the like that often arises in the context of work (Aguiar and Hurst (2005) present empirical evidence for such complementarities).[39]

Previous work by Monacelli and Perotti (2008), Bilbiie (2011) and Hall (2009) has shown that allowing for complementarities between consumption and labor can have powerful implications for the government spending multiplier. The basic intuition is that, in response to a government spending shock, households must work more to produce the additional output. This raises consumption demand since consumption is complementary to labor. But to be able to consume more, still more production must take place, further raising the effects on output.

The second column of table 7 presents estimates of the open economy relative multiplier for the model with GHH preferences. The New Keynesian model with GHH preferences can match our empirical findings in section 3 of an open economy multiplier of roughly 1.5 (assuming $\rho_g = 0.917$ as in the military spending data). As in the model with separable preferences, this statistic is entirely insensitive to the specification of aggregate policies. For the case of more transitory government spending shocks ($\rho_g = 0.5$), the open economy relative multiplier rises to 2.1. The Neoclassical model, however, continues to generate a low multiplier (0.3) in this model.

Figure 6 plots relative output and consumption in the New Keynesian model with GHH preferences after a positive shock to home government spending. Both output and consumption rise on impact by a little more than twice the amount of the shock. They then both fall more rapidly than the shock. The fact that the initial rise in consumption is as large as the rise in output implies that the home region responds to the shock by running a trade deficit in the short run. Consumption

[38] Models with hand-to-mouth consumers of the type studied by Gali, Lopez-Salido, and Valles (2007) may also have the potential to generate large open economy relative multipliers.

[39] Schmitt-Grohe and Uribe (2009) estimate a rich business cycle model with Jaimovich and Rebelo (2009) preferences—which nests GHH and King and Rebelo (1988) preferences as special cases. The values that they estimate for the preference parameters of their model are those for which Jaimovich-Rebelo preferences reduce to GHH preferences.

eventually falls below its steady state level for a period of time. During this time, the home region is running a trade surplus. Intuitively, the complementarity between consumption and labor implies that home households want to shift their consumption towards periods of high work effort associated with positive government spending shocks.

How does the introduction of GHH preference affect the closed economy aggregate multiplier? The first column of Table 7 reports the closed economy aggregate multiplier in our model with GHH preferences. Under certain circumstances—in particular, the case of a fixed nominal rate rule meant to proxy for the zero lower bound—this model can generate an extremely large closed economy aggregate multiplier. However, if monetary policy is highly responsive to output as in the case of Volcker-Greenspan policy, or if the government spending shock is highly persistent, the New Keynesian model with GHH preferences implies a low closed economy aggregate multiplier, just as the Neoclassical model does.

Table 7 makes clear that the introduction of GHH preferences does not generically increase the closed economy aggregate multiplier. In the Neoclassical model, introducing GHH preferences lowers the closed economy aggregate multiplier (to zero) by eliminating the wealth effect on labor supply.[40] The introduction of GHH preferences also lowers the closed economy aggregate multiplier in the New Keynesian model when monetary policy responds aggressively to the inflationary effects of government spending shocks—as in the case of the Volcker-Greenspan policy rule. For this policy, the endogenous increase in real interest rates chokes off the chain of increases in output, employment and consumption that otherwise generates a large multiplier in the GHH model. A key reason why the introduction of GHH preferences raises the open economy relative multiplier when compared to the case of separable preferences is thus that the monetary union implies an accommodative "relative" monetary policy—sufficiently accommodative not to choke off the increase in relative output.

Summing up our results thus far, our estimates of equation (1) based on the military procurement data yield an open economy relative multiplier of roughly 1.5. This lies far above the open economy relative multipliers for the Neoclassical model—which are below 0.5 for both separable preferences and GHH preferences. Our empirical estimate of 1.5 is also substantially higher than the open economy relative multiplier of 0.85 implied by the New Keynesian model with separable preferences.

[40] In the New Keynesian model, government spending shocks affect the markup of prices over marginal costs and therefore affect output by shifting labor demand. Similarly, the open economy relative multiplier in the Neoclassical model with GHH preferences is non-zero because the government spending shock shifts labor supply when it is written in terms of the real product wage.

The New Keynesian model with GHH preferences, however, is able to match the open economy relative multiplier we estimate in the data. Our results are thus consistent with a model in which demand shocks *can* have large effects on output—if monetary policy is sufficiently accommodative (as it is at the zero lower bound) and the government spending shock is not too persistent.

5.4 Model with Variable Capital

In appendix B, we develop an extension of the model presented in section 4 that includes investment, capital accumulation and variable capital utilization. The specification that we adopt for these features mirrors closely that of Christiano, Eichenbaum, and Evans (2005). Table 8 presents open economy relative multipliers for several calibrations of this model with GHH preferences.[41] Introducing investment into the model does not change the main message of the previous sections regarding the relationship between the open economy relative multiplier and its closed economy aggregate counterpart.

However, introducing investment allows for an additional margin of adjustment: increases in government spending "crowd out" private investment, implying that a smaller increase in production is needed to fulfill the increase in aggregate demand associated with the government spending shock. Matching the open economy relative multiplier that we estimated in our empirical analysis therefore requires parameter values that make the economy more "elastic" than those we adopted in section 4.4. A key parameter in determining the multiplier (both aggregate and relative) is the elasticity of labor supply, as emphasized by Hall (2009). Table 8 reports the open economy relative multiplier both for our baseline parameterization and for a "high labor supply elasticity" parameterization in which we set the Frisch-elasticity of labor supply to $\nu = 25$. This calibration of labor supply is closer to the indivisible labor model of Hansen (1985) and Rogerson (1988), which implies that the economy acts as though it were populated by agents with an infinite labor supply elasticity.[42]

Table 8 also presents open economy relative multiplier for employment and prices. The employment and output multipliers are similar in the model as in the data. The New Keynesian model generates a small increase in relative inflation in response to the increase in relative government spending. This lines up well with our empirical findings on relative inflation. In this model, prices adjust only gradually to demand shocks, due to price rigidity. In contrast, the Neoclassical model

[41] A disadvantage of introducing investment into the model is that the methods we use to implement the constant real-rate and constant nominal-rate monetary policies are substantially more difficult to apply. We therefore focus on the case of Volcker-Greenspan monetary policy for this model.

[42] King and Rebelo (1999) argue that introducing indivisible labor into business cycle models helps to improve the models' fit to the data along a number of dimensions.

predicts that relative prices jump up on impact in the region hit by the spending shock, and then fall gradually.

6 Conclusion

We study the effects of government spending on output in a monetary union. Our empirical analysis makes use of historical data on military procurement spending across U.S. regions. We measure the consequences of a differential increase in military procurement spending in a particular region on output, employment, and prices in that region relative to other regions in the union. Since regional procurement spending is potentially determined partly by underlying economic conditions in the region, we focus only on changes in relative procurement spending arising from aggregate military build-ups or draw-downs. We use time fixed effects to difference out aggregate shocks and policy that affect all regions. Our estimates imply an "open economy relative multiplier" of approximately 1.5.

We develop a framework for interpreting this open economy relative multiplier and relating it to estimates of "closed economy aggregate multipliers." The closed economy aggregate multiplier is highly sensitive to how strongly aggregate monetary and tax policy "leans against the wind." In contrast, the open economy relative multiplier differences out these effects because different regions in the union share a common monetary and tax policy. Since the monetary authority cannot raise interest rates differentially in one region relative to other regions in response to a regional spending shock, our open economy relative multiplier is akin to an aggregate multiplier for a more accommodative monetary policy than the monetary policy seen in the United States under Volcker and Greenspan. This implies that our high values of the open economy relative multiplier are not inconsistent with lower aggregate multipliers found in the literature (e.g., Barro and Redlick, 2011).

Our estimate provides evidence in favor of models in which demand shocks can have large effects on output. Among the models that we consider, a New Keynesian model with complementarities between consumption and labor in the form of GHH preferences best matches the open economy relative multiplier we estimate in the data. This model implies a low closed economy aggregate multiplier for monetary policy that "leans against the wind" in the way monetary policy did in the U.S. during the Volcker-Greenspan period. However, it implies that the closed economy aggregate multiplier can be very large if monetary policy is sufficiently accommodative (as it is at the zero lower bound) and if the increase in government spending is not too persistent.

A Constant Real Rate Monetary Policy

The paper considers specifications of monetary policy that hold the real or nominal interest rate constant in response to a government spending shock. Here, we illustrate the method used to solve for these monetary policy specifications. We do this for the case of separable preference and a monetary policy that holds the real interest rate constant. We use an analogous approach for the case of GHH preference and the fixed nominal-rate policy.

Consider the closed economy limit of our model. A log-linear approximation of the key equilibrium conditions of this model are

$$\hat{c}_t = E_t \hat{c}_{t+1} - \sigma(\hat{r}_t^n - E_t \hat{\pi}_{t+1}), \tag{27}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\zeta\sigma^{-1}\hat{c}_t + \kappa\zeta\psi_\nu \hat{y}_t, \tag{28}$$

$$\hat{y}_t = \left(\frac{C}{Y}\right)\hat{c}_t + \hat{g}_t, \tag{29}$$

where $\zeta = 1/(1+\psi_\nu\theta)$ and $\psi_\nu = (1-\nu^{-1})/a - 1$.

Using equation (29) to eliminate $\hat{c}_t$ from equations (27) and (28) yields

$$\hat{y}_t = E_t \hat{y}_{t+1} - \left(\frac{C}{Y}\right)\sigma(\hat{r}_t^n - E_t\hat{\pi}_{t+1}) + (\hat{g}_t - E_t\hat{g}_{t+1}), \tag{30}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\zeta_y \hat{y}_t - \kappa\zeta_g \hat{g}_t, \tag{31}$$

where $\zeta_y = \zeta(\psi_\nu + (C/Y)^{-1}\sigma^{-1})$ and $\zeta_g = \zeta(C/Y)^{-1}\sigma^{-1}$.

An equilibrium with a fixed real interest rate must satisfy

$$\hat{y}_t = E_t \hat{y}_{t+1} + (\hat{g}_t - E_t\hat{g}_{t+1}), \tag{32}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\zeta_y \hat{y}_t - \kappa\zeta_g \hat{g}_t. \tag{33}$$

We conjecture a solution of the form $\hat{y}_t^* = a_y \hat{g}_t$, $\hat{\pi}_t^* = a_\pi \hat{g}_t$. Using the method of undetermined coefficients, it is easy to verify that such an equilibrium exists with

$$a_y = 1, \quad a_\pi = \kappa\tfrac{\zeta_y - \zeta_g}{1-\beta\rho_g},$$

where ρ_g is the autoregressive coefficient of the AR(1) process for $\hat{g}_t$.

This equilibrium can be implemented with the following policy rule

$$\begin{aligned} \hat{r}_t^n &= E_t\hat{\pi}_{t+1} + \phi_\pi(\hat{\pi}_t - \hat{\pi}_t^*) \\ &= a_\pi\rho_g\hat{g}_t + \phi_\pi\hat{\pi}_t - a_\pi\phi_\pi\hat{g}_t \\ &= \phi_\pi\hat{\pi}_t - a_\pi(\phi_\pi - \rho_g)\hat{g}_t. \end{aligned} \tag{34}$$

B Model with Capital

This appendix presents the an extension of the model presented in section 4 that incorporates investment, capital accumulation and variable capital utilization. We adopt a specification for these features that mirrors closely the specification in Christiano, Eichenbaum, and Evans (2005).

B.1 Households

Household preferences in the home region are given by equations (4)-(6) as before. Household decisions regarding consumption, saving and labor supply are thus the same as before. However, in addition to these choices, households own the capital stock, they choose how much to invest and they choose the rate of utilization of the capital stock. Let $\bar{K}_t$ denote the physical stock capital of capital available for use in period t and I_t the amount of investment chosen by the household in period t. For simplicity, assume that I_t is a composite investment good given by an index of all the products produced in the economy analogous to equations (5)-(6) for consumption. The capital stock evolves according to

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + \Phi(I_t, I_{t-1}), \tag{35}$$

where δ denotes the physical depreciation of capital and Φ summarizes the technology for transforming current and past investment into capital. Households choose the utilization rate u_t of the capital cost. The amount of capital services provided by the capital cost in period t is then given by $K_t = u_t\bar{K}_t$.

The budget constraint of households in the home region is given by

$$\begin{aligned} &P_tC_t + P_tI_t + P_tA(u_t)\bar{K}_t + E_t[M_{t,t+1}B_{t+1}(x)] \\ &\quad \leq B_t(x) + W_t(x)L_t(x) + R_t^k u_t\bar{K}_t + \int_0^1 \Xi_{ht}(z)dz - T_t. \end{aligned} \tag{36}$$

The differences relative to the model presented in section 4 are the following. First, households spend P_tI_t on investment. Second, they incur a cost $P_tA(u_t)\bar{K}_t$ associated with utilizing the capital stock. Here $A(u_t)$ denotes a convex cost function. Third, they receive rental income equal to $R_t^k u_t\bar{K}_t$ for supplying $u_t\bar{K}_t$ in capital services. Here R_t^k denotes the rental rate for a unit of capital services.

In addition to equations (8)-(11), (14) and a standard transversality condition, household optimization yields the following relevant optimality conditions. Optimal capital utilization sets the marginal cost of additional utilization equal to the rental rate on capital,

$$A'(u_t) = \frac{R_t^k}{P_t}. \tag{37}$$

Optimal investment and capital accumulation imply

$$D_t \Phi_1(I_t, I_{t-1}) + \beta E_t[D_{t+1}\Phi_2(I_{t+1}, I_t)] = u_c(C_t, L_t(x)), \tag{38}$$

$$D_t = \beta(1-\delta)E_t D_{t+1} + \beta E_t[(A'(u_{t+1})u_{t+1} - A(u_{t+1}))u_c(C_{t+1}, L_{t+1}(x))], \tag{39}$$

where D_t is the Lagrange multiplier on equation (35) and $\Phi_j(\cdot,\cdot)$ denotes the derivative of Φ with respect to its jth argument.

B.2 Firms

The production function for firm z is

$$y_t(z) = f(L_t(z), K_t(z)). \tag{40}$$

The demand for firm z's product is given by

$$y_t(z) = (nC_{Ht} + (1-n)C^*_{Ht} + nI_{H,t} + (1-n)I^*_{H,t} + nG_{Ht})\left(\frac{p_{ht}(z)}{P_{Ht}}\right)^{-\theta}. \tag{41}$$

Firm optimization then yields

$$W_t(x) = f_\ell(L_t(z), K_t(z))S_t(z), \tag{42}$$

$$R^k_t = f_k(L_t(z), K_t(z))S_t(z), \tag{43}$$

and a firm price setting equation given by equation (22).

B.3 Calibration

We set the rate of depreciation of capital to $\delta = 0.025$, which implies an annual depreciation rate of 10 percent. The investment adjustment cost function is given by

$$\Phi(I_t, I_{t-1}) = \left[1 - \phi\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \tag{44}$$

where $\phi(1) = \phi'(1) = 0$ and $\kappa_I = \phi''(1) > 0$. We set $\kappa_I = 2.5$. This is the value estimated by Christiano et al. (2005). We require that capital utilization $u_t = 1$ in steady state, assume that the cost of utilization function $A_1 = 0$ and set $\sigma_a = A''(1)/A'(1) = 0.01$. Again, this is the value estimated by Christiano et al. (2005). We assume that the production function is Cobb-Douglas with a capital share of 1/3.

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TABLE I
States Most Sensitive to Aggregate Military Buildups

Missouri
Connecticut
Texas
Vermont
New Hampshire
Massachusetts
Kansas
California
Georgia
Louisiana

The table lists the 10 states for which state military procurement spending is most sensitive to national military procurement spending in descending order.

TABLE II

The Effects of Military Spending

	Output		Output defl. State CPI		Employment		CPI		Population
	States	Regions	States	Regions	States	Regions	States	Regions	States
Prime Military Contracts	1.43	1.85	1.35	1.85	1.28	1.76	0.03	-0.14	-0.12
	(0.36)	(0.58)	(0.36)	(0.71)	(0.29)	(0.62)	(0.18)	(0.65)	(0.17)
Prime Contracts plus Military Compensation	1.61	1.62	1.36	1.45	1.39	1.51	0.19	0.06	0.07
	(0.40)	(0.84)	(0.39)	(0.88)	(0.32)	(0.90)	(0.16)	(0.41)	(0.21)
Num. Obs.	1989	390	1989	390	1989	390	1785	350	1989

The dependent variable is stated at top of each column. Each cell in the table reports results for a different regression with the main regressor of interest listed in the far left column. Standard errors are in parentheses. Military spending variables are per capita except in Population regression. All regressions include region and time fixed effects, and are estimated by two stage least squares. The sample period is 1966-2006 for output, employment and population, and 1969-2006 for the CPI. Output is state GDP, first deflated by the national CPI and then by our state CPI measures. Employment is from the BLS payroll survey. The CPI measure is described in the text. Standard errors are clustered by state or region.

TABLE III

Alternative Specifications for Effects of Military Spending

	Output Level Instr.		Employment Level Instr.		Output per Working Age		Output OLS	
	States	Regions	States	Regions	States	Regions	States	Regions
Prime Military Contracts	2.48	2.75	1.81	2.51	1.46	1.94	0.16	0.56
	(0.94)	(0.69)	(0.41)	(0.31)	(0.58)	(1.21)	(0.14)	(0.32)
Prime Contracts plus Military Comp.	4.79	2.60	2.07	1.97	1.79	1.74	0.19	0.64
	(2.65)	(1.18)	(0.67)	(0.98)	(0.60)	(1.00)	(0.19)	(0.31)
Num Obs.	1989	390	1989	390	1785	350	1989	390

	Output w/ Oil Controls		Output w/ Real Int. Contr.		Output LIML		BEA Employment	
	States	Regions	States	Regions	States	Regions	States	Regions
Prime Military Contracts	1.32	1.89	1.40	1.76	1.95	2.07	1.52	1.64
	(0.36)	(0.53)	(0.34)	(0.78)	(0.62)	(0.66)	(0.37)	(0.98)
Prime Contracts plus Military Comp.	1.43	1.72	1.52	1.38	2.21	1.90	1.62	1.28
	(0.39)	(0.66)	(0.37)	(1.05)	(0.67)	(1.02)	(0.42)	(1.16)
Num Obs.	1785	350	1938	380	1989	390	1836	360

The dependent variable is stated at top of each column. Each cell in the table reports results for a different regression with the main regressor of interest listed in the far left column. Standard errors are in parentheses. Specifications: 1) and 2) Use national military spending scaled by fraction of military spending in the state in 1966-1971 relative to the average fraction as the instrument for state spending; 3) Constructs per-capita output using the working age population, which is available starting in 1970; 4) OLS estimates of the benchmark specification; 5) Adds the price of oil interacted with state dummies as controls; 6) Adds the real interest rate interacted with state dummies as controls; 7) LIML estimate of baseline specification; 8) Estimates the employment regression using the BEA employment series, which starts in 1969. All specifications include time and regions fixed effects in addition to the main regressor of interest. Standard errors are clustered by state or region depending on the specification.

TABLE IV
Effect of Military Spending on Sectoral Output

	Weight	States	Regions
Construction	0.05	5.43*	5.51*
		(1.24)	(1.33)
Manufacturing	0.20	2.83*	3.45*
		(0.95)	(1.50)
Retail	0.09	1.36*	1.78*
		(0.28)	(0.51)
Services	0.18	0.99*	0.84*
		(0.39)	(0.41)
Wholesale	0.07	0.44	0.80
		(0.35)	(0.63)
Mining	0.02	-0.48	12.88
		(3.03)	(6.89)
Agriculture	0.02	1.85	0.72
		(1.13)	(3.81)
Transportation and Utilities	0.08	-0.05	0.03
		(0.41)	(0.67)
Finance, insurance, rental, estate	0.17	0.22	1.93
		(0.71)	(1.39)
Government	0.13	0.15	0.30
		(0.34)	(0.64)
Federal Military	0.01	0.23	-1.37
		(0.82)	(1.87)

The table reports results of regressions of the change in sectoral state output on the change in state military spending. All regressions include region and time fixed effects, and are estimated by two stage least squares. The sample period is 1966-2006. The first data column reports the weight of each sector in total output over our sample period. All variables are in per capita terms. A star indicates statistical significance at the 5% level.

TABLE V

Effects of Military Spending in High Versus Low Unemployment Periods

	Output		Employment	
	States	Regions	States	Regions
β_h	3.54	3.27	1.85	2.20
	(1.51)	(1.60)	(0.85)	(1.53)
β_l - β_h	-2.80	-1.85	-0.75	-0.57
	(1.49)	(1.91)	(0.89)	(1.61)

The dependent variable is stated at top of each column. Standard errors are in parentheses. The two regressors are 1) change in military spending and 2) change in military spending interacted with a dummy indicating whether the national unemployment rate is below its median value over the sample period. This yields the effect of spending during high unemployment periods (β_h) and the difference between the effect of spending during low and high unemployment periods (β_l - β_h). All regressions include region and time fixed effects, and are estimated by two stage least squares. The sample period is 1966-2006. Output is state GDP. Employment is from the BLS payroll survey. All variables are per capita.

TABLE VI

Government Spending Multiplier in Separable Preferences Model

	Closed Economy Agg. Multiplier	Open Economy Rel. Multiplier
Panel A: Sticky Prices		
Volcker-Greenspan Monetary Policy	0.22	0.85
Constant Real Rate	1.00	0.85
Constant Nominal Rate	-0.39	0.85
Constant Nominal Rate (ρ_g=0.85)	1.70	0.90
Panel B: Flexible Prices		
Constant Income Tax Rates	0.39	0.43
Balanced Budget	0.30	0.43

The table reports the government spending multiplier for output deflated by the regional CPI for the model presented in the text with the separable preferences specification. Panel A presents results for the model with sticky prices, while panel B presents results for the model with flexible prices. The first three rows differ only in the monetary policy being assumed. The fourth row varies the persistence of the government spending shock relative to the baseline parameter values. The fifth and sixth rows differ only in the tax policy being assumed.

TABLE VII

Government Spending Multiplier in GHH Model

	Closed Economy Agg. Multiplier	Open Economy Rel. Multiplier
Panel A: Sticky Prices		
Volcker-Greenspan Monetary Policy	0.15	1.48
Constant Real Rate	7.00	1.48
Constant Nominal Rate	-0.64	1.48
Constant Nominal Rate (ρ_g=0.50)	8.73	2.09
Panel B: Flexible Prices		
Constant Income Tax Rates	0.00	0.30
Balanced Budget	-0.25	0.30

The table reports the government spending multiplier for output deflated by the regional CPI for the model presented in the text with the GHH preferences specification. Panel A presents results for the model with sticky prices, while panel B presents results for the model with flexible prices. The first three rows differ only in the monetary policy being assumed. The fourth row varies the persistence of the government spending shock relative to the baseline parameter values. The fifth and sixth rows differ only in the tax policy being assumed.

TABLE VIII

Open Economy Relative Multipliers for Output, Employment and Inflation

	Output	Employment	CPI Inflation
Fixed Capital	1.48	2.10	0.15
Var. Capital, Baseline	1.10	0.79	0.10
Var. Capital, High Labor Supply Elast.	1.47	1.44	0.02
Var. Capital, Flexible Prices	0.45	0.23	0.30

The table reports the open economy relative government spending multiplier for output, employment and CPI inflation for the model with GHH preferences both excluding and including capital. Output is deflated by the regional CPI. The first row presents results for the baseline specification of the GHH model (same as in in table 5). The second row presents results for the baseline calibration of the model with variable capital. The third row presents results for the model with variable capital and with a labor supply elasticity of 25. The last row presents results for the model with variable capital and flexible prices.

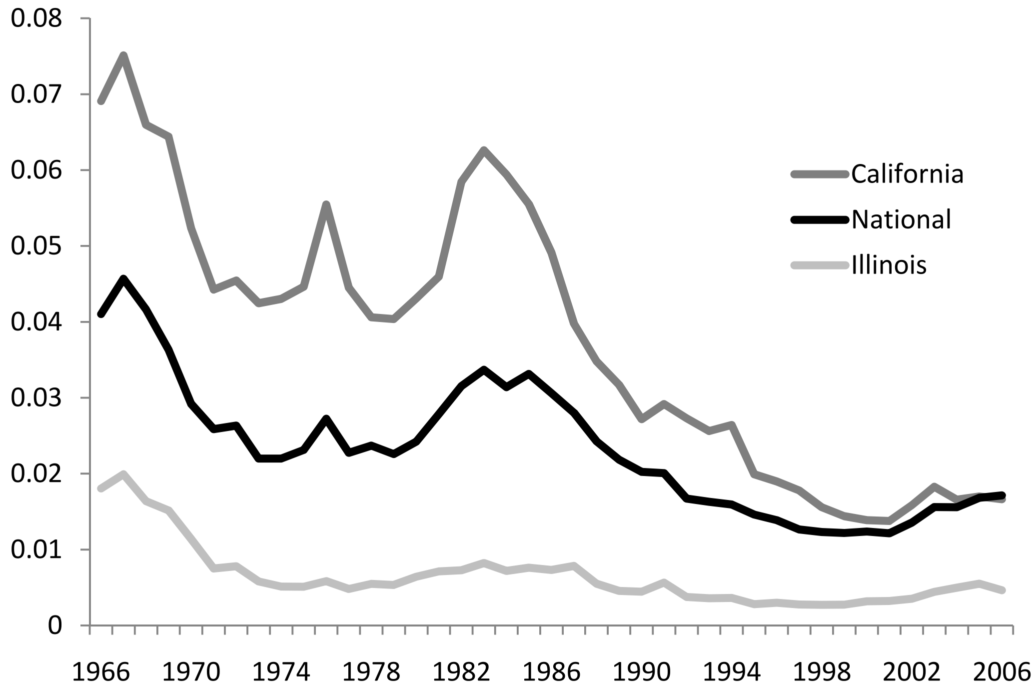

Figure I
Prime Military Contract Spending as a Fraction of State GDP

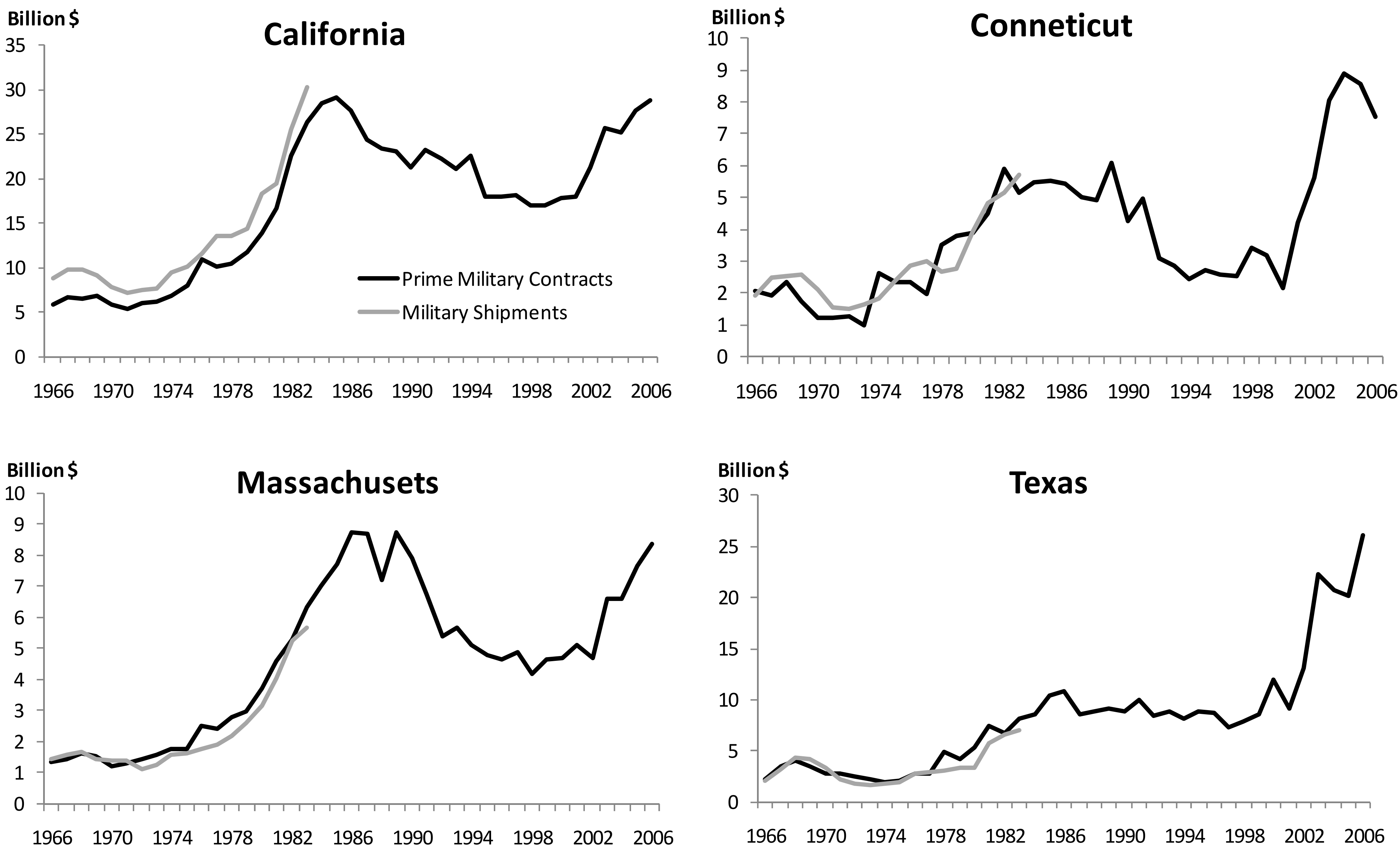

Figure II
Prime Military Contracts and Military Shipments

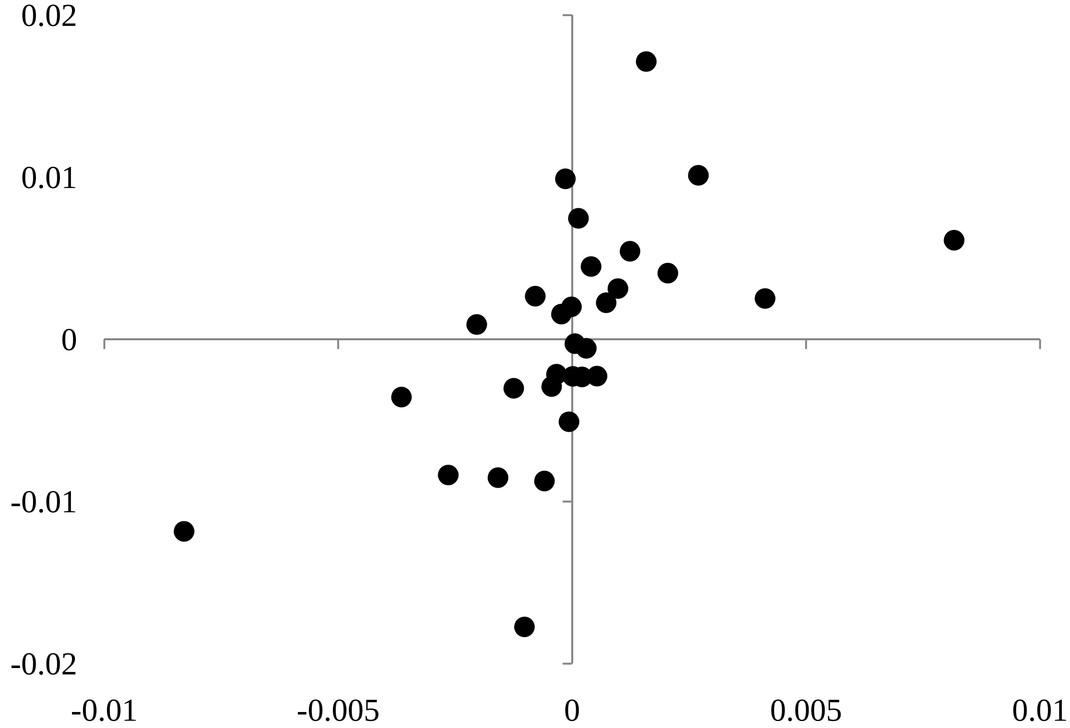

FIGURE III
Quantiles of Change in Output Versus Predicted Change in Military Spending

The figure shows averages of changes in output and predicted military spending (based on our first-stage regression), grouped by 30 quantiles of the predicted military spending variable. Both variables are demeaned by year and state fixed effects.

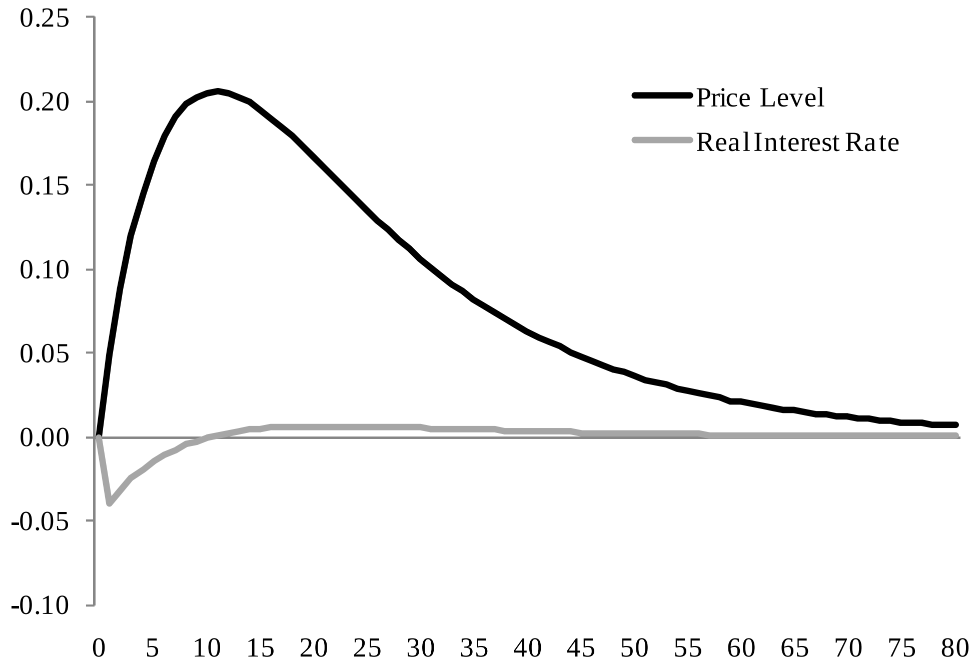

Figure IV
Prices and Real Interest Rates after a Government Spending Shock

The figure plots the relative price level and the relative real interest rate in the two regions for the model with separable preferences after a positive government spending shock to the home region.

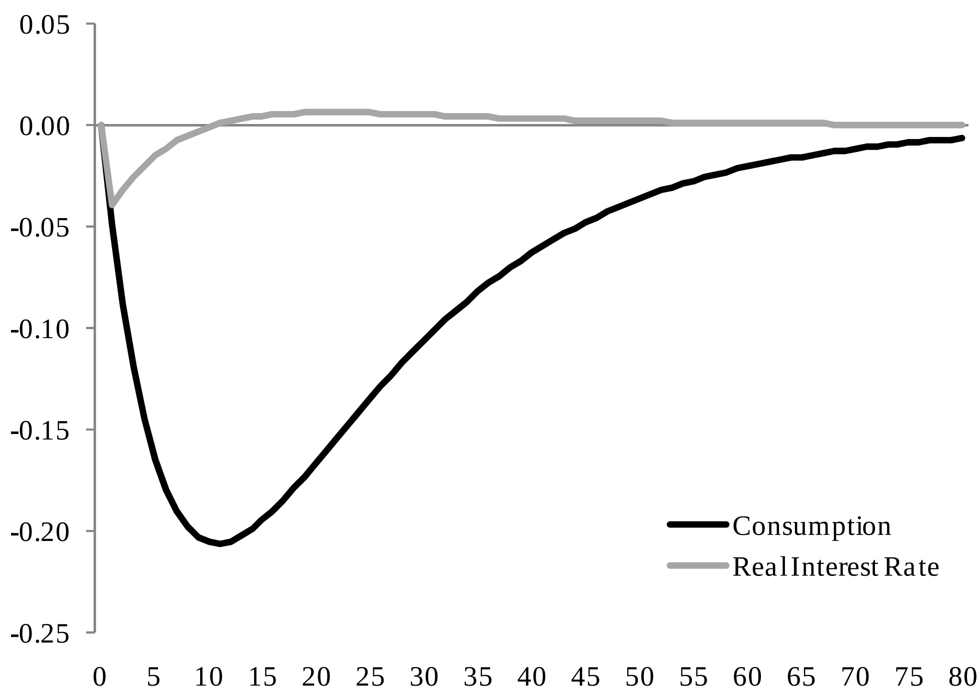

Figure V
Consumption and Real Interest Rate after a Government Spending Shock

The figure plots the relative consumption and the relative real interest rate in the two regions for the model with separable preferences after a positive government spending shock to the home region.

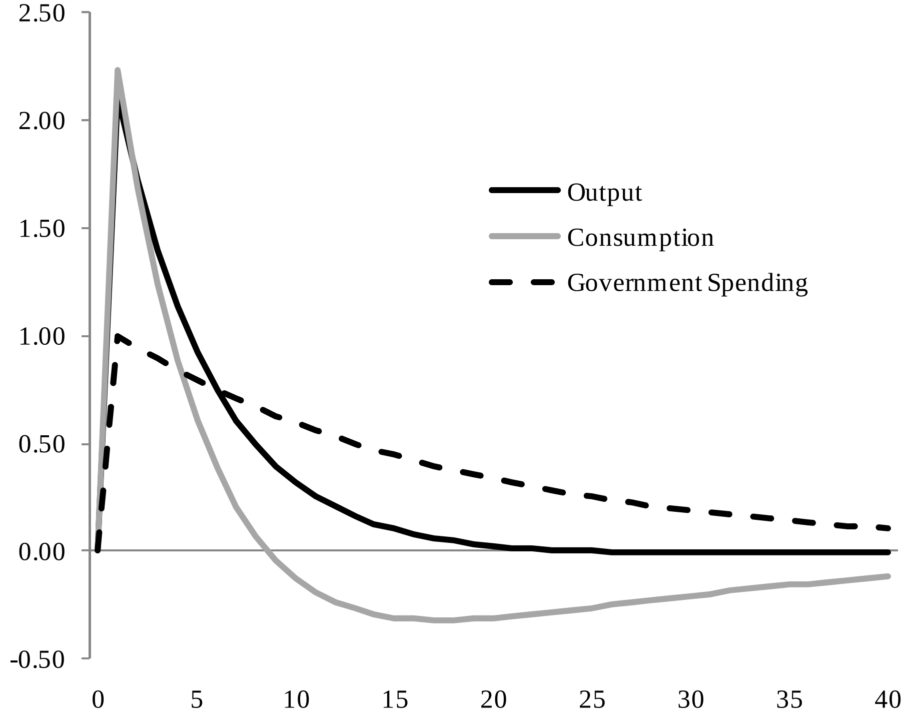

Figure VI
Output and Consumption after a Government Spending Shock in GHH Model

The figure plots the relative output and consumption in the two regions for the model with GHH preferences after a positive government spending shock to the home region.