# Fiscal Stabilization and the Credibility of the U.S. Budget Sequestration Spending Austerity*

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**Abstract**

Structural fiscal imbalances are typically addressed with stabilization programs that display similarities and differences in timing, design, and scope. These programs' ability to succeed may depend on their credibility, a point well established by the time inconsistency of optimal plans literature. A formal assessment of that credibility, however, is often lacking in debates provoked by the diversity of responses those programs have elicited from observed macroeconomic variables. This paper provides just such an assessment for the most recent attempt to restore fiscal sustainability in the U.S.: the so-called budget sequestration spending cuts triggered in 2013 by legislation enacted in 2011. The paper assesses the credibility of the spending cuts targeted by the budget sequestration with a novel methodology that draws its elements from the "event-study" and Business Cycle Accounting traditions. The main finding of the paper is that the budget sequestration spending cuts scheduled for 2014 and beyond enjoyed little, if any credibility, during the relevant 2012–13 event-study window. Studies evaluating the outcomes of the budget sequestration spending cuts should take that finding into account, before jumping to the conclusion that similar programs will deliver a similar performance. More generally, the policy recommendations suggested by the observed outcomes of fiscal stabilization programs might be misleading, absent consideration of the extent to which they were perceived as sustainable. In that regard the paper contributes a methodology suitable for such an assessment, useful for a future research agenda exploring what may be still undiscovered connections between the credibility of fiscal stabilization programs when launched, their timing and design, their macroeconomic effects, and their ultimate success or failure in correcting fiscal imbalances.

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*The views expressed herein do not necessarily reflect those of the Federal Reserve Bank of Dallas, or of the Federal Reserve System.

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# 1 Introduction

Government debt escalated significantly following the Great Recession in five of the Group of Seven (G7) advanced economies. In France, Italy, Japan, the United Kingdom, and the United States, general government net debt, as reported by the International Monetary Fund, rose by about 30 to 50 percentage points of GDP between 2007 and 2015. That debt represented at least 80% of GDP in those G7 nations at the end of the period, an amount large enough to prompt concerns about the sustainability of governments' fiscal policies.

Of particular interest, the U.S. general government net debt nearly doubled, from about 40 percent of GDP in 2007, to 80 percent of GDP in 2012. This surge cannot be attributed solely to the cyclical increase of fiscal deficits in economic downturns, even with the especially deep 2008–09 Great Recession. It was also a byproduct of structural fiscal imbalances predating that contraction.

The Congressional Budget Office (CBO hereafter), a non-partisan federal agency, in a December 2007 report documented that the fiscal policy regime then in place implied an explosive path for the U.S. government debt.[1] A subsequent report by that same agency (CBO, 2010a), found that the Great Recession simply exacerbated the preexisting fiscal imbalances.

Concerned with the negative long-run consequences of those structural imbalances, the Congress passed the Budget Control Act of 2011. An interesting feature of the law was the inclusion of a contingent clause that, starting in 2013, triggered a decade of government consumption expenditure reductions cumulatively totaling the equivalent to about 10% of nominal GDP in 2011. This provision has come to be known generically as "budget sequestration," because its implementation entailed the revocation, or sequestration, of previously authorized expenditures.

The magnitude of the spending cuts has rekindled a debate in academic and policy forums about attempts to correct structural fiscal imbalances by reducing government expenditures and the effects of those cuts on economic activity. The result reported by Alesina and Perotti (1995) that those effects have been positive in several expenditure-based fiscal stabilization programs has been disputed, for example, in an International Monetary Fund (2010) study. Often forgotten in the heat of the discussion is the qualification, hinted at by McDermott and Wescott (1996), that the output effects of those programs depend critically on the extent to which economic agents expect the scheduled spending cuts to be enforced.

The goal of the present paper is precisely to provide an assessment of the credibility of the U.S. budget sequestration spending cuts with a novel methodology. It is one that in principle is applicable to other fiscal stabilization experiences, and for that reason potentially of interest in its own right.

The design of the methodology was guided by the implication of a wide class of economic models that show how different degrees of credibility of future spending cuts affect economic

[1] The CBO obtains the projections of fiscal variables implied by the prevailing policy regime with assumptions captured by an "alternative scenario." The rather close correspondence of that scenario with current policy, rather than with "current law," is documented more explicitly in analyses of the U.S. fiscal situation by the Peterson Foundation. See, for example, Peterson Foundation (2012).

agents' decisions and induce, as a result, a corresponding quantitatively distinctive response in key macroeconomic variables. It should be possible, therefore, to infer with well-accepted statistical tools which of the alternative credibility spending cuts scenarios are more likely to have accounted for the observed performance of those variables over the relevant period.

The methodology proceeds to make that inference by combining two approaches typically used in isolation in the economic literature: an "event study" approach, common in finance and exploited by Ramey and Shapiro (1998) to study the effects of government spending policy shocks, and a "Business Cycle Accounting" (BCA) approach, originally developed by Chari, Kehoe, and McGrattan (2007) to study economic fluctuations within the analytical framework of general equilibrium models.

The motivation for incorporating an event-study perspective into the methodology was the prospect of obtaining a cleaner reading of the credibility of the spending cuts by limiting attention to evidence around the time of their initiation. The focus on a narrow window of time reduces the chances of contamination of responses of macroeconomic variables to that "policy event" from rare though sizable unanticipated shocks from other sources. This advantage was particularly handy, because the U.S. economy started to register the consequences of a large and persistent negative shock to oil prices in 2014. This development, as well as the chronology of events discussed in more detail later, buttress support for confining the evidence relevant for this paper to the years 2012 and 2013.

The BCA analytical framework was incorporated into the methodology adopted for this paper to inspire greater confidence in inferences obtained with a general equilibrium model. This is due to the BCA's ability to accommodate various views of economic environment elements responsible for macroeconomic variables' responses to shocks. On top of being endowed with these desirable properties, the BCA approach renders itself to a state-space representation of the economy that replicates the data exactly. This feature, along with the event-study approach, was key to making inferences about the credibility of alternative budget sequestration spending cuts scenarios with well-accepted likelihood-based techniques.

Implementation of this methodology surmounted three principal empirical challenges. First, measurement issues, which were addressed by treating the data with the "private sector economy" approach suggested by Gomme and Rupert (2007) and by introducing in the model economy an external-like sector in the manner proposed by Trabandt and Uhlig (2011). Secondly, the need to take into account the transitional dynamic effects of a permanent increase in the capital income tax rate scheduled to become effective in 2013 as a result of legislation enacted in 2010. Finally, a lack of consensus about the magnitude of two macroelasticities controlling the size of those transitional effects—the intertemporal elasticity of substitution in consumption and the labor supply Frisch elasticity, resolved by assessing the credibility of alternative spending cuts scenarios for several combinations of values of those parameters.

The main finding of the paper is that, for all those combinations and by the standards of the maximum likelihood criterion, the budget sequestration spending cuts scheduled for 2014 and beyond enjoyed little, if any credibility during the relevant 2012–2013 event-study window.

For the reasons hinted at earlier, that is a finding that should be kept in mind before drawing policy conclusions from discrepancies between the predicted and observed outcomes of attempts to correct fiscal imbalances with spending austerity. The potential contribution of this paper along this dimension can be best illustrated by a brief discussion of the output effects, precisely, of the budget sequestration spending cuts. According to Cashin, Lenney, Lutz, and Peterman (2017), they negatively affected the level of economic activity. The finding in this paper suggests that the magnitude of those effects was determined at least in part by the lack of credibility of the spending austerity. Put differently, the responses of output and other macroeconomic variables could have been qualitatively or quantitatively different were the prospect of spending cuts credible.

More generally, the results reported by studies evaluating the responses of macroeconomic variables to expenditure-based fiscal consolidation programs might be misinterpreted absent a formal assessment of the credibility of the prescribed spending cuts. This paper proposes a methodology suitable for such an assessment. Examination of other fiscal austerity programs with a properly adapted version of the methodology might shed further light on the policy debate generated by program outcomes that do not always coincide with those predicted by theoretical or empirical considerations.

The rest of the paper is organized as follows. Section 2 reviews background material, chronology of events, and measurement issues that motivated many of the assumptions and details of specification of the model presented in Section 3. Section 4 discusses first intuitively, and then in more detail, the adaptation of the BCA approach and the statistical tools that the paper exploits to make inferences about the credibility of the budget sequestration spending cuts. Section 5 reports the findings. Section 6 concludes. An appendix scrutinizes further with Bayesian techniques the findings of the paper for a particularly relevant pair of values of the two macroelasticities identified above.

## 2 Background Material

### 2.1 The Budget Sequestration: Revelent Details and Timeline of Events

Background information on the institutional features of the budget sequestration and a timeline of events leading up to it provides context for several of the modeling choices made in the paper to gauge the credibility of spending cuts prescribed by U.S. legislation enacted in 2011.

Table 1 provides a background for the account below of the historical circumstances, not exempt of dramatic twists, that ultimately ended in the cuts. It identifies by date key developments, along with brief comments regarding their significance relative to the motivation and purpose of this paper.[2]

The road to the budget sequestration started when the Treasury requested on January 6, 2011, that the Congress authorize an increase in the debt ceiling, necessary to roll over the outstanding debt as well as to finance current fiscal deficits. The U.S. government can borrow

[2] Interested readers can find a more detailed chronology in http://www.cnn.com/2011/POLITICS/07/25/debt.talks.timeline/

Table 1: Timeline of Events/Developments Leading up to the Budget Sequestration Cuts

| Date | Event / Development |
|---|---|
| January 6, 2011 | U.S. Treasury requests Congress raise debt ceiling. Routinely granted authorization withheld by lawmakers concerned by explosive debt path projected in a June 2010 CBO report. |
| July 14, 2011 | Debt ceiling nearly reached. Potential inability of U.S. Treasury to meet its obligations prompts Standard & Poor's credit rating agency to place U.S. government debt on "CreditWatch with negative implications." |
| August 2, 2011 | Last-minute deal allows Congress to pass the Budget Control Act, reducing fiscal deficits in two staggered installments. Second installment would trigger a budget sequestration procedure and sizable automatic spending cuts starting in 2013 if a bipartisan Joint Committee can't agree on fiscal reduction measures by January 15, 2012. |
| November 21, 2011 | Joint Committee admits deal to avert automatic spending cuts not possible. |
| Year 2012 | President and Congress vow to find compromise to prevent activation of automatic spending cuts. With some temporary tax cuts expiring, deliberations create opportunity for another last-minute agreement. |
| January 1, 2013 | American Taxpayer Relief Act passed, postponing automatic spending cuts by just two months. |

to finance a revenue shortfall relative to expenditures so long as it doesn't exceed the "debt ceiling" explicitly authorized by Congress. The authorization step is usually a formality, as it simply provides the U.S. Treasury the means to pay for government spending Congress previously approved. At the beginning of 2011, however, a large number of lawmakers were reluctant to rubber stamp the authorization as they had routinely done in the past. They indicated concern with the rapidly growing government debt the CBO had projected.

These legislators demanded, therefore, that any increase in the debt ceiling be accompanied by fiscal deficit reduction measures to blunt debt growth. There was, however, considerable disagreement about the form of those measures, and grueling negotiations to resolve the differences put the U.S. at the brink of a sovereign debt default. A last-minute agreement avoided that outcome. The Budget Control Act was signed into law on August 2, 2011. The law created a bipartisan Joint Select Committee on Deficit Reduction of lawmakers, assigned the task of finding fiscal deficit reduction measures totaling $1.5 trillion (equivalent to about 10% of nominal GDP at the time) over the following decade.

The Budget Control Act included a provision stating that if the Joint Committee failed to propose reductions and Congress subsequently failed to act on deficit cuts totaling at least $1.2 trillion by January 15, 2012, spending caps on discretionary budget authority would be imposed in the cumulative amount just mentioned, starting in January 2, 2013, and lasting through fiscal year 2021.

In practice, this contingent clause would accomplish its $1.2 billion fiscal stabilization goal (inclusive of savings in interest payments on government debt) either with the deliberate measures suggested by the Joint Select Committee or, in their absence, with automatic spending cuts evenly split between across-the-board between discretionary defense and non-defense programs.

The lower spending caps stipulated wouldn't legally apply to previously authorized but not yet materialized spending, an institutional difficulty identified by the CBO (2013, p. 31). The Budget Control Act got around that technicality by ordering the application of "budget sequestration" procedures that revoked (or sequestered) de facto preexisting authority to spend, in the amount needed to conform to the lower caps. This is why the paper refers to all the spending cuts implied by the contingent clause of the Budget Control Act as budget sequestration cuts, even if strictly speaking, sequestration applied only to the budget items that the CBO had noted.

In order to trust that the model below is an adequate abstract representation of the actual economy, it is important to note that the sequestration cuts would affect public sector payrolls only through furloughs of limited duration and scope. Given the lack of a measurable effect on public sector employment, this feature of the legislation turned out to be convenient for circumventing the measurement difficulties hinted at in the introduction. It allows consideration, without loss of realism, of a model economy in which the government doesn't make any contributions to value added and whose spending is captured by the quantity of goods and services that it removes from the private sector.

More relevant is the observation that, if implemented in full, budget sequestration would reduce discretionary spending to the lowest level on record as a share of GDP, according to CBO (2012b) estimates.[3] It didn't seem plausible to treat spending cuts that reduced government consumption and investment that much as a manifestation of one of the many fluctuations that the macroeconomic variable typically exhibited under the existing policy regime. A more appropriate interpretation would appear to be that budget sequestration, if triggered, would represent a decade-long policy regime shift.

For that reason, the model treats the ratio of government absorption of goods and services to private sector output as consisting of two components, rigorously presented in section 3.3.1. The first, an exogenous stochastic component, is meant to capture run-of-the-mill historical fluctuations of that ratio around a long-run mean. The second, a deterministic component, is meant to capture the temporary policy regime change that sequestration would eventually bring.

Back to the chronology of events, the strong incentive to reach an agreement on a fiscal deficits reduction package introduced in the Budget Control Act by the rather blunt budget sequestration threat didn't seem to be working as intended, however, when on November 21, 2011, the Joint Committee announced that, *"after months of hard work and intense delibera-*

[3]More specifically, in table 1 of the cited CBO report, discretionary spending at the end of the sequestration period, in 2021, is projected to represent 5.7% of GDP, the lowest level observed since at least 1972.

*tions,"* it had come to the conclusion that it wouldn't be possible to reach an agreement on an alternative fiscal deficit reduction package before the January 15, 2012 deadline.

That development was sufficiently significant to perhaps induce the private sector to expect the budget sequestration to be effectively launched a year later and for the private sector to adjust its behavior accordingly in 2012. There are also good reasons, however, to be skeptical that that was the case. First, that the Congress would eventually act when faced with sizable cuts eventually impairing the ability of government agencies to adequately perform core functions. Second, negotiations regarding extension of temporary tax cuts enacted in 2001 and 2003 and due to expire in 2012 were viewed as offering legislators a golden opportunity to come up with alternative deficit reduction measures that met the necessary conditions to cancel, or at least suspend budget sequestration. Such speculation may have been reinforced by repeated public statements from Congress and even the President on their determination to find a compromise.[4]

There is, therefore, the distinct possibility that, as of the end of 2012, households and businesses were still dismissing materialization of the policy regime change represented by the budget sequestration. But that may have changed rather dramatically when Congress passed the American Taxpayer Relief Act in early 2013 and modified the tax code as expected, but failed to take any substantial action with respect to sequestration, other than postponing its implementation by two months, from January 2 to March 1, 2013. The law's passage may have convinced households and businesses that the budget sequestration was no longer a distant, unlikely event.

Given the timing of events and circumstances surrounding them, the assessment of the credibility of the budget sequestration cuts required establishing when it was most likely that economic agents would incorporate those cuts in their decisions, as early as 2012 or when they were effectively triggered a year later, in 2013. The observation that an event study approach is particularly well-equipped to confront this challenge was one of the reasons, therefore, to have incorporated it to the methodology developed in this paper.

Finally, another detail with implications for the evidence that will be examined in the paper is that, as mentioned in the introduction, the Health Care and Education Reconciliation Act of 2010 introduced an additional tax of 3.8% on net investment income—a form of capital income taxation—that would enter into effect in 2013, precisely at the same time that the circumstances described above triggered the budget sequestration spending cuts under study.

## 2.2 Spending Cuts in Real Terms

The goal of fiscal stabilization programs is typically to prevent the government debt from ballooning out of control relative to the size of the economy. Their specific measures must be designed, therefore, with the target of reducing fiscal deficits by a certain amount in *real terms*. Given that the Budget Control Act represented an attempt to correct U.S. fiscal imbalances,

[4] In fact, according to press reports, the Department of Defense, one of the federal agencies that would be hit particularly hard by the spending cuts, wasn't making any contingent plans to deal with them as late as September 2012.

Table 2: Annual Budget Sequestration Spending Cuts

| Year | $ Billion (*) | $ Billion Normalized to 2012 Nominal Output | Targeted Spending Cuts | |
|---|---|---|---|---|
| | | | Per Unit of Output in Real Terms | Per Unit of Output in Real Terms, Detrended |
| 2013 | 35 | 0.0025 | 0.0024 | 0.00238 |
| 2014 | 75 | 0.0053 | 0.0051 | 0.00491 |
| 2015 | 85 | 0.0060 | 0.0057 | 0.00534 |
| 2016 | 89 | 0.0063 | 0.0058 | 0.00538 |
| 2017 | 90 | 0.0064 | 0.0058 | 0.00523 |
| 2018 | 90 | 0.0064 | 0.0057 | 0.00502 |
| 2019 | 89 | 0.0063 | 0.0055 | 0.00478 |
| 2020 | 88 | 0.0062 | 0.0053 | 0.00454 |
| 2021 | 87 | 0.0062 | 0.0051 | 0.00431 |

(*): Congressional Budget Office (2013), p. 10 and Table 1-5, p. 27.

such a target must have dictated the size of the spending cuts it prescribed. What should be assessed, therefore, is the credibility of the size of those cuts in real terms targeted by that legislation.

Unfortunately, information about that target is missing from the Budget Control Act or any of the other many official records examined for the purpose of this project. Moreover, as indicated in the previous section, that law lowered existing caps to nominal government spending, with the effect of implying the spending cuts of interest for this paper only in nominal terms.

For the purposes of this project it was necessary, therefore, to convert those nominal spending cuts into ones in real terms. To be informative, any procedure used to that end must start out from a reliable sequence of the nominal spending cuts implied by the Budget Control Act. Fortunately, such a sequence can be readily constructed from the data provided in an analysis of that legislation by the CBO (2013), as summarized in the second column of Table 2.

The third column of the table shows the result of dividing the figures in the second one by the private sector nominal GDP in 2012, the last one that economic agents could observe before the initiation of the budget sequestration in 2013.[5] This algebraic operation simply rescales the sequence of nominal spending cuts to that that would be observed in an economy with a nominal GDP level of one in 2012, but preserving their size relative to the actual level of that variable in the data. The motivation for this intermediate step is that that level of output at its steady-state in the model economy is normalized, precisely, to the value of one.

The normalized spending cuts in the third column of Table 2 are still in nominal terms, because they were obtained making abstraction of inflation. In order to estimate their magni-

[5] Nominal private sector GDP in 2012 was $14,126 billion, as estimated with the "private sector output" methodology mentioned in the paper, using the relevant data from the U.S. National Income and Product Accounts (NIPA) prepared with the comprehensive methodological revision introduced in 2013.

tude in real terms, it was necessary to make assumptions about the evolution of the inflation rate over the period the budget sequestration would be in effect. It seemed sensible to conjecture that the legislators that enacted the Budget Control Act implicitly prescribed the nominal spending cuts they did because they projected that their size in real terms would be enough to correct fiscal imbalances in an environment free of inflationary surprises.

In other words, it is legitimate to assume that U.S. lawmakers were counting on the ability of the Federal Reserve to keep the inflation rate rather close to its 2% annual target for the budget sequestration spending cuts to deliver their underlying fiscal stabilization goal. It seems fair to conclude, therefore, that the Budget Control Act was passed in the understanding that inflation would erode the value of the spending cuts it prescribed at the annual rate of 2%.[6] From a mechanical point of view, this assumption is equivalent to dividing those cuts by a price index that grows exponentially at the annual factor of 1.02 from its 2012 base year value of 1. The application of this "gross down" factor to the normalized spending cuts in Table 2 resulted in the sequence of spending cuts per unit of output adjusted by projected inflation, that is, in real terms, recorded in the fourth column of that table.

Finally, for the reasons discussed in section 3, all real variables of the actual economy that can be represented as a proportion of GDP were detrended by the secular 2% annual growth rate of real output implied by the calibration of the model. Since government expenditures meet that condition, methodological consistency required to detrend the budget sequestration spending cuts in the same manner. The results of that detrending procedure is captured in the last column of Table 2. The figures in that column correspond to the spending cuts in real terms per unit of output implicitly *targeted* by the Budget Control Act, as "reversed-engineered" from their nominal counterparts with the assumptions described above.

To avoid misunderstandings, it is important to emphasize that the paper doesn't assume that economic agents expected those targeted spending cuts in real terms to be actually enforced. In fact, the purpose of the paper is precisely to establish the credibility of those cuts from the perspective of households and businesses, as captured by the effects of their unobserved decisions on observed macroeconomic variables during the relevant event-study window.

Furthermore, it should be kept in mind that, although presented for convenience of exposition in terms of per unit of output, in the empirical implementation of the model the targeted spending cuts in real terms identified in the last column of Table 2 will be treated as the *absolute value* of those cuts, because they will correspond to the absolute deviation of government consumption from its steady-state level in a model economy whose steady-state level of output will be calibrated to the value of 1.

The Budget Control Act didn't stipulate spending caps past the year 2021, so it didn't impose any legal restrictions on the level of government absorption of goods and services as a share of GDP in the long run. The value of this ratio in the long run is needed, however, because the steady state equilibrium of the model economy will be an important reference for

[6] This assumption is consistent with the projections of several inflation rate indicators that can be found in the same CBO report cited as the source of the nominal spending cuts implicitly mandated by the budget sequestration.

the empirical implementation of the BCA approach adopted by the paper. The developments summarized above suggest that the budget sequestration was a fiscal stabilization measure of last resort and, as such, didn't have any lasting effects in the long-run government absorption of goods and services to private sector output ratio, as measured in section 3.4 of the paper.

### 2.3 Measurement Issues

Given the limited data inherently available to a methodology that, as the one adopted for this paper, peeks at the evidence with an event-study perspective, it seemed important to minimize the imprecisions in the assessment of the credibility of the budget sequestration spending cuts introduced by the measurement errors pointed out by Gomme and Rupert in their already cited paper.

It would take a long detour to go over the measurement inaccuracies, potentially severe, that those authors trace to procedures that take the national accounts at face value in the attempt of mapping macroeconomic variables represented in the standard neoclassical growth model into their empirical counterparts. For the purpose of this paper, it suffices to say that some of those inaccuracies can be mitigated with a version of the neoclassical growth model in which all value added is generated by private sector firms. The empirical counterpart of this output concept in the model economy is obtained by subtracting from GDP in NIPA the value added by the general government in the process of producing non-market goods and services.

It is important to emphasize that the Gomme-Rupert "private sector economy" approach will not be an obstacle to make inferences about the credibility of the budget sequestration cuts because, as mentioned earlier, they fell mostly on the government absorption of goods and services produced by the private sector, rather than on the value added by the government, a large fraction of which is just the compensation of the labor services provided by government employees.

The data necessary to obtain the historical series of private sector output, in a manner consistent with the treatment of government economic activities in NIPA, are available at an annual frequency only since 1977. The analysis in this paper uses therefore data from that year until 2013, the last year providing relevant evidence from the event-study perspective adopted by the paper. A thorough discussion of the steps required to make the data for the 1977-2013 period consistent with the conceptual entities in the model are rather involved and would detract from the main focus of the paper. Readers interested in the details will be able to find them, however, in Kydland and Zarazaga (2016), who applied an entirely analogous procedure in the process of answering a different fiscal policy question.

## 3 The Model Economy

Taking into account that the paper incorporates a BCA approach to the methodology proposed for inferring the credibility of the budget sequestration spending cuts, it seemed sensible to respect the principle generally followed by previous implementation of that approach that the long-run features of aggregate models should be consistent with the balanced growth facts documented by Kaldor (1961). Accordingly, preferences, technology, and government policies have been restricted to the types that are consistent with balanced growth, as characterized by King, Plosser, and Rebelo (1988a, b).

All real variables were obtained by dividing their nominal counterparts by the price index of non-durable goods and services. This procedure guarantees that all investment-specific technological progress can be transformed, with the appropriate choice of production function, into labor-augmenting technological progress, the only kind of technological progress consistent with balanced growth, as discussed in King, Plosser, and Rebelo (1988a, b).

Also, when applicable, all real variables are represented in terms of per population 16 years of age and over and detrended by the long-run growth rate of total factor productivity. This procedure typically removes the secular trend from the variables of interest. The exception is the fraction of available time that households are at work in the private sector. The rising trend exhibited by this labor input series, driven by an increasing participation of women in the labor force and demographics, was removed with the procedure proposed by Kydland and Zarazaga.

In other words, the variables of the actual economy were transformed to those corresponding to an economy without growth with the appropriate detrending procedures. As is well known, this transformation is without loss of generality, because it displays the same transitional dynamics as the original economy with secular deterministic growth, but is more convenient to work with when, as in the case of this paper, the technique for computing the equilibrium allocations involves Taylor expansions of the first-order conditions around the deterministic steady-state.

### 3.1 The Typical Household's Choice Problem

The model economy is assumed to be inhabited by an infinitely-lived household, which stands for the large number of them present in the actual economy and whose preferences can be ordered by a time-separable Constant Frisch Elasticity (CFE hereafter) utility function defined over infinite streams of consumption $\{c_t\}_t^\infty$ and the fraction of available time devoted to work $\{h_t\}_t^\infty$. In addition to being consistent with balanced growth, this utility function is the only one that allows consumption and leisure to be non-separable within periods without at the same time tying the value of the *marginal-utility-held-constant* labor supply real wage elasticity–the so-called Frisch elasticity–to that of the *labor-held-constant* intertemporal elasticity of substitution in consumption (IES hereafter) and to the fraction of time devoted to work. Given the purpose of this paper, the flexibility of this utility function for specifying different values for the Frisch elasticity and the IES was important for conceptual and computational reasons.

The conceptual reason is that the strength of the response of endogenous macroeconomic variables to a fiscal policy change, such as the one studied in this paper, is controlled not only by the credibility inspired by the policy, but also by the value of the two macroelasticities just mentioned. Given the considerable disagreement about those values prevailing in the profession, it seemed prudent to explore the credibility of the budget sequestration with a utility function consistent with combinations of them that would be disallowed by the one-to-one correspondence between the value of the IES and that of the Frisch elasticity implied by the alternative popular Constant Elasticity of Substitution (CES) specification for the utility function, also consistent with balanced growth.

The computational reason for the adoption of a CFE utility function specification is that the unavoidable approximation errors introduced by the perturbation method used to compute the private sector's decision rules are likely to be compounded by utility function that imply, as the alternative CES specification does, that the Frisch elasticity varies with the fraction of available time devoted to market activities and is different, therefore, at the steady state and out of it.

Accordingly, the stand-in household is assumed to solve the following maximization problem:

$$\underset{\{c_t,\, h_t,\, k_{t+1}\}}{Max} E \sum_{t=s}^{\infty} [\beta(1+\gamma)^{1-\sigma}(1+\eta)]^t \frac{c_t^{1-\sigma}[1-\kappa\,(1-\sigma)\, h_t^{1+\frac{1}{\varphi}}]^{\sigma}-1}{1-\sigma} \tag{3.1}$$

subject to the following constraints:

$$\begin{aligned} c_t + (1+\tau_t^x)x_t &= (1-\tau_t^h)w_t h_t + r_t k_t - \tau^k (r_t - \delta)k_t + ni_t + \tau_t & (3.2)\\ x_t &= (1+\eta)(1+\gamma)k_{t+1} - (1-\delta)k_t & (3.3)\\ 1 &= l_t + h_t & (3.4)\\ h_t &= h_t^{pr} + h_t^{pu} & (3.5)\\ & \text{government policies} & (3.6) \end{aligned}$$

The objective function in (3.1) is the expected discounted value of a utility function in the CFE class, where $\beta > 0$ is the discount factor, $\eta$ is the working age population annual growth rate, $\gamma$ is the annual growth rate of total factor productivity, $t$ is a time index, $c_t$ is detrended consumption per working age person, $h_t$ is the fraction of available time the representative household allocates to work in the market, $\sigma > 0$ is the inverse of the IES, $\kappa > 0$ is a parameter that controls the household's valuation of consumption relative to leisure, and $\varphi$ is the constant Frisch elasticity of aggregate labor supply.[7]

Equation (3.2) is the household's budget constraint, where $x_t$ is gross private domestic investment, $w_t$ is the wage rate in terms of consumption per unit of the available time the stand-in household devotes to work, $r_t$ is the rental price of period $t$ private sector capital, $k_t$, $\tau^k$ is the tax rate on income from that capital, $\delta$ is the depreciation rate, and are $\tau_t$ lump-sum transfers (taxes if negative.) The three symbols not discussed yet, $\tau_t^x$, $\tau_t^h$ and $ni_t$, introduce in the model three of the four "wedges" that will implement the BCA approach incorporated to the methodology for making inferences about the credibility of the budget sequestration. In particular, $\tau_t^x$ and $\tau_t^h$ play the same role as in CKM, by determining what those authors refer to, respectively, as the *labor wedge*, $1-\tau_t^h$, and the investment wedge, $1/(1+\tau_t^x)$.

[7]Recall that the multiplication of the discount factor $\beta$ by the factor $(1+\eta)(1+\gamma)^{(1-\sigma)}$ is the result of removing from aggregate consumption the deterministic annual secular growth rate $(1+\eta)(1+\gamma)$.

As in CKM, the wedges summarize in convenient "auxiliary " variables the presence of not explicitly modeled frictions that distort equilibrium allocations relative to those of a frictionless model economy. For example, the investment wedge $\tau_t^x$ might be interpreted as capturing output losses or gains associated with the relaxation or tightening of both, liquidity constraints on consumers and/or financing restrictions on firms. It can be verified that also this wedge will capture, through its effects on intertemporal equilibrium conditions, changes in the effective real interest rate–the effective real return on capital in the model–induced by variables not explicitly included in the analysis.

The variable $ni_t$ stands for net imports and captures the net exports component of aggregate demand that CKM lumped together with a government consumption wedge. It could be interpreted therefore as a stochastic *external sector wedge*, introduced in the minimalist manner proposed by Trabandt and Uhlig. These authors introduced this wedge to mitigate the lack of correspondence between the otherwise closed economy neoclassical growth model and the U.S. economy, whose economic interactions with the rest of the world are considerably more challenging to model and parameterize explicitly.

The empirical implementation of the model will take into account that in balanced growth the ratio of $ni_t$ to output should be characterized by a stationary stochastic process with unconditional mean $niy$. Section 4.2 will provide further details about this process, as well as of those governing the evolution over time of the labor wedge $\tau_t^h$ and of the investment wedge $\tau_t^x$.

Equation (3.3) states the evolution over time of the detrended capital stock that the household rents to private firms which, for consistency with the NIPA methodology, excludes the public sector capital stock. This law of motion links the private sector capital stock available for production at the beginning of a period, $k_t$, with the households' investment decisions during that same period, $x_t$, and with the private sector capital stock that will be available at the beginning of the following period, $k_{t+1}$.[8]

Equation (3.4) states the time constraint that the stand-in household can distribute its total available time, normalized to 1, among non-market activities, $l_t$, (generically labeled as "leisure") and work in the marketplace, $h_t$.

Equation (3.5) states that the household can allocate the time it devotes to work between private sector firms, $h_t^{pr}$, and public sector agencies (inclusive of government-owned enterprises), $h_t^{pu}$. Note that for consistency with the standard treatment of labor input in the neoclassical growth model, the empirical counterpart of variable $h_t$ is the fraction of time actually worked, not just paid. The data were therefore adjusted to exclude the time for which workers were paid but not actually working, because they were on vacation, sick leave, etc.

Notice also that without the uncommon explicit distinction between the time households allocation to work in the public and private sectors, the computation of the model output would have been unfeasible with the private sector output methodology approach adopted by this paper.

[8] Again, the presence of the factor $(1 + \eta)(1 + \gamma)$ on the right-hand side of the equation is a direct consequence of removing the deterministic TFP and population growth rates from the capital stock.

### 3.2 Private Sector Firms' Maximization Problem

There are two kinds of firms that produce output in the stationary economy without growth and without a government final good: private firms and government enterprises. As pointed out by Gomme and Rupert in the paper repeatedly mentioned, the decisions of the latter are guided by administrative, rather than profit-maximizing considerations and are taken, therefore, as exogenous.

The model adopts the standard assumption that a large number of privately-owned businesses operate in competitive markets, transforming labor and capital inputs into output with constant returns to scale technology that exhibits labor-augmenting technical progress and unitary elasticity of substitution between inputs. As is well known, under those conditions the aggregate output of the model economy corresponds to that generated by a single representative firm endowed with a Cobb-Douglas production function:

$$y_t^{pr} = \frac{1}{e^{(1-\theta)\gamma t}} A e^{(1-\theta)z_t} k_t^{\theta} [e^{\gamma t} h_t^{pr}]^{1-\theta}, \tag{3.7}$$

where $y_t^{pr}$ is the output per working age person produced by private sector firms, $\theta$ the proportion of the remuneration to capital services in the private sector value added, and $z_t$ is a stochastic technology level that introduces the fourth wedge implementing the BCA approach incorporated to the methodology proposed by this paper. This technology level shifter corresponds conceptually to the *efficiency wedge* in CKM. The properties of the stochastic process governing its evolution over time will be discussed in subsection 4.2.[9]

The representative firm that stands for the large number of them making decisions in the economy solves, therefore, the following maximization problem:

$$\underset{h_t^{pr},\, k_t}{Max} \left[ A e^{(1-\theta)z_t} k_t^{\theta} (h_t^{pr})^{1-\theta} - w_t h_t^{pr} - r_t k_t \right]. \tag{3.8}$$

Notice that in this economy, it is the stand-in household that makes the investment decisions. Absent the intertemporal dimension, the representative firm's problem reduces to a sequence of static, single-period problems.

### 3.3 Public Sector Policies

The allocation of resources by public sector entities is the result of complex social, political, and economic considerations, not aptly captured by the same profit- and utility-maximizing incentives faced by households and private sector firms. Given the difficulties in modeling explicitly the behavior underlying the economic decisions made by public sector agencies, the variables under their control are assumed to be exogenously determined.

[9] Given that all variables have been detrended, the growth factor $e^{\gamma}$ in equation (3.7) is obviously redundant. It was made explicit, however, to emphasize that the model economy is characterized by secular technical progress that the Cobb-Douglas production function permits one to represent as labor augmenting. As shown by Greenwood, Hercowitz, and Krusell (1997), that is the only production function always consistent with balanced growth in the presence of investment-specific, or capital-embodied, technological change, provided the depreciation rate is interpreted as the economic, rather than physical, depreciation rate. The constant economic depreciation rate $\delta$ in equations (3.2) and (3.3) implicitly assumes, therefore, a constant growth rate of investment-specific technological progress.

### 3.3.1 Government Budget Constraint and the Sequester

Fiscal solvency is imposed in the model economy by imposing the restriction that any change in the government purchases of goods and services (excluding labor services counted in government value added) must be offset by a corresponding change in net revenues. Thus, in the model the government absorption of output exclusively produced by the private sector, denoted $ga_t$, will be assumed to be equal every period to revenues from all sources minus transfer payments, as indicated by the following government budget constraint:

$$ga_t = \tau_t^h w_t(h_t^{pr} + h_t^{pu}) - w_t h_t^{gc} + \tau^k(r_t - \delta)k_t + s_t^{ge} - \tau_t, \tag{3.9}$$

where $h_t^{pu}$ is equal to $h_t^{gc} + h_t^{ge}$, with $h_t^{gc}$ and $h_t^{ge}$ representing the fraction of time the stand-in household works for government agencies and government-owned enterprises, respectively, where $s_t^{ge}$denotes, for consistency with the NIPA methodology, surpluses (deficits, if negative) transferred by government-owned enterprises, and where $\tau_t$ stands for lump-sum transfers. In line with the treatment of variables corresponding to physical quantities discussed before, those of the same type in the government budget constraint are measured in units of the consumption good per working age population as well.

For the purposes of the present paper, it will be convenient to interpret the variable $ga_t$ as made up of a systematic, exogenous stochastic component, $ega_t$, and of a non-systematic, deterministic component, $pga_t$, as represented by the relationship

$$ga_t = ega_t + pga_t. \tag{3.10}$$

In line with the historical developments described in section 2.1, the stochastic component $ega_t$ is meant to capture the ups and downs of the government spending policy historically followed until the sequestration took place in 2013.

The non-systematic, deterministic component $pga_t$ is meant to capture the "policy regime change" of limited duration (from 2013 to 2021, to be precise) implied by the budget sequestration spending cuts. This policy component of $ga_t$ is a placeholder that in the quantitative implementation of the model will be replaced by the values in the last column of Table 2, with the practical effect of shifting down the government absorption of private output relative to the level implied by the exogenous component $ega_t$.

For consistency with the balanced growth assumption, that exogenous stochastic component is postulated to evolve over time according to a stationary stochastic process with the following autoregressive representation:

$$\ln \frac{ega_t}{y_t^{pr}} = (1 - \rho_{ga}) \ln gy + \rho_{ga} \ln \frac{ega_{t-1}}{y_{t-1}^{pr}} + \sigma_{gy}\varepsilon_t^{gy}, \tag{3.11}$$

where $gy$ and $\sigma_{gy}$ are scalars, and $\varepsilon_t^{gy}$ is a random variable with a standard normal distribution.

### 3.3.2 Public Sector Labor Demand

In line with the pattern of the previous stochastic process, the general government and government enterprises' demand for labor services is also assumed to be autocorrelated, with the following representation:

$$\ln h_t^{pu} = (1 - \rho_{hpu}) \ln h_{ss}^{pu} + \rho_{hpu} \ln h_{t-1}^{pu} + \sigma_{hpu} \varepsilon_t^{hpu} \tag{3.12}$$

where $h_{ss}^{pu}$ and $\sigma_{hpu}$ are scalars and $\varepsilon_t^{hpu}$ is a random variable characterized by a standard normal distribution.

### 3.3.3 Government Enterprises Value Added

The value added by government enterprises, $va_t^{ge}$, which NIPA treats as originated in the private business sector, should grow at the same rate as private sector output along a balanced growth path. Therefore, it is sensible to assume that the evolution of this variable over time is determined by the following stochastic processes:

$$\ln \frac{va_t^{ge}}{y_t^{pr}} = \ln vy + \sigma_{vy} \varepsilon_t^{ge} \tag{3.13}$$

where $vy$ and $\sigma_{vy}$ are scalars, and $\varepsilon_t^{ge}$ is a random variable characterized by a standard normal distribution.

### 3.3.4 Resource Constraint

For the purpose of subsequent analysis, it is useful to make explicit the resource constraint that results from consolidating the household's budget constraint (3.2) with the government budget constraint (3.9), after taking into account that, for consistency with the NIPA methodology, output in the model economy originates in private sector firms according to (3.7) and in government-owned enterprises according to (3.13), as well as that the operating surpluses of the latter (revenues minus labor costs) are transferred as a lump sum to the households:

$$c_t + (1 + \tau_t^x) x_t = \left[ 1 + \frac{va_t^{ge}}{y_t^{pr}} - \frac{ga_t}{y_t^{pr}} + \frac{niy_t}{y_t^{pr}} \right] A e^{(1-\theta) z_t} k_t^{\theta} (h_t^{pr})^{1-\theta}.$$

## 3.4 Model Calibration

As it should be apparent from the preceding section, the model economy involves a fairly large number of parameters and the attempt of estimating all of them with available statistical tools at an acceptable level of precision is doomed to failure given the limited available data, at most 36 annual observations, from 1977 to 2013, for the aggregate variables of interest. Therefore, it seemed wise to calibrate as many parameter values as possible with the widely accepted quantitative discipline imposed by the requirement that the steady state economic relationships between variables and/or parameters predicted by the model economy should match those prevailing in the actual economy, on average, over fairly long periods of time.

The parameters of the model economy whose values were set with a calibration approach are listed in Table 3. Whenever the calibrated values involved the use of historical averages, they correspond to the period 1997-2007. The observations pertaining to the Great Recession and its aftermath were deliberately excluded, on the grounds that the large changes that many macroeconomic variables experienced during that unusually deep contraction were persistent, but not permanent, and didn't have an everlasting impact, therefore, in the long run trends of the actual economy. The paper will take into account, however, that the permanent increase of the capital income tax rate effective in 2013, mentioned at the end of section 2.1, did change the steady state of the economy after it was enacted in 2010.

Missing from that table are the model parameters that can only be inferred from the high frequency movements of the economic variables under their influence, by their nature not identifiable from steady state relationships. Three types of parameters fall in this class: 1) the coefficients of stationary stochastic processes that drop out from the model equations in steady state, 2) parameters controlling intertemporal substitution effects in consumption and labor, the IES and the Frisch elasticity, and 3) parameters whose steady state values depend on these two macroelasticities.

Parameters in the first type of those just listed will be estimated with the techniques discussed in the next section. A different approach is followed, however, for the second type of parameters, the IES and the Frisch elasticity. To avoid the controversies surrounding their empirically relevant values, the paper explored the extent to which the spending cuts prescribed by the budget sequestration were credible for different combinations of values of those macroelasticities, representative of those advocated by some and disputed by others in the literature.

Thus, for the IES, captured by the reciprocal of the parameter $\sigma$ in the model, the paper will consider the following two values most commonly invoked as empirically relevant in the literature:

- 0.5, and 1.

For the Frisch elasticity, captured by the parameter $\varphi$, the paper will consider the following five values:

- 0.5, 1, 1.9, 2.5, and 3.

The first Frisch elasticity value is the median estimate inferred from so-called microeconomic studies, because they estimate that macroelasticity from evidence at the level of individuals or households, rather than from aggregate variables. The value of 1 is suggested by the survey evidence on the response of labor supply to a large wealth shock examined by Kimball and Shapiro (2008). The value of 1.9 has been proposed in an often-cited paper by Hall (2009). The value of 3 has been inferred by Prescott (2004) from a macroeconomic study, in the sense that he drew that as an implication from the behavior of the aggregate labor supply in countries with different labor income tax rates. Finally, the values of 2.5 in between the last two was added to the list for completeness.

Table 3: Calibration

| Parameter | Value | Description |
|---|---|---|
| $\eta$ | 0.0126 | working-age annual population net growth rate; |
| $\gamma$ | 0.0078 | TFP annual net growth rate; |
| $\delta$ | 0.0621 | depreciation rate; |
| $i$ | 0.0858 | before-tax annual net rate of return on private capital |
| $y_{ss}^{pr}$ | 1.00 | private sector output; |
| $x/y^{pr}$ | 0.2121 | investment-output ratio; |
| $k/y^{pr}$ | 2.5681 | private capital–private sector output ratio; |
| $\theta$ | 0.38 | private capital income share; |
| $gy$ | 0.0825 | fraction of private sector output absorbed by general government; |
| $vy$ | 0.0156 | government enterprises value added–private sector output ratio; |
| $\sigma_{vy}$ | 0.0856 | standard deviation of $vy$; |
| $niy$ | 0.026 | net exports–private sector output ratio; |
| $h_{ss}^{pu}$ | 0.03 | fraction of time worked in public sector; |
| $h_{ss}^{pr}$ | 0.21 | fraction of time worked in private sector; |
| $\tau_{ss}^{x}$ | 0 | investment wedge; |
| $\tau_{ss}^{h}$ | 0.23 | labor income tax rate; |
| $\tau_{ss}^{k}$ | 0.35 up to 2011;<br>0.388 since 2011 | capital income tax rate. |

Finally, recall that the third type of parameters that could not be calibrated includes those that are implied by steady state relationships that depend, precisely, on the values of the macroelasticities just discussed. That is the case of the parameters $\kappa$ and $\beta$ in the utility function.

For example, the Euler equation associated with the intertemporal first order necessary condition for the household's maximization problem described in section 3.1 implies the following steady state relationship between the latter parameter and the IES:

$$1 + (1 - \tau^k)(r - \delta) = \frac{(1+\gamma)^\sigma}{\beta}.$$

Accordingly, the value of $\beta$ was recalculated for each value of $\sigma$, taking into account that the studies by Poterba (1998), Siegel (2002), and Mehra and Prescott (2008) have established with some confidence that the long-run annual real return on capital for the U.S. economy, captured by the factor $(r - \delta)$ in the equation above, is in the order of magnitude of 8%.

A similar procedures was applied to the parameter $\kappa$, whose dependence on the Frisch elasticity $\varphi$ is manifested by the intratemporal first order condition of the stand-in household's maximization problem.

# 4 Inferring the Credibility of the Budget Sequestration with a BCA Event-Study Methodology

## 4.1 Overview

This section provides a narrative overview of the "Business Cycle Accounting event-study" methodology developed in the paper, to allow those readers not initially inclined to go over the technical subtleties to then jump directly to the following section, which reports the findings of the paper.

The first step in the implementation of the methodology is the same as in CKM: to represent the model economy in a state-space form, suitable for estimating with maximum likelihood techniques unobserved state variables and the unknown parameters of the stochastic processes controlling the evolution of such variables over time.

As indicated before, the lack of consensus on the values of the IES and the Frisch elasticity suggested the wisdom of not including these two parameters among the list of those to be estimated. Instead, the steps described below were repeated for each of the ten possible combinations of candidate values for those parameters identified in section 3.4.

The second step of the methodology, also as in CKM, proceeds to estimate the parameters and unobserved state variables with data for the period 1977-2010. The arguments for limiting the evidence to that period, for estimation purposes, will be provided in the more detailed discussion of this step later. It suffices to mention now that an important consideration was the permanent increase of the capital income tax rate effective in 2013 stipulated by 2010 legislation, mentioned at the end of section 2.1.

In fact, the third step was motivated precisely by that anticipated change in the tax code. Even if enacted in 2010, it seems reasonable to conjecture that households and businesses would have been able to take into account the consequences of that forthcoming tax code change for their decisions only one year later, in 2011. In that case, the macroeconomic variables capturing those decisions were registering in 2013 not only the transitional dynamic effects induced by the anticipated tax policy change, but also the effects of the budget sequestration spending cuts triggered that same year. Inferences about the credibility of those cuts could be misleading if made with a methodology that fails to isolate the response of macroeconomic variables to each of those two different policy changes.

The third step of the methodology proposed by the paper avoids that potential methodological flaw. Specifically, this third step incorporates the forthcoming higher capital income tax regime in the equilibrium decision rules for 2011 and 2012, with the technique that will be described in due course, taking as given the parameter values estimated in the previous step. This third step also proceeds to calculate the evolution of the state variables up to 2012 implied by the new equilibrium decision rules and associated laws of motion.

The last step, and the one most different from that in CKM, is the critical one for the purposes of this paper. Recall that CKM exploited the state-space representation of the model to recover the wedges that would replicate the data exactly at each point in time and then feed them one at a time in the model economy, in order to establish their marginal effects on the fluctuations of the macroeconomic variables of interest. In this paper, whose goal instead is to assess the credibility of the budget sequestration cuts, what is fed into the model is rather sequences of spending cuts that differ in a certain percentage, roughly ranging from 0% to 100%, from those targeted by the Budget Control Act.

The parameterization of the targeted spending cuts in the manner just sketched gives rise to a range of "credibility scenarios," each of them capturing the hypothesis that economic agents were making their decisions, when the budget sequestration was launched, as if expecting that only a certain percentage of the targeted spending cuts would, in the end, be enforced. In the empirical implementation of the model, the fully credible spending cuts scenario is captured, therefore, by entering into the decision rules 100% (full size) of the targeted spending cuts. At the opposite extreme, the "zero credibility" scenario is captured by entering in the decision rules 0% of the targeted spending cuts, that is, by feeding in the model decision rules that dismiss the budget sequestration altogether as a credible policy regime change. In between those two polar scenarios, the paper considers a large number of "intermediate credibility" scenarios, indexed by the percentage of the targeted spending cuts incorporated in the decision rules.

In principle, different configurations of innovations to the wedges will be necessary to replicate the data exactly for each of the spending cuts credibility scenarios considered. The distribution of those shocks, along with that of the estimated unobserved state variables derived in the previous steps, makes it possible to compute the likelihood of the data for alternative spending cuts scenarios and rank them by the value of the corresponding likelihood function. For a given combination of Frisch elasticity and IES values, the credibility scenario that accounts best for the observed performance of macroeconomic variables during the relevant time frame is that for which the likelihood function value is the highest.

Notice that given the possibility, mentioned in section 2.1, that economic agents started to incorporate the prospects of the sequester in 2012 rather than, as more widely believed, in 2013, it was necessary to apply sequentially the fourth and last step of the methodology to those two years.

## 4.2 Technical Details

### 4.2.1 State-Space Representation

The first step in implementing the adapted BCA approach just outlined is to represent the model in a state-space form, which is accomplished as usual, by specifying transition equations that govern the evolution of state variables over time and measurement equations that define the mapping between the states and the relevant observed data.

In general stochastic equilibrium models as the one in this paper, the link between observables and state variables in the measurement equations is provided by the equilibrium decisions rules which, as already anticipated, this paper computes with the standard practice of approximating the true decision rules with a first order Taylor expansion around the non-stochastic steady state. This ensures a linear mapping between state variables and observables. With the further assumption that the transition from one state to the other is governed by a linear Markov process, the state-state representation of the model economy of this paper can be formalized by the *transition equation*

$$S_t = TS_{t-1} + Q\omega_t, \tag{4.1}$$

and the *measurement equation*

$$Y_t = DS_{t-1} + C\omega_t. \tag{4.2}$$

In the *transition equation* (4.1), $S_t$ is a $7x1$ vector of state variables at the end of period $t$, $T$ a $7x7$ matrix, $\omega_t$ a $7x1$ vector whose elements are all the exogenous shocks assumed present in the model economy, and $Q$ a $7x7$ matrix whose elements are discussed in detail below.

In the *measurement equation* (4.2), $Y_t$ is the vector of observable variables, $D$ a $7x7$ matrix, and $C$ a $7x7$ matrix.

To see more clearly how the different elements of the model economy presented in the previous sections fit into the state-space representation, it will prove useful to spell out more fully the vectors and matrices involved as follows, starting with those of the transition equation:

$$S_t = [k_{t+1} - k_{ss},\, \ln \frac{ega_t}{y_t^{pr}} - \ln gy,\, \ln h_t^{pu} - \ln h_{ss}^{pu},\; z_t - z_{ss},\, \frac{ni_t}{y_t^{pr}} - niy,\, \tau_t^h - \tau_{ss}^h,\, \tau_t^x - \tau_{ss}^x]',$$

where a subindex "*ss*" identifies the steady state value of the period $t$ variable immediately to the left[10].

Continue with the matrix $T$:

$$T = \begin{bmatrix} T_{11} & T_{12} & T_{13} & T_{14} & T_{15} & T_{16} & 0 \\ 0 & \rho_{ga} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \rho_{hpu} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \rho_z & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \rho_{ni} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \rho_{\tau h} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \rho_{\tau x} \end{bmatrix},$$

where the first row of this matrix is simply the result of replacing in the law of motion for the private capital stock, (3.3), the equilibrium decision rule for investment, $x_t$, approximated as a linear function of the end-of-period $t-1$ state of the economy, that is, of the state variables in $S_{t-1}$, and of the innovations $\omega_t$ hitting the economy in period $t$. The second and third rows of the matrix $T$ simply replicate the stochastic processes in equations (3.11) and (3.12), respectively. The rest of the rows of this matrix represent the wedges, expressed in terms of ratios to private sector output when appropriate, as stochastic Markovian processes that depend only on their own past. Interactions between these processes were ruled out by assumption, for the same reasons given earlier: the limited data available would have prevented

[10]For consistency with the timing convention adopted in the law of motion of capital (3.3), the capital stock at the end of period t is denoted in the vector $S_t$ as the beginning of period $t+1$ capital stock, $k_{t+1}$.

the reliable estimation of the large number of parameters implied by a less parsimonious specification.[11]

Consider next the vector $\omega$ :

$$\omega_t = [\varepsilon_t^{gy},\, \varepsilon_t^{hpu},\, \varepsilon_t^{ge},\, \varepsilon_t^{z},\, \varepsilon_t^{ni},\, \varepsilon_t^{\tau h},\, \varepsilon_t^{\tau x}]', \tag{4.3}$$

where the first three elements corresponds to the innovations identified in equations (3.11), (3.12), and (3.13), and the remaining elements capture the innovations to the four wedges $z_t$, $ni_t$, $\tau_t^h$, and $\tau_t^x$. The variance-covariance matrix of this vector, $E[w_t w_t']$, is denoted by $\Sigma$ and characterized by the following elements:

$$\sum = \begin{bmatrix} \Sigma_{11} & 0_{3x4} \\ 0_{4x3} & \Sigma_{22} \end{bmatrix},$$

where $\Sigma_{11}$ is a $3x3$ identity submatrix, and $\Sigma_{22}$ a $4x4$ submatrix, with diagonal elements equal to 1 and possibly non-zero off-diagonal elements. This specification assumes that the stochastic process for the government absorption of private sector output, characterized by equation (3.11), as well as that for the public sector labor input, characterized by equation (3.12), are orthogonal to all the others, whereas the innovations to the wedges are allowed to be correlated with each other.

Fully spelled out, the $7x7$ matrix $Q$ is given by

$$Q = \begin{bmatrix} Q_{11} & Q_{12} & Q_{13} & Q_{14} & Q_{15} & Q_{16} & Q_{17} \\ \sigma_{gy} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \sigma_{hpu} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_z & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_{ni} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \sigma_{\tau h} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \sigma_{\tau k} \end{bmatrix},$$

where the elements of the first row are coefficients implied by the linearized equilibrium decision rule for the capital stock and the rest of the elements just capture the standard deviations of all the exogenous stochastic processes in the model.

In the measurement equation, the $7x1$ column vector $Y_t$ contains the observable variables:

$$Y_t = [y_t^{pr} - y_{ss}^{pr}\,, c_t - c_{ss}\,, x_t - x_{ss},\, h_t^{pr} - h_{ss}^{pr},\, \ln \frac{ega_t}{y_t^{pr}} - \ln gy,\, \ln h_t^{pu} - \ln h_{ss}^{pu},\, \ln \frac{va_t^{ge}}{y_t^{pr}} - \ln vy]', \tag{4.4}$$

where again a subindex "$ss$" identifies the steady state value of the corresponding variable.

It is worth to clarify at this point a potential confusion created by the inclusion of the element $\ln \frac{ega_t}{y_t^{pr}} - \ln gy$ in the vector of observables $Y_t$. Strictly speaking, the variable directly observable in the data is $ga_t$, not its individual components identified in equation (3.10).

[11] It is not clear, in any case, that the interactions would be significant, as they are not statistically different from zero in CKM.

However, as that equation makes apparent, in the absence of the temporary policy regime, the systematic stochastic component $\frac{ega_t}{y_t^{pr}}$ would be equal to $\frac{ga_t}{y_t^{pr}}$ and, therefore, observable as well. This equality holds, therefore, between 1997 and 2012, before the budget sequestration was triggered. When it breaks down in 2013, $\frac{ega_t}{y_t^{pr}}$ is no longer observable but it can be inferred from the data and the spending cuts for that year implied by the legislation that enacted the budget sequestration. In particular, in the absence of the spending cuts, the observation $\frac{ga_{2013}}{y_{2013}^{pr}}$ would have been higher by $\frac{pga_{2013}}{y_{2013}^{pr}}$, the amount by which the sequestration would reduce government spending that year, as per the CBO estimate reported in Table 2. Thus, $\frac{ega_{2013}}{y_{2013}^{pr}}$ can be inferred from the equality $\frac{ega_{2013}}{y_{2013}^{pr}} = \frac{ga_{2013}}{y_{2013}^{pr}} - \frac{pga_{2013}}{y_{2013}^{pr}}$ implied by equation (3.10).

The $7x7$ matrix $D$ can be rewritten as

$$D = \begin{bmatrix} & & & \mathbb{D}_{4x7} & & & \\ 0 & \rho_{ga} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \rho_{hpu} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix},$$

where the elements $\mathbb{D}_{ij}$ of the $4x7$ submatrix $\mathbb{D}$ consist of the coefficients of the linearized equilibrium decision rules for the endogenous variables in the vector $Y_t$, the element $\rho_{ga}$ restates in matrix notation the first term of equation (3.11), and the element $\rho_{hpu}$ restates that of equation (3.12).

Finally, the $7x7$ matrix $C$ is given by

$$C = \begin{bmatrix} & & \mathbb{C}_{4x7} & \\ \sigma_{gy} & 0 & 0 & \\ 0 & \sigma_{hpu} & 0 & 0_{3x4} \\ 0 & 0 & \sigma_{vy} & \end{bmatrix},$$

where the elements $\mathbb{C}_{ij}$ of the $4x7$ submatrix $\mathbb{C}$ are obtained from the equilibrium decision rules and the last three rows restate the second term in equations (3.11), (3.12), and (3.13).

Having made explicit the mapping between the model economy in section 3 and its state-space representation in this one, it is possible to proceed with the second step to estimate the unknown state variables and parameters of the model.

#### 4.2.2 Estimation of Unknown States and Parameters

The parameters that could not be calibrated exploiting steady state relationships or the findings of other studies had to be inferred statistically from the data. To that effect, the estimation procedure used all the available data for the period 1977-2010, rather than those for the more limited 1977-2007 period adopted as reference for the calibration of the parameters in Table 3. The first year in both periods was determined, as indicated earlier, by data availability considerations. The reason to include data for the Great Recession years for the purpose of estimating unknown parameters and state variables is that, by most accounts, several frictions typically present in the economy manifested themselves with particularly intensity during that episode. The observations pertaining to that contraction might contain, therefore, information particularly useful for estimating the parameters of the stochastic processes of the wedges, meant to summarily capture those frictions in the model.

The reason not to use the data after 2010, even if available, was technical in nature: the technique to estimate the not calibrated parameters governing the stochastic processes of the wedges requires stability of the decision rules characterizing the economic agents' choices, a condition that ceases to be satisfied after legislation passed that year enacted, as mentioned before, a permanent increase of 3.8 percentage points in the capital income tax rate that would take effect three years later. As mentioned in the overview of this section, the paper assumes that economic agents started to fully incorporate this policy regime change in their decisions the following year, in 2011. For consistency, all not calibrated parameters, including those of the stochastic process (3.11) for the government absorption of private sector output, and those of the stochastic process (3.12) for the public sector labor input, were estimated therefore with data for the period 1977-2010.

For this estimation step, the paper took advantage of rather standard maximum likelihood procedures, particularly well suited for implementation when the structural model of the economy can be represented in state-space form. To gain intuition on the nature of those tools, notice that the estimates of the unknown parameters in the matrices $T$ and $Q$ will be influenced by the difference between the data for the variables in the measurement equation and their predicted values implied by the corresponding decision rules, in turn a function of the parameters that need to be estimated. The Kalman filter, included in many econometric software packages, was especially developed to deal with this "circularity" problem. Following standard practice, the initial values of the state variables were set equal to their steady state values whenever necessary to start the algorithm.

It is important to reiterate at this point that, given that the paper doesn't take a stand on which of the variety of values for the IES and the Frisch elasticity proposed in the literature are empirically relevant, the parameters that are the subject of this section had to be estimated for each of the ten combination of values of those two macroelasticities listed in section 3.4.

The resulting sets of estimates of the state variables, autocorrelation coefficients, and relevant variances and covariances were assumed to characterize the joint distribution of the stochastic variables, one of the inputs required to execute the subsequent steps of the modified BCA methodology proposed in this paper described next.

#### 4.2.3 Incorporating the Tax Regime Change

In order to interpret the dynamics of macroeconomic variables under the effects of the sequester correctly, it is necessary to establish first how that dynamics was altered by the increase of the capital income tax rate repeatedly mentioned before. With all the parameter values fixed by the last step, this could be accomplished with an algorithm capable of simulating the path of the variables of the model during 2011 and 2012, that is, for the years in which the capital income tax change was anticipated, but not effective yet. Juillard (2006) suggested the general principle behind such an algorithm in the context of perturbation methods: treat perfectly anticipated current and future deviations of a policy variable from its steady state value as exogenous deterministic state variables and approximate the decision rules around the steady state with standard perturbation methods.

In the case of the increase in the capital income tax rate under consideration, the algorithm involves adding a deterministic state variable and modifying the state-space representation of the model accordingly, as follows:

$$S_t = \mathfrak{T} S_{t-1} + \mathfrak{Q}\omega_t + M(\tau^k_{t+1} - \tau^k_{new}), \tag{4.5}$$

$$Y_t = \mathfrak{D} S_{t-1} + \mathfrak{C}\omega_t + R(\tau^k_{t+1} - \tau^k_{new}), \tag{4.6}$$

where $t = 2011,\ 2012$, $M$ and $R$ are matrices of coefficients with dimensions $7x1$, and $\tau^k_{new}$ represents the tax rate on capital income effective since 2013, 0.388, obtained by adding to the capital income tax rate calibrated to the period 1977-2007, 0.35, the surcharge enacted in 2010, 0.038. The matrices $\mathfrak{T}$, $\mathfrak{Q}$, $\mathfrak{D}$, and $\mathfrak{C}$ simply reflect the fact that the elements of those matrices corresponding to decision rules coefficients are different from the corresponding elements in the matrices $T$, $Q$, $D$, and $C$ in the previous step, because they have been computed by linearizing the model equations around the new steady state implied by the permanently higher tax rate. For future reference, keep in mind that it's only the first row of the matrix $\mathfrak{Q}$ that is different from the corresponding row in the matrix $Q$, because the elements of the other rows correspond to parameters of the exogenous stochastic processes whose values where kept at those estimated in the previous step.

Notice that the reformulation of the state-space representation expands the state space with the additional variable $[\tau^k_{t+1} - (\tau^k + 0.038)]$, taking into account that investment decisions in period $t$ depend on the after-tax rate of return on period $t+1$, as the explicit derivation of the Euler equation would make apparent. Thus, when $t = 2011$, $\tau^k_{t+1}$ is still at the level of the old capital income tax rate $\tau^k$, 0.35, and the term $[\tau^k_{t+1} - (\tau^k + 0.038)] = -0.038$ effectively adds a perfectly known in advance, non-zero deterministic state variable that, along with the other ones present in the original formulation, determine the linearized equilibrium decision rules. However, when $t = 2012$, those rules cease to be a function of this extra state variable, which drops out of the model because $\tau^k_{t+1} = \tau^k_{2013} = \tau^k + 0.038 = \tau^k_{new}$.

Thus, it would appear that, for the year 2012, the state-state representation of the model simplifies to:

$$S_t = \mathfrak{T} S_{t-1} + \mathfrak{Q}\omega_t, \tag{4.7}$$

$$Y_t = \mathfrak{D} S_{t-1} + \mathfrak{C}\omega_t, \tag{4.8}$$

However, this formulation assumes that households and businesses were not taking seriously the possibility that the sequester would be actually implemented that year. Since the paper doesn't take that assumption for granted, it will be necessary to modify the decision rules for the year 2012 in a way that they capture the opposite assumption, to be subsequently validated or dismissed statistically, that economic agents behaved as if they were certain already that year that the sequester was going to be actually implemented on the next.

In any case, what is important to keep in mind is that the goal of this step was to determine the effect of the pre-announced tax regime change on the state variables at the end of period 2011 and 2012, whose level will affect the dynamic of macroeconomic variables at the time that those variables started to register as well, perhaps as early as in 2012, the influence of the budget sequestration scheduled for 2013. The next step illustrates precisely the implication of the pre-announced reduction of discretionary spending for the equilibrium decision rules.

### 4.2.4 Incorporating the Budget Sequestration Cuts

Applying to the anticipated spending cuts the same principle behind the algorithm of the preceding section results in the following state-space representation of the model for the years 2012 and 2013:

$$S_t = \mathfrak{T} S_{t-1} + \mathfrak{Q}\omega_t + \mathfrak{M}_t \Delta_{2013}, \tag{4.9}$$

and

$$Y_t = \mathfrak{D} S_{t-1} + \mathfrak{C}\omega_t + \mathfrak{P}_t \Delta_{2013}, \tag{4.10}$$

where $t = 2012, 2013$, $\Delta_{2013}$ is a $nx1$ column vector whose elements will capture different spending cuts scenarios discussed in the next section and $\mathfrak{M}_t$ and $\mathfrak{P}_t$ are conformable matrices, with dimensions $7xn$.

Notice that the matrices $\mathfrak{T}$, $\mathfrak{Q}$, $\mathfrak{D}$, and $\mathfrak{C}$ are the same as those that capture the change in decision rules induced by the capital income tax rate increase because, as argued at the end of section 2, the budget sequestration spending cuts were temporary in nature and assumed accordingly not to have any impact on the steady state equilibrium of the economy. Operationally, this means that the steady state value of the spending cuts is zero. Taking into account, as documented in Table 3 that the steady-state private sector output has been calibrated to one by the appropriate choice of the technology level in steady state, the deviations of the sequence of the targeted spending cuts from their steady state value are given by the values in the last column of Table 2.

The basic idea guiding the methodological steps described in this section is that the issue examined by this paper, the extent to which U.S. households and businesses believed that the budget sequestration would be implemented in the terms originally announced, can be addressed by examining the responses of the endogenous macroeconomic variables in the vector $Y_t$ to sequences of current and future spending cuts that differ in a certain percentage, between 0% and 100%, from those targeted by the budget sequestration.

The paper implements that idea parametrically, by means of two parameters that control the size of the spending cuts fed into the decision rules in order to compute the equilibrium allocation predicted by the model. The first parameter, $\psi_0$, controls the size of the spending cuts for the year 2013, relative to that targeted by the budget sequestration, whereas the second one, $\psi_1$, does the same for the spending cuts from 2014 onwards. The spending cuts scenarios briefly discussed in the overview of this methodology are constructed by alternatively assigning to each of the parameters introduced above the values of evenly separated 100 points defined over the interval [0,1]. This parametric treatment of the spending cuts made it possible to consider a total of 10,201 credibility scenarios.

A typical scenario will be characterized then by a certain value of $\psi_0$, say 0.90, and a certain value of $\psi_1$, say 0.07. The interpretation of this particular scenario is that either at the beginning of 2012, or 2013, as the case may be, economic agents were making their decisions as if expecting that the spending cuts actually implemented would be 90% the size of those targeted for 2013, and 7% of the size of those targeted for subsequent years.

The reason to treat the spending cuts for 2013 and subsequent years separately is to allow for scenarios for which the credibility of the spending cuts targeted for the year 2013 is eventually higher than that of the spending cuts scheduled for the rest of the years. It didn't seem reasonable to exclude such scenarios from consideration, given the chronology of events documented in section 2.1. These are plausible scenarios for the year 2013, because as the budget sequestration was effectively launched in the first quarter of that year, households and businesses may have correctly perceived that it was too late for that year's legislative agenda to accommodate modifications to the cuts for 2013 confirmed by the American Taxpayer Relief Act enacted on January 1st of that year. The same constraint was less binding for future legislation with the potential to change the cuts targeted for 2014 and beyond.

It is important to emphasize that the distinction between the parameter controlling the size of the spending cuts for 2013 and that controlling the size of the spending cuts for the following years adds flexibility to the credibility scenarios that could be realistically considered, without excluding those characterized by equal values of the parameters $\psi_0$ and $\psi_1$, that is, those for which $\psi_0 = \psi_1$.

Formally, the parameterization of the spending cuts is introduced in the state-space representation of the model with the relationship:

$$\Delta_{2013} = \Psi \left[ \frac{0.24}{100}, \frac{0.49}{100}, \frac{0.53}{100}, \frac{0.54}{100}, \frac{0.52}{100}, \frac{0.50}{100}, \frac{0.48}{100}, \frac{0.45}{100}, \frac{0.43}{100} \right]', \tag{4.11}$$

where $\Psi$ is a $9x9$ diagonal matrix whose elements are the values of the parameters controlling the size of the spending cuts in each of the scenarios considered, that is:

$$\Psi = \begin{bmatrix} \psi_0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \psi_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \psi_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \psi_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \psi_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \psi_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \psi_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_1 \end{bmatrix}.$$

Notice that the numerical values in the column vector in equation (4.11) correspond to the size of the targeted spending cuts identified in the last column of Table 2. As indicated in the section interpreting the contents of that table, the nine numerical values indicate the absolute magnitude of the sequence of the spending cuts that the budget sequestration would have targeted for an economy with a steady-state output normalized to the value of one, in units of consumption. For example, according to the second numerical value in that column vector, the target of the budget sequestration was to reduce the government absorption of private sector output in 2014 by 0.0049 units of consumption, equivalent to 0.49% of the model economy steady-state level of output.

### 4.2.5 Assessing the Credibility of the Budget Sequestration

The last stage of the methodology proposed in this paper is designed to infer the credibility of the targeted budget sequestration of the spending cuts with the metric suggested by maximum likelihood techniques.

For the reasons mentioned in the overview of the methodology, this last step had to be applied sequentially, first to the year 2012 and then to the year 2013, in order to establish statistically from the evidence in which of these two years economic agents more likely started to incorporate in their decisions the possibility that the budget sequestration would be actually implemented. The concrete steps of implementation of this last stage are as follows:

1. Back out the vector (4.3) of realized exogenous shocks that replicate the data exactly for the years 2012 and 2013 for each spending cut scenario and combination of macroelasticities from equation (4.10):

$$\omega_{i,m} = \mathfrak{C}_i^{-1} Y_m - \mathfrak{C}_i^{-1} \mathfrak{D}_i S_{i,m-1} - \mathfrak{C}_i^{-1} \mathfrak{P}_{i,m} \Delta_{j,2013},$$

   where the subindex $m$ stands alternatively for the years 2012 and 2013, the subindex $i$ indicates that the elements of the matrix or vector bearing it correspond to those associated with the particular combination $i$ of values of the IES and the Frisch elasticity, out of the ten considered, and the subindex $j$ identifies the particular spending cuts scenario $j$, out of the 10,201 considered.[12]

2. Calculate the likelihood of the data for years 2012 and 2013 for each spending cuts scenario and combination of macroelasticities. Recall that the state variables and innovations to the wedges have been updated as indicated above, but that all distributional parameters required for the calculation of the likelihood have been kept fixed at the values obtained in the estimation step.[13]

[12] Since there are seven equations (one for each of the seven observables) and seven unkowns (seven exogenous shocks), this step is generally feasible, except in the rare case in which $\mathfrak{C}_i$ happens to be singular.

[13] More specifically, the likelihood of the observables for each of the years 2012 and 2013 can be computed quite straigthforwardly, with the formula [13.4.1] on page 385 in Hamilton (1994), after exploiting the isomorphism between the dynamic system of equations (4.1) and (4.2) and the system $\xi_{t+1} = F\xi_t + G\omega_{t+1}, Y_t = A'x_t + H'\xi_t$, where $\xi_{t+1} \equiv \begin{bmatrix} S_t - \mathfrak{M}\Delta_t & \omega_{t+1} \end{bmatrix}'$, $F \equiv \begin{bmatrix} \mathfrak{T} & \mathfrak{Q} \\ 0 & 0 \end{bmatrix}$, $G \equiv \begin{bmatrix} 0 & I \end{bmatrix}'$, $I$ is an identity matrix, $A' \equiv \mathfrak{B}_i$, $x_t \equiv \Delta_t$, and $H' \equiv \begin{bmatrix} \mathfrak{D} & \mathfrak{C} \end{bmatrix}$.

3. Use the information provided by the likelihood of the data under different combinations of macroelasticity values and spending cuts scenarios to make inferences about the extent to which the fiscal austerity implied by the budget sequestration was credible as a fiscal stabilization tool in the year 2012 and, subsequently, in the year 2013.

# 5 Findings

This section reports the results of applying the last step of the methodology described above, first to the year 2012 and then to the year 2013.

As indicated before, the need to check the likelihood of the vector of observables (4.4) for each of those years separately was suggested by the chronology of events discussed in section 2.1, which didn't completely dissipate some ambiguity as to in which of those two years economic agents started to adjust their decisions in response to the spending cuts that the budget sequestration would end up triggering in 2013.

The credibility of the targeted spending cuts as of 2012 is assessed by searching, over all 10,201 scenarios, for the maximum of the likelihood of observables in that particular year, for each of the ten combinations of values for the IES and the Frisch elasticity considered. It turns out that, for all macroelasticities values, the likelihood function attained its maximum value when the two parameters controlling the size of the spending cuts fed into the decision rules are zero. That is, for the scenario identified, for all IES and Frisch elasticity values, by the parameter values $\psi_0 = \psi_1 = 0$ .

This result seems to validate the hypothesis that all throughout 2012 households and businesses in the U.S. economy were making decisions as if taking almost for granted that lawmakers and policymakers would in the end find a way to prevent the budget sequestration spending cuts from happening.

The paper proceeds then to assess the credibility of the spending cuts as of 2013 with an entirely analogous grid search, but starting the procedure in that year, instead of in 2012.

The likelihood function in this case is maximized, again for all macroelasticity values considered, for the scenario in which economic agents behaved as if expecting that the targeted spending cuts would be fully implemented in 2013, but not at all from 2014 onwards. That is, for the scenario identified by a value of 1 for the parameter $\psi_0$ and the value of 0 for the parameter $\psi_1$. This finding is formally summarized in Table 4, which includes also the value of the likelihood function associated with the parameter values just mentioned, $\psi_0 = 1$ and $\psi_1 = 0$.

For completeness, Table 5 documents the likelihood corresponding to the two extreme credibility scenarios, the full credibility scenario, corresponding to the parameter values $\psi_0 = \psi_1 = 1$, and the complete lack of credibility scenario, captured by the parameter values $\psi_0 = \psi_1 = 0$.

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To avoid misunderstandings, note that in Hamilton's book the matrix $Q$ denotes the variance-covariance matrix of the state variables, while in the paper, that notation is reserved for the matrix of coefficients of the shocks in the transition equation.

Table 4: Spending Cuts Scenario that Maximizes the Log Likelihood of 2013 Observables

| Intertemporal elasticity of substitution ($\sigma$) = **1** | | | |
|---|---|---|---|
| Frisch elasticity ($\varphi$) | $\psi_0$ | $\psi_1$ | Likelihood |
| 0.5 | 1 | 0 | 5.9363 |
| 1.0 | 1 | 0 | 5.8779 |
| 1.9 | 1 | 0 | 5.8063 |
| 2.5 | 1 | 0 | 5.7741 |
| 3.0 | 1 | 0 | 5.7509 |
| Intertemporal elasticity of substitution ($\sigma$) = **2** | | | |
| Frisch elasticity ($\varphi$) | $\psi_0$ | $\psi_1$ | Likelihood |
| 0.5 | 1 | 0 | 5.8125 |
| 1.0 | 1 | 0 | 5.7473 |
| 1.9 | 1 | 0 | 5.6575 |
| 2.5 | 1 | 0 | 5.6141 |
| 3.0 | 1 | 0 | 5.5841 |

Table 5: Log Likelihood of 2013 Observables

| Intertemporal elasticity of substitution ($\sigma$) = **1** | | |
|---|---|---|
| | Spending cuts scenario | |
| Frisch elasticity ($\varphi$) | No cuts ($\psi_0 = \psi_1 = 0$) | Full-size statutory cuts ($\psi_0 = \psi_1 = 1$) |
| 0.5 | 4.4539 | 5.7629 |
| 1.0 | 4.3866 | 5.6873 |
| 1.9 | 4.3032 | 5.5945 |
| 2.5 | 4.2653 | 5.5526 |
| 3.0 | 4.2383 | 5.5230 |
| Intertemporal elasticity of substitution ($\sigma$) = **2** | | |
| | Spending cuts scenario | |
| Frisch elasticity ($\varphi$) | No cuts ($\psi_0 = \psi_1 = 0$) | Full-size statutory cuts ($\psi_0 = \psi_1 = 1$) |
| 0.5 | 4.3853 | 5.7230 |
| 1.0 | 4.3144 | 5.6454 |
| 1.9 | 4.2140 | 5.5352 |
| 2.5 | 4.1647 | 5.4809 |
| 3.0 | 4.1305 | 5.4433 |

Overall, the interpretation of these results is that in 2012 economic agents were highly skeptical that the budget sequestration would be triggered in 2013, counting perhaps on legislation then under consideration to at least postpone the prescribed spending cuts indefinitely.

According to the results, that perception changed somewhat in 2013. The failure of the American Taxpayer Relief Act, passed at the very beginning of that year, to postpone the budget sequestration for more than two months may have played a pivotal role in convincing economic agents that the targeted spending cuts scheduled for that year would be indeed implemented. But that doesn't seem to have been enough to convince households and businesses that the targeted spending cuts for the following years would be actually executed. It turns out that subsequent developments validated those doubts: The Bipartisan Budget Act of 2015 reduced the nominal spending cuts originally scheduled for 2016 and 2017 by $50 billion and $20 billion, respectively.

Notice that the combination of macroelasticity values with the highest likelihood in Table 4 is that identified by an IES equal to 1 and a Frisch elasticity equal to 0.5. For that reason, the parameters governing the spending cuts scenarios, namely $\psi_0$ and $\psi_1$, are further scrutinized in the appendix with Bayesian techniques. The results reported therein are largely consistent with those documented in this section.

# 6 Conclusion

Nations confronting structural fiscal imbalances typically attempt to correct them with stabilization programs that significantly alter the existing fiscal policy configuration through steep taxation increases and/or deep government spending reductions.

The variety of outcomes associated with such programs, even those without obvious differences in design or scope, has prompted lively debates in academic and policy forums. Often lost in these exchanges is an important caveat: The outcome of fiscal stabilization programs is not independent of their credibility. As a result, the success or failure of a particular fiscal stabilization program may be attributed to its policy features and design, when, in fact, its credibility may well have been the ultimate determinant of observed outcomes.

The likelihood of such a possibility should be clear from the presence, in virtually every actual economy, of the time-inconsistency mechanism uncovered by Kydland and Prescott (1977) and Calvo (1978): Forward-looking households and businesses will not make the same decisions in the present if they expect an announced fiscal stabilization program to be actually followed through, as they would if they anticipate that it will be repudiated.

Put differently, two plans with exactly the same design can produce different outcomes if one is fully credible and the other is not. An assessment of those programs' credibility could go a long way toward settling policy debates prompted by their different outcomes, particularly when the programs are of similar contours.

The scarcity of formal attempts to establish the credibility of fiscal policy stabilization experiences is surprising. Motivated by the need to address that apparent void in the literature, this paper formally assessed the credibility of a recent fiscal stabilization attempt:

that initiated by the budget sequestration spending cuts triggered in the U.S. by the Budget Control Act of 2011.

In the absence of readily available methodologies to make such an assessment, the paper developed a novel one, merging an "event-study" approach typically used to study the effects of fiscal shocks and a "business cycle accounting" approach originally developed to address economic fluctuations questions.

The resulting blended methodology made it possible to assess the credibility of the spending cuts targeted by the Budget Control Act with a well-established statistical metric, the maximum likelihood criterion.

An important step for the application of that metric was the construction of a rather comprehensive set of "spending cuts scenarios." Leaving some minor details aside, each of the scenarios is basically characterized by forward-looking economic agents which, in the abstraction of the model, make their economic decisions, starting either in 2012 or 2013, in expectation that actually implemented spending cuts will be a fraction of those targeted by the Budget Control Act.

The scenarios "device," as used in the paper, made it possible to exploit the wedges introduced by the BCA approach to capture, in an expedient fashion, the presence in the economy of not explicitly modeled frictions. In order to replicate the data exactly for each of the IES and Frisch elasticity values considered, the configuration of the innovations to those wedges must change across "credibility scenarios." The more likely the configurations of the resulting innovations, the higher the value of the likelihood function implied by the state-space representation of the model economy.

That intuition is formally captured by ranking the credibility scenarios, for each of the 10 possible combinations of macroelasticities considered, by the value of the likelihood function induced by the model economy's state-space representation.

By that standard, the paper's finding can be succinctly summarized as stating that the budget sequestration spending cuts had little to no credibility, regardless of values assigned to the IES and Frisch elasticity. The application of Bayesian inference techniques to the pair of values of the two macroelasticities that delivered the highest likelihood function value also favors low credibility scenarios.

Confidence in the finding, as inferred with the maximum likelihood metric or with a Bayesian metric for a special case, is subject to the limitations of data scarcity inherent in the event-study perspective incorporated into the methodology of the paper. Such a perspective was dictated not only by the nature of the relevant evidence, but also by the fact that the government spending austerity program, whose credibility this paper set to assess, was still unfolding at the time of this writing.

On the other hand, lack of credibility of the targeted budget sequestration spending cuts is the assessment that ought to be expected, limited information notwithstanding, from a methodology capable of anticipating that those cuts would be subsequently watered down. That is exactly what happened: The Bipartisan Budget Act of 2015 reduced the nominal spending cuts originally scheduled for 2016 and 2017 by $50 billion and $20 billion, respectively.

That development suggests that the methodology proposed in this paper could be of value to scholars, policymakers, and even private sector advisors interested in extracting early hints about the likely future course of fiscal stabilization programs from the observed performance of macroeconomic variables around the time of their announcement and/or actual implementation.

In any case, as noted at the beginning of this conclusion, the lack of credibility of the budget sequestration detected by this paper should inform future research seeking to evaluate its ultimate outcome. It could be potentially misleading to extrapolate the policy lessons of the budget sequestration to other fiscal stabilization programs, absent taking into account the finding of this paper. Similar, but credible fiscal austerity programs, may be able to deliver qualitatively and/or quantitatively different outcomes.

That observation applies, of course, to all fiscal stabilization programs. Therein lies the importance of formally assessing the credibility of as many past stabilization programs as possible, as well as of those to come. The paper developed a methodology to assess the credibility of one of those programs. Properly adapted and expanded, that methodology could prove useful to systematically assess the credibility of many other fiscal stabilization programs, the impact of that credibility on macroeconomic outcomes and, ultimately, on the success of the corresponding programs in eliminating structural fiscal imbalances.

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# Appendix

## A Assessing The Credibility Of The Budget Sequestration Cuts With A Bayesian Approach

This section exploits the Bayesian Markov Chain Monte Carlo (MCMC) approach to estimate the parameter vector $\psi$, which governs the spending cuts scenarios.[14] Let $p\left(Y^T|\psi\right)$ and $\pi\left(\psi\right)$ denote the likelihood function and the prior distribution of the parameters, respectively. It can be shown that the posterior distribution of $\psi$, $\pi\left(\psi|Y^T\right)$, satisfies

$$\pi\left(\psi|Y^T\right) \propto p\left(Y^T|\psi\right)\pi\left(\psi\right) \ .$$

Given that the posterior distribution is not analytically tractable, this study employs a Random Walk Metroplis-Hastings (RW-MH) sampler to generate draws from the proposed distribution. The RW-MH sampling algorithm proceeds as follows:

Step 1. Start from $\psi^{(0)} = [\psi_0^{(0)},\, \psi_1^{(0)}]' = [0.5,\, 0.5]'$, and use a symmetric random walk proposal $g$ .
Step 2. For $i = 1$, draw $\epsilon^{(i)} \sim g$ and set $\psi^c = \psi^{(i-1)} + \epsilon^{(i)}$.
Step 3. Compute the acceptance probability for the candidate draw:

$$\alpha\left(\psi^c|\psi^{(i-1)}\right) = min\left\{\frac{p\left(Y^T|\psi^c\right)\pi\left(\psi^c\right)}{p\left(Y^T|\psi^{(i-1)}\right)\pi\left(\psi^{(i-1)}\right)}\frac{g\left(\psi^c-\psi^{(i-1)}\right)}{g\left(\psi^{(i-1)}-\psi^c\right)},\, 1\right\} = min\left\{\frac{p\left(Y^T|\psi^c\right)\pi\left(\psi^c\right)}{p\left(Y^T|\psi^{(i-1)}\right)\pi\left(\psi^{(i-1)}\right)}\,, 1\right\} \ .$$

Step 4. Set $\psi^{(i)} = \psi^c$ with probability $\alpha\left(\psi^c|\psi^{(i-1)}\right)$, and $\psi^{(i)} = \psi^{(i-1)}$ with probability $1 - \alpha\left(\psi^c|\psi^{(i-1)}\right)$.
Step 5. Repeat Step 2 - 4 for $i = 2,\, 3,\, ,...,\, N$.

In this application, the prior distribution of $\psi_0$ and $\psi_1$ is assumed to be $U(0,\, 1)$. Given these uninformative or diffuse priors, the posterior distribution is principally determined by the likelihood function.[15] In addition, this study assumes that the symmetric random walk proposal $g$ is bivariate Gaussian with diagonal variance-covariance matrix $\Sigma_g$, where the standard deviation of $\psi_0$ is set at two-thirds of the standard deviation of $\psi_1$. $\Sigma_g$ is scaled to ensure that the acceptance rate is around 50%. [16]

Table A.1 and Figure A.1 - A.2 report the posterior distribution of $\psi_0$ and $\psi_1$ based on 80,000 draws after a burn-in period of 20,000 draws. For $\psi_0$, which governs the credibility of the spending cut in 2013, the posterior distribution is concentrated at the high end of the zero-one interval. While the posterior mean is 0.61, rounding the accepted draws at the 2nd digit yields posterior mode that is equal to 0.97, which serves as strong empirical evidence that the announced spending cuts in 2013 are highly credible. In contrast, the data seems to provide very limited information to update the prior distribution of $\psi_1$. The posterior distribution of $\psi_1$ seems to be close to uniform with estimated

[14] As indicated in section 3.2.4, $\psi = [\psi_0,\, \psi_1]'$.

[15] Given the event-study nature of this paper, the likelihood function used to compute the acceptance probability incorporates exclusively the likelihood of the data in 2013.

[16] Computing the inverse Hessian of the logarithm of the likelihood in 2013, evaluated at $\psi_0 = \psi_1 = 0.5$, suggests that the standard deviation of $\psi_0$ is smaller than that of $\psi_1$. However, estimation results are robust to other specifications on $\Sigma_g$, such as (1) $std(\psi_0) = std(\psi_1)$; and (2) $std(\psi_0) = \frac{3}{2}std(\psi_1)$.

posterior mean 0.49. Given the limited evidence inherent to an event-study approach as the one adopted for this paper, it is rather remarkable that an uninformative prior distribution shifts the mode of the posterior distribution to 0.07. This feature of the posterior distribution, along with its general tendency to increase the frequency of the parameter $\psi_1$ at its value declines, relative to the flat frequencies of the prior, suggests that a Bayesian inference approach to the evidence favors rather unambiguously the low credibility spending cuts scenarios.

Table A.1 : Posterior Distribution of the Estimated Parameters

| | $\sigma = 1,\ \varphi = 0.5$ | |
|---|---|---|
| | $\psi_0$ | $\psi_1$ |
| Posterior Mean | 0.6140 | 0.4865 |
| Standard Deviation | 0.2728 | 0.2886 |
| Posterior Mode | 0.9700 | 0.0700 |
| 10th Percentile | 0.1950 | 0.0921 |
| 90th Percentile | 0.9429 | 0.8931 |

Figure A.1 : Posterior Distribution of $\psi_0$ ($\sigma = 1,\ \varphi = 0.5$)

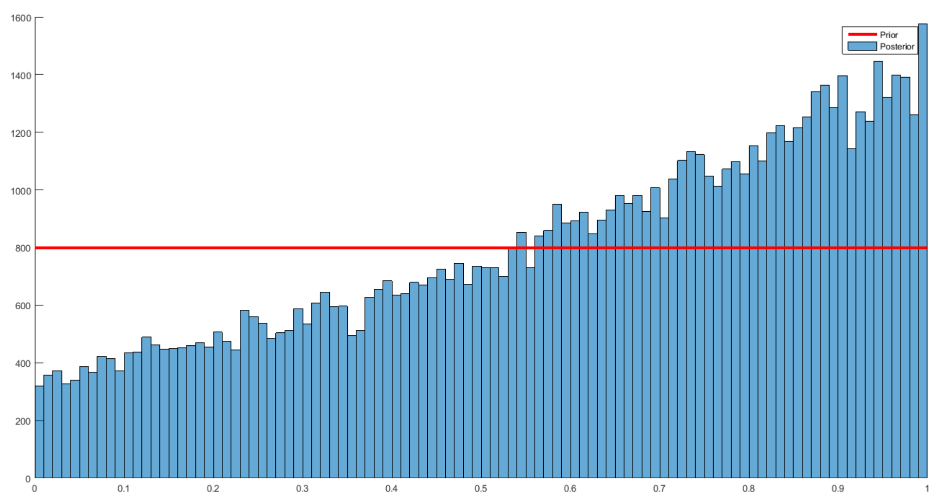

Figure A.2 : Posterior Distribution of $\psi_1$ ($\sigma = 1$, $\varphi = 0.5$)