ESTIMATED MACROECONOMIC EFFECTS OF THE U.S. STIMULUS BILL

By

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Abstract

This paper uses a multicountry macroeconometric model to estimate the macroeconomic effects of the U.S. stimulus bill passed in February 2009. The analysis has the advantage of taking into account many endogenous effects. Real U.S. output is estimated to be $554 billion larger when summed over the 12-year period 2009:1–2020:4 (0.29 percent of the total sum of output). The average number of jobs is 509 thousand larger (0.37 percent). There is some redistribution of output and employment away from 2012–2015. At the end of 2020 the federal government debt is larger by $637 billion in real terms (the debt/GDP ratio is larger by 3.19 percentage points), which may increase the risk of negative asset-market reactions.

1 Introduction

This paper uses a structural multicountry macroeconometric model, denoted the "MC" model, to analyze the macroeconomics effects of the U.S. stimulus bill passed in February 2009. The policy changes are taken from a report issued on March 2, 2009 by the Congressional Budget Office (CBO) (2009). A baseline

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The results in this paper can be duplicated on the author's website, and alternative experiments can be done.

simulation is first run under the assumption that the stimulus bill passed (which it did), and then a simulation is run with the stimulus taken out. The difference between the predicted values from the two simulations for each variable and each quarter is an estimate of the stimulus effects on that variable. The simulation period is 2009:1–2020:4. Because the model is a multicountry model, the effects on other countries are estimated in addition to the effects on the United States.

There is considerable controversy about the stimulus effects, and a number of methodologies have been followed to estimate them. The CBO (2010) uses results from two commercial forecasting models and the FRB-US model of the Federal Reserve Board to choose ranges for a number of government spending multipliers on output. These multipliers are then used to compute stimulus effects. Additional equations are used to link output changes to changes in other variables, like employment and the unemployment rate. The estimates are partial in that they are not the result of solving a complete model. Many potential endogenous effects are ignored. Also, as will be seen, the ranges chosen for the multipliers are large, which leads to large ranges for the estimated stimulus effects.

Another procedure for estimating multipliers is what might be called a "reduced form" procedure. The change in real GDP is regressed on the change in a policy variable of interest and a number of other variables. The equation estimated is not, however, a true reduced form equation because many variables are omitted, and so the coefficient estimate of the policy variable will be biased if the policy variable is correlated with omitted variables. The aim using this approach is to choose a policy variable that seems unlikely to be correlated with the omitted variables. Hall (2010) and Barro and Redlick (2010) are concerned with government spending multipliers and focus on defense spending during wars.[1] Romer and Romer (2009) are concerned with tax multipliers and use narrative records to choose what they consider exogenous tax policy actions, i.e, actions that are uncorrelated with the omitted variables.

This paper uses a model of the economy that captures many important features of the world economy. It has been extensively tested, and it appears to be a good approximation of the economy. It is briefly outlined in the next section. The stimulus experiment that is performed is based on the solution of the entire model. All the endogenous effects in the model are accounted for, including the effects of the stimulus bill on the rest of the world and the effects of the rest of the world responses back on the United States.

The methodology of structural macroeconometric modeling, which goes back at least to Tinbergen (1939), does not have the problem of possible omitted variable bias in reduced form equations, since reduced form equations are not directly estimated. What is required is that the structural equations be consistently estimated. Take, for example, a consumption or investment equation. If there are right hand side endogenous variables, like current income or a current interest rate, and thus correlation between these variables and the error term in the equation, this has to be accounted for. Two stage least squares (2SLS) is one option. First stage regressors must be found that are correlated with the endogenous variables and uncorrelated with the error term. If one suspects that a current government spending or tax rate variable depends on current endogenous variables, the variable would need to be lagged one period before being used as a first stage regressor. The estimation is

[1] Barro and Redlick (2010) also estimate a tax multiplier.

slightly more complicated if the error term in the structural equation is serially correlated. In this case the 2SLS estimator can be modified to jointly estimate the serial correlation coefficient and the structural coefficients—Fair (1970). The aim in structural modeling is to find good structural equations—good approximations to reality—and to estimate them consistently.[2] Reduced form equations are not estimated but derived, and there are many nonlinear restrictions on the reduced form equations.

This structural approach uses much more information on the economy than does the reduced form approach mentioned above. For example, the implicit reduced form equation for U.S. output in the MC model is nonlinear and includes hundreds of exogenous and lagged endogenous variables. There are also hundreds of nonlinear restrictions on the reduced form coefficients. Given the complexity of the economy, it seems unlikely that estimating reduced form equations with many omitted variables and no restrictions from theory on the coefficients will produce trustworthy results even if an attempt is made to account for omitted variable bias.

Another model building methodology is that of dynamic stochastic general equilibrium (DSGE) models. This methodology is criticized in Fair (2009b), and this discussion will not be repeated here. The main argument is that DSGE models leave out too many features of the economy to be trustworthy for policy analysis. Also, the models are based on the assumptions of labor market clearing and rational expectations, which may not be realistic.

[2]Commercial forecasting models like the ones used by the CBO are not in the academic literature, and so it is hard to evaluate them. It does not appear, however, that the structural equations in these models are consistently estimated.

2 The MC Model

The MC model is presented in Fair (2004), and it has been updated for purposes of this paper (version dated January 30, 2010). The updated version is on the author's website. The U.S. part of the MC model will be denoted the "US model," and the rest of the model will be denoted the "ROW model." Sometimes the US model is analyzed by itself, but in this paper the entire MC model is used. The ability of the US model to forecast recessions and booms is analyzed in Fair (2009a). The MC model is completely estimated (by 2SLS); there is no calibration. The estimation periods begin in 1954 for the US model and 1962 for the ROW model and go through the latest data at the time of this study. The following is a brief outline of the models.

US Model

In the US model there are three estimated consumption equations, three investment equations, an import equation, four labor supply equations, two labor demand equations, a price equation, a nominal wage equation, two term structure of interest rate equations, and an estimated interest rate rule of the Federal Reserve, among others. In the interest rate rule the Fed responds to inflation and unemployment. There are a total of 28 estimated equations and about 100 identities in the US model. The unemployment rate is determined by an identity; it equals unemployment divided by the labor force. In the identities all flows of funds among the sectors (household, firm, financial, state and local government, federal government, and foreign) are accounted for. The federal government deficit is determined by an identity, as is the federal government debt. There is an estimated equation determining the interest payments of the federal government as a function of interest rates and the government debt.

There are important real wealth effects in the US model. An increase in household wealth, say from an increase in stock prices or housing prices, leads to an increase in consumption. Spending out of real wealth is about 4 percent per year of the wealth change. Real disposable income is an explanatory variable in the consumption equations. DSGE models like the Galí and Gertler (2007) model have that property that a positive price shock is explosive unless the Fed raises the nominal interest rate more than the increase in the inflation rate. In other words, positive price shocks with the nominal interest rate held constant are expansionary (because the real interest rate falls). In the US model, however, they are contractionary. If there is a positive price shock, the real wage initially falls because nominal wages lag prices. This has a negative effect on consumption demand (because real income is an explanatory variable in the consumption equations). In addition, household real wealth falls because nominal asset prices don't initially rise as much as the price level. This has a negative effect on consumption through the wealth effect. There is little if any offset from lower real interest rates because households appear to respond more to nominal rates than to real rates. Positive price shocks are thus contractionary even if the Fed keeps the nominal interest rate unchanged.

There are also important physical stock effects in the model. There are four physical stock variables: durables, housing, capital, and inventories. Lagged one period, the stock of durables has a negative effect on durable expenditures, the stock of housing has a negative effect on housing investment, the stock of capital has a negative effect on plant and equipment investment, and the stock of inventories has a negative effect on inventory investment. These stock effects mitigate recessions and tame booms. As physical stocks get low in a recession, there is, other things being equal, an increased demand to replenish them, which helps counteract the recession. The opposite happens in a boom. All these stock effects are estimated—again no calibration. Another way of looking at these stock effects is that the model has built in cyclical features. As, say, stimulus measures expand the economy and stocks are built up, forces are at work that will slow the economy later.

ROW Model

The ROW model consists of estimated equations for 37 countries. There are up to 13 estimated equations per country and 16 identities. There are a total of 274 estimated equations in the ROW model. The estimated equations explain total imports, consumption, fixed investment, inventory investment, the domestic price level, the demand for money, a short term interest rate, a long term interest rate, the spot exchange rate, the forward exchange rate, the export price level, employment, and the labor force. The specifications are similar across countries. The short term interest rate for each country is explained by an estimated interest rate rule for that country. In some cases the U.S. interest rate is an explanatory variable in the estimated rule, where the Fed is estimated to have an effect on the decisions of other monetary authorities. The exchange rates are relative to the dollar or the euro. The two key explanatory variables in the exchange rate equations are a relative interest rate variable and a relative price level variable. The two key explanatory variables in the domestic price equation are a demand pressure variable and a cost-shock variable—the price of imports. In the price of exports equation, the price of exports in local currency is a weighted average of the domestic price level and a variable measuring the world export price level (translated into local currency using the exchange rate). The weights are estimated.

There are 59 countries in the MC model (counting an "all other" category), and the trade share matrix is 59×59. Data permitting, a trade share equation is estimated for each country pair. In a trade share equation, the fraction of country i's exports imported by country j is a function of the price of country i's exports in dollars relative to a weighted average of all other countries' export prices in dollars (excluding oil exporting countries). The weights are trade shares lagged one quarter. A total of 1,302 trade share equations are estimated. Trade shares for which there are no estimated equations are still used in the solution of the MC model; they are simply taken as exogenous. The trade share data are from the IFS Direction of Trade data. Quarterly data are available back to 1960. While the trade share equations are all quarterly, the structural equations for some countries are estimated using annual data. Interpolation is used when necessary to convert annual variables to quarterly variables.

There are many links among countries. The use of the trade shares means that the differential effects of one country's total demand for imports on other countries' exports are accounted for. There are interest rate links through the U.S. interest rate affecting some other countries' rates in the estimated interest rate rules. In a few cases the euro (earlier German) interest rate affects other countries' interest rates. Exports are endogenous for each country, since they depend on the imports of other countries, which are endogenous. The price of exports in local currency of each country is endogenous, since they depend, as noted above, on the domestic price level and the world price level. The price of exports in dollars is endogenous because the price of exports in local currency is endogenous and the exchange rate is (for most countries) endogenous. The price of imports in each country is endogenous because it depends on the price of exports of the other countries weighted by the trade shares. Since, as noted above, the price of imports affects the domestic price level in each country's estimated domestic price equation, there are price links among countries. An increase in the price of exports in dollars in one country leads to increases in other countries' import prices, which affects their domestic and thus export prices, which feeds back to the original country, etc.

Government Spending Multipliers in the MC Model

Because of the many links among variables in the model and because there are many simultaneous effects, it is not easy to explain results. There is a danger that the model seems like a black box. It is not feasible to explain everything in one paper, and I have tried to deal with this problem by putting all the documentation on my website. The complete specification of the MC model is presented on the site, and all coefficient estimates are presented along with tests for each estimated equation. Also, the complete model can be used on the site, including duplicating the results in this paper. It can also be downloaded for use on one's own computer, which allows all of the equations to be estimated by the user if desired. The discussion of the results in Section 3 is thus incomplete. Only selected variables are discussed, and the reader is referred to the website for further details.

It will be useful before discussing the experiment to show the multiplier properties of the model regarding U.S. government spending on goods (G) and on transfer payments (TR). (Both G and TR are in real terms.) Table 1 presents results from two simulations, one in which G is permanently increased by 1.0 percent of real GDP and one in which TR is permanently increased by 1.0 percent of real GDP. The simulation period is 2009:1–2020:4, and the baseline run is the one discussed in the next section. No other changes were made for the two simulations. In particular, no tax increases were imposed to pay for the increased spending. These simulations are not meant to be realistic (or desirable) policy actions. They are simply meant to illustrate the properties of the model.

Table 1 shows that the peak G multiplier for output is 1.96 after 4 quarters. The multiplier settles down to about 1.1 after about 16 quarters. The peak TR multiplier for output is about 1.1 after about 6 quarters. The multiplier settles down to about 0.4 after about 18 quarters. Physical stock effects, interest rate effects, and price effects are the main reasons for the decline in the multipliers after the peak. By 2020:4 the debt/GDP ratio has risen by 7.57 percentage points in the G case and by 9.65 percentage point in the TR case. The larger rise in the transfer payments case is because of the smaller output increases (and thus smaller tax increases).

Table 2 presents estimated standard errors of the multipliers. These values are computed using a bootstrap procedure, which is explained in the appendix. The procedure is roughly as follows. Using the historically estimated errors as a base, new data sets are created by drawing from this base and solving the model. For each new data set the model is reestimated, yielding a new vector of coefficient estimates. Given these new coefficient estimates and the new data, the multiplier

Table 1
Government Spending Multipliers
Deviations from Baseline in Percentage Points

qtr	Y	U	P	r	debt	Y	U	P	r	debt
	Spending on Goods (G)					Spending on Transfer Payments (TR)				
2009.1	1.04	-0.23	0.02	0.17	-0.24	0.25	-0.05	-0.01	0.04	0.14
2009.2	1.64	-0.51	0.10	0.44	-0.39	0.55	-0.16	0.00	0.13	0.22
2009.3	1.88	-0.74	0.21	0.66	-0.38	0.81	-0.28	0.03	0.25	0.31
2009.4	1.96	-0.88	0.34	0.77	-0.37	0.99	-0.39	0.09	0.35	0.38
2010.1	1.94	-0.97	0.45	0.82	-0.33	1.08	-0.48	0.15	0.42	0.47
2010.2	1.87	-1.00	0.57	0.86	-0.26	1.10	-0.54	0.22	0.47	0.58
2010.3	1.77	-0.99	0.67	0.87	-0.15	1.07	-0.57	0.29	0.50	0.72
2010.4	1.67	-0.95	0.76	0.86	-0.02	1.01	-0.57	0.35	0.51	0.89
2011.1	1.57	-0.89	0.82	0.82	0.14	0.94	-0.55	0.41	0.50	1.09
2011.2	1.49	-0.82	0.87	0.78	0.32	0.86	-0.51	0.45	0.48	1.30
2011.3	1.41	-0.75	0.91	0.73	0.50	0.77	-0.46	0.49	0.44	1.52
2011.4	1.34	-0.68	0.93	0.68	0.70	0.70	-0.41	0.51	0.41	1.76
2012.1	1.29	-0.62	0.94	0.63	0.90	0.63	-0.35	0.52	0.37	2.00
2012.2	1.24	-0.56	0.94	0.59	1.11	0.57	-0.30	0.53	0.33	2.24
2012.3	1.20	-0.51	0.93	0.55	1.32	0.52	-0.25	0.53	0.29	2.48
2012.4	1.16	-0.47	0.92	0.51	1.54	0.47	-0.22	0.52	0.26	2.73
2013.1	1.13	-0.43	0.92	0.48	1.75	0.44	-0.18	0.52	0.24	2.97
2013.2	1.11	-0.40	0.91	0.46	1.96	0.42	-0.16	0.51	0.22	3.21
2013.3	1.09	-0.38	0.89	0.44	2.17	0.40	-0.14	0.51	0.20	3.44
2013.4	1.08	-0.37	0.89	0.42	2.37	0.38	-0.13	0.50	0.19	3.67
2014.1	1.07	-0.36	0.88	0.41	2.57	0.38	-0.12	0.50	0.18	3.90
2014.2	1.06	-0.35	0.88	0.40	2.77	0.37	-0.12	0.50	0.18	4.12
2014.3	1.06	-0.34	0.88	0.39	2.97	0.37	-0.12	0.51	0.18	4.34
2014.4	1.06	-0.34	0.88	0.39	3.17	0.38	-0.13	0.51	0.18	4.55
2015.1	1.06	-0.34	0.89	0.39	3.36	0.38	-0.13	0.52	0.18	4.76
2015.2	1.06	-0.34	0.89	0.39	3.55	0.39	-0.14	0.53	0.19	4.98
2015.3	1.06	-0.34	0.90	0.38	3.74	0.39	-0.15	0.54	0.19	5.19
2015.4	1.06	-0.35	0.91	0.38	3.93	0.40	-0.16	0.56	0.20	5.40
2016.1	1.06	-0.35	0.92	0.38	4.12	0.41	-0.17	0.57	0.20	5.60
2016.2	1.07	-0.36	0.92	0.38	4.31	0.41	-0.18	0.59	0.21	5.81
2016.3	1.07	-0.36	0.93	0.38	4.49	0.42	-0.19	0.60	0.22	6.02
2016.4	1.08	-0.37	0.94	0.38	4.68	0.43	-0.20	0.62	0.22	6.23
2017.1	1.08	-0.37	0.94	0.38	4.87	0.43	-0.21	0.63	0.23	6.44
2017.2	1.09	-0.38	0.95	0.38	5.05	0.44	-0.22	0.64	0.23	6.65
2017.3	1.10	-0.39	0.95	0.39	5.24	0.45	-0.23	0.65	0.23	6.87
2017.4	1.10	-0.39	0.95	0.39	5.42	0.45	-0.23	0.66	0.24	7.08
2018.1	1.11	-0.40	0.95	0.39	5.61	0.46	-0.24	0.67	0.24	7.29
2018.2	1.12	-0.40	0.95	0.39	5.79	0.46	-0.25	0.68	0.24	7.51
2018.3	1.12	-0.41	0.95	0.39	5.98	0.46	-0.25	0.68	0.25	7.72
2018.4	1.13	-0.42	0.95	0.39	6.16	0.47	-0.26	0.69	0.25	7.94
2019.1	1.14	-0.42	0.95	0.39	6.34	0.47	-0.26	0.69	0.25	8.15
2019.2	1.14	-0.43	0.95	0.39	6.52	0.47	-0.27	0.70	0.25	8.37
2019.3	1.15	-0.44	0.94	0.39	6.70	0.47	-0.27	0.70	0.26	8.58
2019.4	1.15	-0.44	0.94	0.40	6.88	0.47	-0.28	0.71	0.26	8.80
2020.1	1.15	-0.45	0.94	0.40	7.06	0.47	-0.28	0.71	0.26	9.02
2020.2	1.16	-0.45	0.94	0.40	7.23	0.47	-0.28	0.71	0.26	9.23
2020.3	1.16	-0.45	0.94	0.40	7.40	0.46	-0.29	0.72	0.26	9.44
2020.4	1.16	-0.46	0.94	0.41	7.57	0.46	-0.29	0.73	0.27	9.65

• percent deviations for Y and P, absolute deviations for U, r, and $debt$.
Y = real GDP, U = unemployment rate, P = GDP deflator, r = three-month Treasury bill rate, $debt$ = federal government debt/GDP ratio.

Table 2
Estimated Standard Errors of Government Spending Multipliers
Deviations from Baseline in Percentage Points

qtr	Y	U	P	r	debt	Y	U	P	r	debt
		Spending on Goods (G)				Spending on Transfer Payments (TR)				
2009.1	1.04	-0.23	0.02	0.17	-0.24	0.25	-0.05	-0.01	0.04	0.14
	(0.073)	(0.036)	(0.009)	(0.037)	(0.167)	(0.035)	(0.011)	(0.003)	(0.011)	(0.038)
2009.2	1.64	-0.51	0.10	0.44	-0.39	0.55	-0.16	0.00	0.13	0.22
	(0.096)	(0.059)	(0.017)	(0.078)	(0.283)	(0.069)	(0.027)	(0.006)	(0.028)	(0.085)
2009.3	1.88	-0.74	0.21	0.66	-0.38	0.81	-0.28	0.03	0.25	0.31
	(0.115)	(0.071)	(0.029)	(0.092)	(0.353)	(0.104)	(0.043)	(0.011)	(0.046)	(0.133)
2009.4	1.96	-0.88	0.34	0.77	-0.37	0.99	-0.39	0.09	0.35	0.38
	(0.124)	(0.083)	(0.044)	(0.104)	(0.397)	(0.122)	(0.060)	(0.021)	(0.061)	(0.172)
2010.1	1.94	-0.97	0.45	0.82	-0.33	1.08	-0.48	0.15	0.42	0.47
	(0.142)	(0.084)	(0.055)	(0.095)	(0.396)	(0.137)	(0.068)	(0.033)	(0.062)	(0.203)
2010.2	1.87	-1.00	0.57	0.86	-0.26	1.10	-0.54	0.22	0.47	0.58
	(0.166)	(0.097)	(0.069)	(0.100)	(0.432)	(0.142)	(0.073)	(0.046)	(0.065)	(0.217)
2010.3	1.77	-0.99	0.67	0.87	-0.15	1.07	-0.57	0.29	0.50	0.72
	(0.177)	(0.119)	(0.081)	(0.106)	(0.457)	(0.147)	(0.082)	(0.056)	(0.063)	(0.238)
2010.4	1.67	-0.95	0.76	0.86	-0.02	1.01	-0.57	0.35	0.51	0.89
	(0.173)	(0.122)	(0.097)	(0.107)	(0.449)	(0.156)	(0.089)	(0.064)	(0.066)	(0.250)
2011.4	1.34	-0.68	0.93	0.68	0.70	0.70	-0.41	0.51	0.41	1.76
	(0.146)	(0.122)	(0.141)	(0.108)	(0.397)	(0.129)	(0.088)	(0.091)	(0.086)	(0.228)
2012.4	1.16	-0.47	0.92	0.51	1.54	0.47	-0.22	0.52	0.26	2.73
	(0.102)	(0.081)	(0.150)	(0.114)	(0.360)	(0.107)	(0.068)	(0.108)	(0.068)	(0.236)
2013.4	1.08	-0.37	0.89	0.42	2.37	0.38	-0.13	0.50	0.19	3.67
	(0.106)	(0.063)	(0.145)	(0.111)	(0.337)	(0.089)	(0.055)	(0.100)	(0.071)	(0.242)
2014.4	1.06	-0.34	0.88	0.39	3.17	0.38	-0.13	0.51	0.18	4.55
	(0.102)	(0.074)	(0.144)	(0.110)	(0.329)	(0.086)	(0.054)	(0.093)	(0.062)	(0.230)
2015.4	1.06	-0.35	0.91	0.38	3.93	0.40	-0.16	0.56	0.20	5.40
	(0.090)	(0.064)	(0.148)	(0.111)	(0.324)	(0.073)	(0.044)	(0.086)	(0.062)	(0.269)
2016.4	1.08	-0.37	0.94	0.38	4.68	0.43	-0.20	0.62	0.22	6.23
	(0.085)	(0.064)	(0.147)	(0.113)	(0.310)	(0.070)	(0.041)	(0.089)	(0.065)	(0.378)
2017.4	1.10	-0.39	0.95	0.39	5.42	0.45	-0.23	0.66	0.24	7.08
	(0.097)	(0.069)	(0.145)	(0.117)	(0.365)	(0.080)	(0.051)	(0.085)	(0.068)	(0.411)
2018.4	1.13	-0.42	0.95	0.39	6.16	0.47	-0.26	0.69	0.25	7.94
	(0.099)	(0.074)	(0.149)	(0.106)	(0.433)	(0.079)	(0.058)	(0.092)	(0.062)	(0.478)
2019.4	1.15	-0.44	0.94	0.40	6.88	0.47	-0.28	0.71	0.26	8.80
	(0.117)	(0.083)	(0.153)	(0.119)	(0.445)	(0.093)	(0.055)	(0.103)	(0.073)	(0.590)
2020.4	1.16	-0.46	0.94	0.41	7.57	0.46	-0.29	0.73	0.27	9.65
	(0.116)	(0.095)	(0.165)	(0.126)	(0.550)	(0.103)	(0.072)	(0.103)	(0.089)	(0.633)

- See notes to Table 1.
- Estimated standard errors in parentheses.

experiment is performed and the multipliers are recorded. Doing this, say, N times results in N values of each multiplier, from which measures of dispersion can be computed. The estimated standard errors in Table 2 are based on 100 trials. The formula used for the estimated standard errors is presented in the appendix. This procedure does not require any assumption about the distribution of the error terms in the model since the drawing is from the historically estimated errors.

The results in Table 2 show that the estimated standard errors are generally small relative to the size of the multipliers. For example, the four-quarter-ahead G multiplier for output of 1.96 has an estimated standard error of 0.124. For the 48-quarter-ahead G multiplier for the debt/GDP ratio of 7.57, the estimated standard error is 0.550. There is somewhat less precision relative to the size of the multiplier for the transfer payment experiment, where the four-quarter-ahead TR multiplier for output of 0.99 has an estimated standard error of 0.122. The fairly low estimated standard errors are consistent with results in Fair (2004), which show that uncertainty from estimated coefficients is generally small relative to uncertainty from structural error terms. Multiplier uncertainty is from the uncertainty of the coefficient estimates and not also from the uncertainty of the structural error terms because the latter cancel out when computing multipliers.[3]

3 The Stimulus Experiment

Stimulus Changes

The results in this paper are based on actual data through 2009:4 (data available as of January 30, 2010). The simulation period is 2009:1–2020:4, 48 quarters. The baseline values for 2009:1–2009:4 are the actual values, and the baseline values for 2010:1–2020:4 are values from a forecast I made on January 30, 2010. These

[3]This is exactly true for a linear model and close to being true for typical macroeconometric models—see footnote 8 in the appendix.

values are on my website and are values used in Fair (2010) to examine possible consequences of future federal government deficits. This forecast incorporates the stimulus measures (since the stimulus was passed).

The simulation that was run for the experiment has the stimulus measures taken away. In order to do this, the stimulus measures have to be chosen. This was done as follows. The stimulus bill has tax cuts, transfer payment increases, and increases in government purchases of goods and services. (Unless otherwise stated, "government" in what follows means federal government.) Some of the transfers are to state and local governments and some are directly to households. In the model it makes no difference whether the federal government makes transfer payments directly to households or makes them to state and local governments if the state and local governments in turn pass on the transfer payments to households. In either case there is an increase in disposable income of the household sector. To keep matters simple in the present experiment, all transfer payment increases are put into federal transfer payments to households. In addition, tax cuts are taken to be increases in transfer payments to households rather than decreases in the personal income tax rate in the model. Most of the tax cuts do not involve cutting tax rates, and so it seems better to put them into transfer payments. Therefore, only two variables are changed for the stimulus experiment, federal transfer payments to households and federal purchases of goods and services.

The timing of expenditures is a major issue in trying to capture the effects of any stimulus package. I have roughly followed the CBO (2009) timing for the present experiment. I have assumed that the nominal value of transfer payments is \$172 billion larger in fiscal 2009, \$370 billion larger in fiscal 2010, \$103 billion larger in fiscal 2011, \$12 billion larger in fiscal 2012, and \$11 billion larger (at an annual rate) in 2012:4. I have roughly spread these increases evenly within the four quarters of the fiscal year. I have assumed that nominal government spending on goods is \$21 billion larger at an annual rate in 2009:2, \$29 billion larger at an annual rate in 2009:3, \$29 billion larger in fiscal 2010, \$31 billion larger is fiscal 2011, \$24 billion larger in fiscal 2012, and \$17 billion larger at an annual rate in 2012:4. No changes in transfer payments and government spending were made for 2009:1. Also, no changes were made after 2012:4. In particular, no tax increases or government spending decreases were imposed. The total nominal government spending increase over the four-year period is \$762 billion, of which \$660 billion is in transfer payments and \$102 billion is in purchases of goods.

The two relevant exogenous policy variables in the model are real federal transfer payments to households, TR, and real federal purchases of goods and services, G.[4] These are the variables changed for the results in Table 1. To get the stimulus increases for G the above nominal increases were divided by predicted values of the government spending deflator from the baseline forecast. Similarly, to get the stimulus increases for TR the above nominal increases were divided by predicted values of the GDP deflator from the baseline forecast. Table 3 presents the stimulus changes for the two variables as a fraction of real GDP from the baseline forecast. The main increases are between 2009:2 and 2010:3. The increases are slightly larger for 2010 than for 2009.

[4]The notation on the website is $TRGHQ$ and COG, but simpler notation is used here.

Table 3
Stimulus Changes for G and TR
Percent of Real GDP in Percentage Points

qtr	G	TR
2009.1	0.00	0.00
2009.2	0.16	2.27
2009.3	0.22	2.64
2009.4	0.22	2.62
2010.1	0.21	2.62
2010.2	0.21	2.60
2010.3	0.21	2.57
2010.4	0.22	0.71
2011.1	0.21	0.70
2011.2	0.21	0.68
2011.3	0.20	0.67
2011.4	0.16	0.07
2012.1	0.15	0.07
2012.2	0.15	0.07
2012.3	0.14	0.07
2012.4	0.10	0.07

Results

As noted above, the baseline values are actual values for 2009:1–2009:4 and forecast values for 2010:1–2020:4.[5] If the actual residuals for 2009:1–2009:4 are added to the model (with zero residuals used for 2010:1–2020:4) and a simulation is run for the 2009:1–2020:4 period, the solution values reproduce the baseline values. (Zero residuals are used for 2010:1–2020:4 because these were used for the forecast.) In order to have the experiment with the stimulus measures taken out be consistent with this, the same (actual) residuals for 2009;1–2009:4 were used (with zero residuals used for 2010:1–2020:4). Given these residuals and the

[5]For countries other than the United States not all variable values were available through 2009:4, and when necessary missing values were chosen ahead of time (usually by simple extrapolation).

new (lower) values of G and TR, the model was solved for 2009:1–2020:4. This solution is the model's estimate of what the world economy would have been like had there been no stimulus bill. Results are presented in Tables 4 and 5 for selected variables. Table 4 presents results for the United States, and Table 5 presents results for other countries. Note that the only changes made were to G and TR. No future tax increases or spending cuts were imposed to pay for some of the stimulus. This experiment thus does not necessarily represent a realistic (or desirable) long run policy. It is simply examining the macroeconomic consequences of the stimulus bill with no other changes made. The values in Tables 4 and 5 are baseline values divided by or subtracted from the predicted no-stimulus values.

Values are presented in Table 4 for real GDP, employment, the unemployment rate, the GDP deflator, the three-month Treasury bill rate, the ratio of federal interest payments to GDP, the ratio of the federal government deficit to GDP, and the ratio of the federal government debt to GDP. The cyclical features of the model are immediately evident from Table 4. The stimulus in 2009–2011 has negative effects afterwards. These effects are mostly from the negative stock effects (durable stock, housing stock, and capital stock) that were discussed in Section 2. There are also slight negative effects from the higher price level and the higher level of interest rates.

The peak output effect is in 2010:3, where output is 3.62 percent larger. The peak employment effect is in 2010:4, where employment is 3.07 percent larger (3.757 million jobs). In this quarter the unemployment rate is 1.76 percentage points lower. The GDP deflator effect reaches a peak in 2011:4, where the GDP deflator is 1.52 percent higher. The increase in the three-month Treasury bill rate

Table 4
Estimated Stimulus Effects
Baseline Values Divided By or Subtracted From Predicted No-Stimulus Values
Percentage Points

qtr	Y	J	U	P	r	int	def	debt	J[a]
2009.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
2009.2	0.72	0.22	-0.16	-0.02	0.12	0.01	2.24	0.27	271.
2009.3	1.69	0.67	-0.47	0.01	0.16	0.02	2.42	0.48	825.
2009.4	2.51	1.25	-0.84	0.13	0.06	0.03	2.16	0.59	1528.
2010.1	3.12	1.86	-1.21	0.30	0.12	0.03	1.98	0.69	2264.
2010.2	3.49	2.42	-1.52	0.53	0.36	0.04	1.86	0.83	2945.
2010.3	3.62	2.88	-1.74	0.78	0.73	0.06	1.79	1.04	3507.
2010.4	3.13	3.07	-1.76	1.06	0.91	0.07	0.13	1.12	3757.
2011.1	2.39	2.99	-1.60	1.27	0.85	0.10	0.31	1.44	3687.
2011.2	1.67	2.71	-1.32	1.42	0.66	0.12	0.51	1.84	3381.
2011.3	1.08	2.34	-0.98	1.49	0.45	0.15	0.68	2.25	2942.
2011.4	0.44	1.87	-0.61	1.52	0.22	0.17	0.23	2.60	2378.
2012.1	-0.08	1.37	-0.25	1.48	-0.02	0.19	0.39	2.95	1763.
2012.2	-0.43	0.90	0.07	1.38	-0.25	0.20	0.51	3.27	1167.
2012.3	-0.64	0.48	0.32	1.25	-0.44	0.22	0.58	3.54	638.
2012.4	-0.79	0.14	0.51	1.10	-0.58	0.22	0.59	3.78	183.
2013.1	-0.95	-0.17	0.65	0.96	-0.68	0.23	0.49	4.01	-225.
2013.2	-1.00	-0.41	0.73	0.80	-0.76	0.23	0.51	4.17	-552.
2013.3	-0.97	-0.58	0.76	0.65	-0.79	0.23	0.51	4.28	-785.
2013.4	-0.88	-0.68	0.74	0.52	-0.78	0.23	0.48	4.35	-927.
2014.1	-0.78	-0.72	0.68	0.41	-0.74	0.22	0.45	4.38	-995.
2014.2	-0.66	-0.72	0.60	0.32	-0.68	0.21	0.42	4.39	-1002.
2014.3	-0.54	-0.69	0.51	0.25	-0.62	0.21	0.37	4.38	-962.
2014.4	-0.43	-0.64	0.41	0.20	-0.55	0.20	0.33	4.34	-888.
2015.1	-0.33	-0.57	0.32	0.16	-0.47	0.19	0.29	4.31	-794.
2015.2	-0.24	-0.49	0.23	0.15	-0.40	0.18	0.25	4.25	-689.
2015.3	-0.15	-0.41	0.15	0.14	-0.33	0.17	0.21	4.20	-578.
2015.4	-0.08	-0.33	0.08	0.14	-0.27	0.16	0.18	4.13	-467.
2016.1	-0.03	-0.26	0.02	0.14	-0.22	0.16	0.15	4.07	-362.
2016.2	0.02	-0.19	-0.03	0.14	-0.18	0.15	0.13	4.01	-265.
2016.3	0.06	-0.12	-0.07	0.15	-0.14	0.15	0.10	3.94	-176.
2016.4	0.09	-0.07	-0.10	0.16	-0.10	0.14	0.09	3.88	-96.
2017.1	0.11	-0.02	-0.12	0.16	-0.08	0.14	0.07	3.83	-28.
2017.2	0.13	0.02	-0.14	0.16	-0.06	0.13	0.06	3.77	31.
2017.3	0.14	0.06	-0.15	0.17	-0.04	0.13	0.05	3.72	81.
2017.4	0.15	0.08	-0.16	0.17	-0.02	0.13	0.04	3.67	122.
2018.1	0.16	0.11	-0.16	0.17	-0.01	0.13	0.04	3.62	156.
2018.2	0.16	0.13	-0.16	0.17	0.00	0.13	0.04	3.58	182.
2018.3	0.16	0.14	-0.16	0.16	0.01	0.13	0.03	3.53	203.
2018.4	0.16	0.15	-0.15	0.16	0.02	0.13	0.03	3.49	219.
2019.1	0.16	0.16	-0.15	0.16	0.02	0.13	0.04	3.45	230.
2019.2	0.16	0.16	-0.15	0.16	0.03	0.13	0.04	3.41	238.
2019.3	0.15	0.17	-0.14	0.16	0.04	0.13	0.04	3.37	243.
2019.4	0.15	0.17	-0.14	0.16	0.04	0.14	0.05	3.34	246.
2020.1	0.15	0.17	-0.13	0.16	0.05	0.14	0.05	3.30	247.
2020.2	0.14	0.17	-0.13	0.17	0.05	0.14	0.06	3.26	246.
2020.3	0.14	0.16	-0.12	0.17	0.06	0.14	0.06	3.23	244.
2020.4	0.13	0.16	-0.12	0.18	0.06	0.14	0.07	3.19	240.

[a] thousands of jobs.
- percent deviations for Y, J, and P, absolute deviations for U, r, int, def, and $debt$.
- sum of Y changes = $554 billion (0.29 percent).
- average of J changes = 509 thousand (0.37 percent), average U changes = -0.17.
- in 2020:4 federal debt larger by $1005 billion ($637 billion in real terms).

Y = real GDP, J = employment (jobs), U = unemployment rate, P = GDP deflator,
r = three-month Treasury bill rate, int = federal interest payments/GDP ratio,
def = federal deficit/GDP ratio, $debt$ = federal government debt/GDP ratio.

Table 5
Estimated Stimulus Effects: Other Countries
Baseline Values Divided By Predicted No-Stimulus Values
Percentage Points

qtr	Y_{ca}	Y_{ja}	Y_{uk}	Y_{ge}	Y_{fr}	Y_{me}	Y_{ch}	Y_{id}
2009.1	0.00	0.00	0.00	0.00	0.00			
2009.2	0.16	0.01	0.01	0.02	0.01			
2009.3	0.49	0.04	0.04	0.06	0.03			
2009.4	0.95	0.08	0.08	0.11	0.06	0.53	0.12	0.03
2010.1	1.50	0.14	0.13	0.18	0.10			
2010.2	2.12	0.20	0.19	0.26	0.14			
2010.3	2.76	0.26	0.25	0.34	0.19			
2010.4	3.26	0.31	0.31	0.42	0.23	2.83	0.61	0.13
2011.1	3.62	0.36	0.35	0.48	0.27			
2011.2	3.82	0.38	0.39	0.54	0.30			
2011.3	3.89	0.39	0.41	0.58	0.32			
2011.4	3.79	0.39	0.41	0.59	0.33	3.75	0.76	0.17
2012.1	3.54	0.38	0.40	0.61	0.34			
2012.2	3.16	0.36	0.38	0.60	0.33			
2012.3	2.69	0.33	0.34	0.57	0.31			
2012.4	2.15	0.30	0.29	0.52	0.27	2.51	0.45	0.12
2013.1	1.57	0.26	0.26	0.48	0.25			
2013.2	0.98	0.23	0.22	0.41	0.21			
2013.3	0.41	0.19	0.17	0.33	0.16			
2013.4	-0.14	0.17	0.13	0.24	0.11	0.86	0.08	0.05
2014.1	-0.63	0.13	0.10	0.16	0.08			
2014.2	-1.06	0.11	0.07	0.07	0.05			
2014.3	-1.42	0.09	0.05	-0.01	0.01			
2014.4	-1.71	0.08	0.03	-0.09	-0.01	-0.15	-0.12	0.00
2015.1	-1.93	0.06	0.01	-0.18	-0.03			
2015.2	-2.08	0.05	0.00	-0.24	-0.04			
2015.3	-2.17	0.05	-0.01	-0.30	-0.04			
2015.4	-2.18	0.05	-0.02	-0.34	-0.04	-0.47	-0.16	-0.03
2016.1	-2.14	0.04	-0.02	-0.40	-0.04			
2016.2	-2.04	0.04	-0.02	-0.42	-0.03			
2016.3	-1.89	0.05	-0.02	-0.43	-0.01			
2016.4	-1.70	0.06	-0.01	-0.43	0.01	-0.38	-0.10	-0.04
2017.1	-1.48	0.06	-0.01	-0.44	0.02			
2017.2	-1.23	0.06	0.00	-0.42	0.05			
2017.3	-0.95	0.07	0.01	-0.39	0.07			
2017.4	-0.67	0.08	0.02	-0.34	0.10	-0.15	-0.03	-0.04
2018.1	-0.37	0.09	0.03	-0.31	0.12			
2018.2	-0.08	0.09	0.04	-0.26	0.14			
2018.3	0.20	0.10	0.05	-0.20	0.16			
2018.4	0.47	0.11	0.07	-0.14	0.18	0.06	0.03	-0.04
2019.1	0.72	0.12	0.08	-0.09	0.19			
2019.2	0.94	0.12	0.09	-0.03	0.21			
2019.3	1.14	0.13	0.10	0.03	0.22			
2019.4	1.31	0.13	0.11	0.08	0.22	0.22	0.06	-0.03
2020.1	1.44	0.14	0.12	0.13	0.23			
2020.2	1.54	0.15	0.12	0.17	0.23			
2020.3	1.60	0.15	0.12	0.20	0.23			
2020.4	1.63	0.15	0.12	0.23	0.22	0.33	0.07	-0.02

Y = real GDP
ca = Canada, ja = Japan, uk = United Kingdom, ge = Germany, fr = France, me = Mexico, ch = China, id = India.
Values for Mexico, China, and India are yearly.

from the estimated Fed rule reaches a peak in 2010:4 at 0.91 percentage points.

After the stimulus measures are over in 2012, the negative cyclical features begin to kick in. The peak negative output effect is in 2013:2, where output is 1.00 percent lower. It is interesting to see how much difference the stimulus bill made over the entire 12 year period. The sum of the real output changes over the 48 quarters is $554 billion (2005 dollars), which is 0.29 percent of the sum of total real output. The average number of jobs is larger by 509 thousand jobs, which is 0.37 percent of the average number of jobs. The unemployment rate is on average 0.17 percentage points lower.

Since no tax rate increases or government spending decreases were imposed in the new simulation, federal government interest payments, the federal government deficit, and the federal government debt all increased relative to nominal GDP. By the end of 2020 the debt/GDP ratio is 3.19 percentage points larger (although not shown, from 67.00 percentage points without the stimulus to 70.19 points with the stimulus). Interest payments are larger because of the larger debt and the higher interest rates, and the deficit is larger primarily because of the increased interest payments.

As noted at the bottom of Table 4, the nominal federal government debt is $1,005 billion larger in 2020:4. Dividing this figure by the value of the GDP deflator in 2020:4 gives a value of $637 billion in 2005 dollars. This compares to the sum of the real output gain of $554 billion. Again, the increase in interest payments is an important factor in increasing the debt. Comparing $554 billion to $637 billion, which may seem an obvious comparison to make, ignores discounting. The output gains occurs essentially in the first three years, and the debt increase slowly occurs over time. More will be said about this in the Conclusion.

Table 5 presents output results for other countries. Canada and Mexico have large effects. For China the peak output effect occurs after three years, at 0.76 percent. The cyclical features of the model are also evident in Table 5; they are driven by the cyclical effects on the United States. Results for other countries and variables are available on my website.

Uncertainty Estimates

The bootstrap procedure used for the results in Table 2 can be used to estimate standard errors for the stimulus experiment. This was done using 100 trials. Again, the estimated standard errors are small relative to the size of the effects. For the sum of the output changes of $554 billion, the estimated standard error is $71 billion; for the average unemployment rate change of -0.17, the estimated standard error is 0.027; and for the average of the employment changes of 509 thousand jobs, the estimated standard error is 69 thousand jobs.

The estimated uncertainty here is much smaller than that used by the CBO (2010) in their analysis of the stimulus bill. Table 6 compares the CBO ranges with the present results for 2009:1–2010:4. In almost every case an estimate here is within the CBO range. Since the CBO ranges are large, it is, of course, not surprising that the current estimates are within the ranges.

Table 6 also presents the estimated standard errors of the current stimulus estimates. For example, the estimated 3.6 percent increase in output for 2010:3 has an estimated standard error of 0.45 percent. This compares to the CBO low and high estimates of 1.3 percent and 4.0 percent, respectively.

Table 6
Current Stimulus Estimates Versus
CBO (2010) Ranges
Baseline Values Divided By
or Subtracted From
No-Stimulus Values
Percentage Points

Output

qtr	CBO low	CBO high	current	standard error
2009.1	0.1	0.1	0.0	0.00
2009.2	0.9	1.5	0.7	0.09
2009.3	1.3	2.7	1.7	0.19
2009.4	1.5	3.5	2.5	0.30
2010.1	1.5	3.9	3.1	0.37
2010.2	1.7	4.5	3.5	0.41
2010.3	1.3	4.0	3.6	0.45
2010.4	1.1	3.4	3.1	0.42

Unemployment Rate

qtr	CBO low	CBO high	current	standard error
2009.1	0.0	0.0	0.0	0.00
2009.2	-0.2	-0.3	-0.2	0.03
2009.3	-0.4	-0.7	-0.5	0.08
2009.4	-0.5	-1.1	-0.8	0.12
2010.1	-0.6	-1.5	-1.2	0.16
2010.2	-0.7	-1.8	-1.5	0.19
2010.3	-0.7	-1.9	-1.7	0.23
2010.4	-0.7	-1.9	-1.8	0.25

Employment[a]

qtr	CBO low	CBO high	current	standard error
2009.1	0.0	0.0	0.0	0.00
2009.2	0.3	0.5	0.2	0.03
2009.3	0.7	1.3	0.5	0.09
2009.4	1.0	2.1	1.0	0.13
2010.1	1.2	2.7	1.4	0.19
2010.2	1.4	3.3	1.8	0.25
2010.3	1.3	3.5	2.2	0.29
2010.4	1.2	3.4	2.2	0.30

[a] employment is the number of people employed, not the number of jobs.

4 Conclusion

This paper provides estimates of the effects on the world economy from the 2009 U.S. stimulus bill. It has the advantage of taking into account many endogenous effects. The results show that the output and employment effects over 12 years are positive, with some redistribution away from 2012–2015 and with an increase in the federal debt/GDP ratio. The estimated standard errors of the stimulus estimates are fairly low.

An interesting question is that conditional on the current results being accurate, was the stimulus bill a good idea? Ignoring redistribution issues, the main cost would seem to be the increased government debt. How should one think about the $637 billion real increase in the debt? If there are no bad asset market reactions due to the larger debt levels, the macro costs of the debt increase might be considered minor. There is nothing in the MC model that predicts bad macro outcomes from a rising debt/GDP ratio. The story is, of course, changed if there are in fact bad asset market reactions, like a large dollar devaluation, a large fall in U.S. stock prices, or a large increase in interest rates on U.S. government securities because of added risk. These reactions cannot be predicted since asset-market changes are essentially unpredictable, which makes it hard to know how to weight the potential cost of a rising debt/GDP ratio. This issue is discussed in Fair (2010). All that can be said from the current results is that the stimulus bill led (or will lead) to an increase in real output over the 12-year period of $554 billion (0.29 percent) and an increase in the average level of employment of 509 thousand jobs (0.37 percent). The costs are 1) some redistribution of output and employment away from 2012–2015 and 2) some increased risk of bad asset-market reactions from a larger debt/GDP ratio.

Appendix: Computing Standard Errors

There are 1,604 estimated equations in the MC model, of which 1,302 are trade share equations. The estimation period for the United States is 1954:1–2009:4. The estimation periods for the other countries begin as early as 1962:1 and end as late as 2009:3. The estimation period for most of the trade share equations is 1966:1–2008:4. For each estimated equation there are estimated residuals over the estimation period. Let $\hat{u}_t$ denote the 1604-dimension vector of the estimated residuals for quarter t.[6] Most of the estimation periods have the 1972:1–2007:4 period—144 quarters– in common, and this period is taken to be the "base" period. These 144 observations on $\hat{u}_t$ are used for the draws in the bootstrap procedure discussed below.[7]

The solution period used to create new data is 1954:1–2020:4—268 quarters. For a given set of coefficient estimates and error terms, the model can be solved dynamically over this period. Equations enter the solution as data become available. For example, for the period 1954:1–1959:4 only the equations for the United

[6]For equations estimated using annual data, the error is put in the first quarter of the year with zeros in the other three quarters (which are never used). If the initial estimate of an equation suggests that the error term is serially correlated, the equation is reestimated under the assumption that the error term follows an autoregressive process (usually first order). The structural coefficients in the equation and the autoregressive coefficient or coefficients are jointly estimated (by 2SLS). The $\hat{u}_t$ error terms are after adjustment for any autoregressive properties, and they are taken to be iid for purposes of the draws.

[7]If an estimation period does not include all of the 1972:1–2007:4 period, zero errors are used for the missing quarters.

States are used. The links from the other countries to the United States are shut off, and the U.S. variables that these links affect are taken to be exogenous. By 1972 almost all the equations are being used. Actual data for the United States end in 2009:4 and somewhat earlier for the other countries. Exogenous variable values from the end of the actual data through 2020:4 are the ones that were chosen for the baseline forecast made in January 30, 2010, which is used in the text.

Each trial of the bootstrap procedure is as follows. First, 268 error vectors are drawn with replacement from the 144 vectors in the base period. (Each vector consists of 1,604 errors.) Using these errors and the coefficient estimates base on the actual data, the model is solved dynamically over the 1954:1–2020:4 period. Using the solution values as the new data set, the 1,604 equations are reestimated. Given these new coefficient estimates and the new data, the stimulus experiment is performed for the 2009:1–2020:4 period—as in Tables 4 and 5.[8] The multipliers

[8]Given the new data and new coefficient estimates, residuals can be computed for the 2009:1–2020:4 period—1,064 residuals for each quarter. If these residuals are added to the model and the model is solved for the 2009:1–2020:4 period, the solution values reproduce the values in the new data set. This is taken to be the baseline run. These residuals and the no-stimulus values of G and TR are then used for the no-stimulus solution. These no-stimulus solution values can then be compared to the values in the new data set to estimate the stimulus effects.

Another procedure for the stimulus experiment is the following. Compute the new data set and new coefficient estimates as above. Then for trial i draw from the historical error distribution (the 144 observations on $\hat{u}_t$) errors for 2009:1–2020:4. Given these errors, the new data set, and the new coefficient estimates, solve the model twice, once using the stimulus values of G and TR and once using the no-stimulus values. For each variable and quarter record the difference between the two solution values. Do M trials, which gives M values of each difference. Compute the mean of the M values for each difference, and take this as the expected value of the stimulus effect. This procedure is a bootstrap within a bootstrap. For a linear model this procedure is not necessary because the errors cancel out and so each trial gives exactly the same difference for each variable and quarter. For a nonlinear model (which the MC model is) this is not the case, but a common property of models like the MC model—see Fair (2004)—is that predicted values from deterministic simulations are close to mean values from stochastic simulations. This means in the present context that mean values from the second bootstrap procedure would be close to the values computed using the one set of residuals. This second bootstrap procedure was not used here.

are recorded. This is one trial. The procedure is then repeated, say, N times. (Note that the coefficient estimates used to generate the new data on each trial are the estimates based on the actual data.) This gives N values of each multiplier, from which measures of dispersion can be computed.

The measure of dispersion used in the text is as follows. Rank the N values of a given multiplier by size. Let m_r denote the value below which r percent of the values lie. The measure of dispersion is $(m_{.8413} - m_{.1587})/2$. For a normal distribution this is one standard error.

The experiment done after each new data set and new set of coefficient estimates can be any experiment. For the results in this paper three experiments were done using 100 trials each. Two are the ones in Tables 1 and 2 and one is the stimulus experiment. The same random numbers were generated for each experiment, which avoids noise in comparing across experiments. There were 8 solution failures for each experiment. When a failure occurred, a new draw was taken, so the number of good trials was 100 (not 92). Ignoring solution failures is likely to bias downward the estimated standard errors, although there is no obvious way to estimate by how much.

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