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Issues in Dynamic Revenue Estimating

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Summary

Dynamic revenue estimating, which accounts for macroeconomic feedback effects on revenue costs of tax changes, has become increasingly important. An analysis of these effects is now required before a tax bill can come to the House floor.

The initial study of the President's budget proposals for 2003 by the Congressional Budget Office (CBO) revealed a wide range of effects — from a 30% decrease in revenues to a 15% increase. Subsequent studies and studies by the Joint Committee on Taxation and the Treasury Department also find varying results. These differences reflect the types of effects included, the models used, and the behavioral responses. There are three types of effects: short-run stimulus, or Keynesian, effects, which reduce costs; crowding out effects of deficits, which increase costs; and supply side effects, which could go in either direction. There are four basic types of models: neoclassical growth models, short-run models with unemployed resources, and infinite horizon and life cycle intertemporal models. Only the second type includes Keynesian effects. All include supply side effects. Deficit effects can be included but eventually have to be resolved in certain intertemporal models or the models cannot be solved.

Arguments have been made that Keynesian effects not be considered. These effects also apply to spending, are not the objective of permanent tax policy, and are dependent on how tax cuts are financed and the reaction of the Federal Reserve. The two models CBO used with Keynesian effects found opposing effects. Some also argue that the effects of deficits should not be considered because these effects, as well, apply to spending and, eventually, deficit issues must be resolved.

Supply side effects in neoclassical growth models include labor supply response, savings response, and the ability to substitute labor and capital. Given reasonable savings elasticities, savings effects are not very important in the short run; the main issue is labor supply. Most evidence suggests, however, that labor supply response is small (so that assuming no response is probably reasonable). It is even less likely that labor can respond in the short run, where considerable institutional barriers exist.

Intertemporal models are based on individual optimization over a long period of time. There are three reservations about these models. First, do they represent actual behavior of individuals? Second, the outcomes are sensitive to many assumptions and the behavioral responses in many of these models (including those used by CBO) result in much larger savings and labor supply responses than are justified by empirical evidence. Finally, intertemporal models with foresight cannot be solved without some presumption about how the budget deficit is dealt with, and the choice can make a great deal of difference in the outcome (indeed, it changes the direction of effects). These models cannot address a stand-alone tax cut.

The range of results in the Congressional Budget Office study would be even larger if further sensitivity analysis for supply response were undertaken; in particular, such sensitivity analysis would probably cause larger additional costs (rather than revenue offsets) from feedback effects. This report will not be updated.

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Dynamic revenue estimating, which accounts for macroeconomic feedback effects of tax changes on revenues, has become increasingly important. The Joint Committee on Taxation (JCT) has been engaged for some time with a study of how to include these effects and has been attempting to develop a model for this purpose. In early 2003, a rule adopted by the House required a macroeconomic analysis to be prepared (or a reason given for why it cannot be prepared) before tax legislation can come to the floor, and this rule has been retained by subsequent Congresses.

Also in 2003, the Congressional Budget Office (CBO) presented its first dynamic analysis of the President's budgetary proposals, using a variety of models and assumptions (hereafter CBO study).[1] These proposals provided for permanent tax cuts in individual rates and on income from capital. A range of effects, both positive and negative (although generally small) was reported in these analyses, with feedback effects on budgetary costs ranging from a 15% increase in cost to a 17% decrease in cost. The CBO study examined both spending and tax changes and considered effects on the entire budget (including effects of increased interest on the debt). The CBO has subsequently produced studies of both the President's budget and other proposals. The most recent study was of the President's FY2008 budget proposal.[2] As with the 2003 study, feedback effects were relatively small and ranged from positive to negative.

Subsequently, the JCT prepared an analysis of the tax cut passed in the House on May 9, 2003 (hereafter JCT study).[3] This tax cut was temporary in nature and many of the provisions directly affecting wage income had effects only in the first five years because they were accelerations of existing tax cuts. The JCT analysis focused only on revenue effects (and not the entire budget). Average effects over the 10-year period were a reduction in revenue costs (ranging from 2.6% to 23.4%). However, its study, while estimating positive effects on real output in the first five years, found negative effects in the second five years (and these effects would be expected to continue to be negative). The JCT has continued its studies; the most recent study was of a income tax reform proposal that would broaden the base and lower the rate.[4] This proposal was not a tax cut, but a revenue neutral reform, and

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[1] Congressional Budget Office. *An Analysis of the President's Budgetary Proposals for Fiscal Year 2004*, March 2003.

[2] Congressional Budget Office. *An Analysis of the President's Budgetary Proposals for Fiscal Year 2004*, March 2003.

[3] "Macroeconomic Analysis of H.R. 2, the 'Jobs and Growth Reconciliation Tax Act of 2003,'" Prepared by the Staff of the Joint Committee on Taxation.

[4] Joint Committee on Taxation, Macroeconomic Analysis of a Proposal to Broaden the (continued...)

resulted in output increases ranging from 0.1% to 1.2% for the first five years, depending on the model used.

The Treasury Department's Office of Tax Analysis prepared its first dynamic analysis in 2006 with a study of the proposals by the President's Advisory Panel on Tax Reform, also a revenue neutral tax change.[5] For the income tax reform, the effects on output in the budget window ranged from 0.1% to 0.4%. For the consumption tax proposal, the effects ranged from 0.1% to 1.9%.[6] A subsequent analysis examined the effects of the 2001-2004 tax cuts.[7] This study did not report revenue feedback effects, but CRS calculations indicate revenue costs would be reduced by 7% in their base case and would range, depending on responses in the models, from less than 1% to 18%.[8] Treasury also reported some short-run effects in its mid-session review.[9]

The estimates of feedback effect depend on the kinds of effects included, the nature of the model used, and a variety of assumptions regarding underlying behavioral responses. This report explains these issues and discusses the empirical evidence on some of the crucial supply-side behavioral responses. Some of the more technical material and details are presented in appendices.

The first section explains the three basic sources of feedback effects that can be considered: short-run stimulus, deficit crowding-out, and supply side; and how these three effects relate to the four basic types of models. The following sections discuss the issues surrounding each type of effect.

Types of Effects and Types of Models

There are three types of revenue feedback effects:

- short-run stimulus, or Keynesian effects
- crowding out effects of deficits

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[4] (...continued)
Individual Income Tax Rate and Lower the Base, JCX-53-06, December 14, 2006.

[5] Robert Carroll, John Diamond, Craig Johnson, and James Mackie III, *A Summary of the Dynamic Analysis of the Tax Reform Options Prepared for the President's Advisory Panel on Federal Tax Reform*, U.S. Department of the Treasury, Office of Tax Analysis, May 25, 2006, prepared for the American Enterprise Institute Conference on Tax Reform and Dynamic Analysis, May, 2006.

[6] This analysis is discussed in greater detail in CRS Reform in CRS Report RL33545, *The Advisory Panel's Tax Reform Proposals*, by Jane G. Gravelle.

[7] Office of Tax Analysis, United States Department of the Treasury, *A Dynamic Analysis of Permanent Extension of the President's Tax Relief,* July 25, 2006.

[8] CRS Report RL33672, *Feedback Effects from the 2001-2004 Tax Cut*, by Jane G. Gravelle.

[9] U.S. Office of Management and Budget, *Fiscal Year 2007 Mid-Session Review, Budget of the U.S. Government*, July 11, 2006.

- supply side effects.

The first two — the short-run stimulus effect in an underemployed economy and the crowding out effects of deficits — apply to spending increases as well as tax cuts. Spending increases actually have a more powerful effect than most tax cuts because some fraction of a tax cut is not spent. Some have argued that the first effect or even the first two effects should not be included in dynamic revenue estimates. The third type of effect is commonly called a supply side effect because it refers to the effects of tax or other policies on the amount of labor supplied or the amount of savings (which would affect the size of the capital stock). This supply side effect is more closely associated with tax changes although it could apply to certain spending programs as well. (For example, spending on infrastructure such as bridges or highways would affect productivity.)

There are also four basic types of economic models; all of these models can incorporate supply side effects, but they vary in whether and how they incorporate the Keynesian or deficit crowding out effects:[10]

- Basic neoclassical growth models (also called Solow models);
- Short-run models with underemployed resources typically used for short-run forecasting. These models are also referred to as ISLM [11] models and usually transition or are made to transition to a neoclassical growth model;
- Infinite horizon intertemporal models, also called Ramsey models or referred to as "Barro-type" models; and,
- Life cycle intertemporal models (also called overlapping generation or OLG models).

Only the second type of model can include short-run stimulus effects because all of the other models are full employment models.

All of the models include supply side effects but they introduce them in different ways. In the basic neoclassical growth model and the ISLM-growth model, the savings rate and the labor supply depend (or can be made to depend) on after-tax rates of return on savings and after-tax wage rates, and the elasticities (percentage change in quantity divided by percentage change in price) used are derived directly from statistical estimates of these parameters (referred to as reduced forms). A change in tax rates on labor or capital income induces changes in savings rates and labor supply that affect output in this period and the capital stock in the next period. The change in the capital stock alters the return on capital and wage and induces another adjustment in the savings rate and labor supply. This process continues over

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[10] This report does not address direct estimates of tax revenue response to specific tax changes since these responses cannot be generalized across different tax cuts.

[11] ISLM refers to the two basic demand side equations in a short-run model that determine aggregate demand levels and interest rates: an investment-savings relationship where output is the sum of spending on consumption, investment, government expenditures, and net exports, and a money demand equation where individuals trade off liquidity against interest rates in determining how much assets are held in money versus bonds.

a period of time until it approaches a new equilibrium where the savings generated in the economy just equals the amount of net investment needed to grow the economy at a steady state. The effects are determined by three responses: the savings elasticity, the labor supply elasticity, and the factor substitution elasticity; the last reflects the ease with which labor and capital are substituted in the production process.

In the infinite horizon and life cycle models, savings (and, depending on the model, labor supply) arise from an optimization of spending over time — over infinity in the infinite horizon model and over a lifetime in the life cycle model. The size of these effects depends on many different factors, but some of the important ones are the willingness of individuals to substitute leisure for consumption within a time period (measured by the intratemporal substitution elasticity), the willingness of consumers to substitute over time (the intertemporal substitution elasticity), and the factor substitution elasticity. Another very important feature of these models for the short run is the amount of available hours which directly affects the labor supply response that arises from the model.

All of the models can deal with deficit effects, but the infinite horizon model and some versions of the life cycle model (those with foresight) cannot permit deficits to run indefinitely because deficits eventually cause the model to explode (i.e., the cumulating deficit will grow without limit). These types of models rely on future values to solve even the very short run and must be subject to a government budget constraint which requires the budget deficit eventually to be addressed. How the budget deficit is addressed can make a great deal of difference to the outcome.

Each of these model types has been used in dynamic analysis of tax provisions. The Joint Committee on Taxation (JCT) convened a number of researchers in 1996 for a study for fundamental tax reform (with results published in 1997, hereafter referred to as the JCT Symposium): models there represented two of the first type, three of the second type, one of the third type, and three of the final type.[12] These studies focused largely on supply side effects because the groups modeled revenue-neutral tax substitutions, although the disruptions from changing tax collection sources caused some negative short-run effects in models with unemployment. The two recent studies presented in March and May of 2003 respectively also used a variety of model types. The CBO study analyzed the President's budget proposals using all of these model types; the JCT study used the two models of the second type and one of the fourth type.[13] More recently, JCT has used one model of each except the first type, although the infinite-horizon intertemporal model was substantially modified to include a share of individuals who simply spend all of their income. Treasury initially used the first, third, and fourth type in its analysis of the tax reform

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[12] The results were presented in *Joint Committee on Taxation: Tax Modeling Project and 1997 Symposium Papers*, Joint Committee Print JCS-21-97, U.S. Government Printing Office, 1997.

[13] Note that although the JCT refers to its Macroeconomic Equilibrium Growth model as a neoclassical growth model, it actually falls in the category of models with underemployment equilibrium which become similar to neoclassical growth models in the long run.

proposals. It has used the second, third, and fourth types in its analyses of the 2001-2004 tax cut.

Different models have different strengths and weaknesses. Moreover, because of the complexity of modeling, within each type of model, certain aspects may modeled in great detail and others simplified. For example, of the three life cycle models represented in the 1997 JCT Symposium, one model used perfect foresight (the assumption that consumers can project the effects of their behavior on future rates of return and wage rates), but had a single good and a single representative income level. Another life cycle model had considerable detail with respect to different industry sectors, different types of assets, and different income levels of individuals, but did not assume agents could predict and act on future prices. A third life cycle model had neither perfect foresight nor disaggregation but allowed for risk, uncertainty, and precautionary savings. Comparative studies have shown that these models are sensitive to a variety of parameters and assumptions and numerous characteristics that can influence effects on behavior in life cycle models.[14]

There are issues surrounding the estimation and even the appropriateness of including these various effects, which are discussed in turn.

Short-Run Stimulus Effects

A number of issues arise with respect to including the effects of short-run stimulus of the economy (Keynesian effects), where real output increases because of the employment of involuntarily unemployed labor. The effect is relatively straightforward: output rises by some multiple of the tax cut, called the multiplier, that arises from successive rounds of spending (the original tax cut, the spending of those who receive income from the individual round, and so forth). That increase results in a feedback effect, at least for the time the output is increased. Multipliers typically rise as the fiscal stimulus spreads through the economy but then fall as the economy returns to full employment. If the multiplier is 1 for a given year, and the tax rate is 0.2, then there is a 20% revenue feedback effect for that year arising from the stimulus.

The first issue is whether these stimulus effects should be included at all, especially if the dynamic estimate is to be the official estimate for budget scoring

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[14] These characteristics include presence of endogenous labor, myopia vs. perfect foresight regarding pretax rates of return and wage rates, uncertainty, the presence of bequests and the bequest determination (arising from intergenerational altruism, joy-of-giving, uncertain life-span, fixed size of bequest), existing consumption tax treatment, substitution elasticities (intertemporal, intratemporal and factor substitution), use of a Stone-Geary utility function which requires a minimum consumption in each time period, inclusion of depreciation, assumed size of potential work hours, single vs. multisector economy, and open vs. closed economy. For the tax substitution experiment, the presence and form of transition relief was also important. For a table characterizing the directional effect of these features on short and long run gross output effects, see Jane G. Gravelle, "Behavioral Responses to a Consumption Tax," in *United States Tax Reform in the Twentieth Century*, Ed. George R. Zodrow, and Peter Mieszkowski, New York, Cambridge University Press, 2002.

purposes (a use not currently contemplated), rather than for informational purposes. A principal reason for excluding these effects is that they also apply to spending increases, and to consider short-run effects for tax changes and not for spending changes would create a misperception of the relative costs of these alternatives. Moreover, if the purpose of the tax cut is as a stimulus it is unclear what the value of calculating the feedback effect is. The relevant public policy issue is not the cost after feedback, but rather the desirable size and effectiveness of the initial tax cut on output, an assessment that requires knowing the cost without feedback. If the purpose is a permanent tax cut, however, then any short-run feedback effect is transitory, and to include it in assessing the cost of a tax cut can make the cost appear artificially small.

Aside from these issues of whether to include the stimulus effect, there are a number of reasons that such an effect is difficult to assess. Since the effect depends on how close the economy is to full employment, several tax cuts considered separately would have a larger summed up effect on output than a combined tax. Indeed, the feedback effect might be different at the time a tax is proposed, compared to the time it is actually enacted.

Moreover a tax cut bill may be considered to be financed by a deficit (in which case it would have a stimulus effect), by a spending offset (in which case it would probably have a slightly contractionary effect), or by an offsetting tax increase. Any analysis that includes a stimulus effect is making an implicit judgment about whether the tax cut would be financed by borrowing.

Another reservation about incorporating short-run effects is that they depend on the actions taken by the Federal Reserve Board. In theory, any fiscal stimulus could be offset by contractionary monetary policy (or accommodated with expansionary policy, although this effect is less likely under current monetary regimes). The degree to, and speed with which, the monetary authorities act to offset (or magnify) the effects of a tax cut will determine how large the effect will be, which means that each analysis implicitly includes an assumption about the behavior of another government agent. A tax change might also induce behavioral changes by foreign governments that affect the impact.

The final problem is the accuracy with which the stimulus effect can be estimated. The effect of a tax cut on output depends crucially on several factors on which the economics community does not have a consensus. For example, there is considerable disagreement about how much of an individual tax cut will be spent, depending on how expectations about the future are presumed to be formed, whether a tax cut is permanent or temporary, whether it is received by higher or lower income individuals, and whether it is received in a lump sum form or through withholding. Effects of an investment stimulus provided to firms are even more uncertain, because of a lack of empirical evidence on the responsiveness of business investment to tax subsidies. The effects are also influenced by the degree to which interest rates rise as income expands (and the subsequent crowding out of private investment). The degree of openness of the economy is also crucial; in a flexible exchange rate environment with very mobile capital, a fiscal stimulus has little power other than in the very short run because the associated rise in interest rates which induces an inflow of foreign capital will cause the price of the dollar to rise and reduce net

exports. In such a model, investment crowding out is greatly reduced but so is the output effect. Finally, a shift in aggregate demand will cause some increase in output and some increase in price level; the relative shares depend (or should depend) on how close the economy is to full employment. To the extent that prices rise, feedback effects can become very confusing unless they are expressed in constant dollars.[15]

The estimated stimulus effect depends on which model is used. A study by economists at the Federal Reserve Board (holding nominal interest rates fixed, which produces the largest multipliers via an accommodative Fed stance) found that multipliers, while larger for a spending change than a tax cut, varied substantially across four models considered: the Federal Reserve's own model, an older Federal Reserve model and two commercial macroeconomic models: DRI and Washington University Macro Model (WUMM).[16] After two years, multipliers for tax cuts ranged from 1 to 1.75. The overall effect on deficits (which depends not only on output change but interest rate effects) also varied substantially. The authors suggest that the multipliers in the Federal Reserve's model tend to be smaller because they have forward looking expectations. The multipliers would all, of course, be smaller if money supply were contracted, or even held constant, rather than expanded. Gregory Mankiw, for example, reports the tax multiplier in a major macroeconomic model (Data Resources Inc., or DRI, a predecessor of DRI-WEFA and, in turn, a predecessor of Global Insight) is 1.19 if the interest rate is held constant (which would require a monetary expansion), 0.26 if the money supply is held constant (the interest rate would rise but output could also rise), and zero if the inflation rate is held constant (the interest rate rises so much that output is fixed).[17]

As an illustration of the differences in the models, the 2003 CBO study of the President's proposal compared simulations on two commercial macro models, Macroeconomic Advisors which is the current version of WUMM and Global Insight, a model that resulted from a merger of DRI with another modeling firm. Feedback effects varied from positive to negative because of the offsetting effect of deficits (discussed next) and differed substantially across models (ranging from an increase in cost of 9% in the first five years to a decrease of 29%). It is clear from the disaggregation reported by CBO that the effects on revenues were largely composed of short-run Keynesian effects. In its initial study in 2003, the JCT used its own model termed Macroeconomic Growth Model or MEG (adapted from Macroeconomic Advisors) and the Global Insight model to assess effects on real revenues (and thus did not include the direct effects of higher interest costs arising from the deficit, only the crowding out effects on capital income and their subsequent

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[15] If effects are expressed in nominal dollars, a cut in taxes can appear to be less costly because the increase in price level increases the nominal level of receipts. This price effect also increases any spending that is tied to inflation, but since much spending is set in nominal terms, this change will also cause the nominal deficit to fall, basically by effectively reducing the real level of government spending.

[16] Eileen Mauskopf and David Reifschneider, "Dynamic Scoring, Fiscal Policy, and the Short-run Behavior of the Macroeconomy," *National Tax Journal*, vol. 50, September 1997, pp. 631-655.

[17] N. Gregory Mankiw, *Macroeconomics*, 5th Edition, New York: Worth Publishers, p. 287.

effects on revenues). Results for the first 10 years varied significantly depending on the model and Federal Reserve action: from a 3.6% revenue offset for MEG with an aggressive Fed offset to a 23.4% for MEG with Fed neutrality. For Global Insight which has a delayed Fed offset, the feedback was 11.8%. For the House tax bill, clearly the dominant effect was short-run stimulus, but that effect is partly due to the transitory nature of the tax cuts and the focus on the revenue side.

Deficit Effects and Crowding Out

While the short-run stimulus effect acts to reduce the revenue cost of a tax cut, the effect of deficits causes tax cuts to cost more. One cannot have a short-run stimulus without a deficit, but one can have a deficit without a short-run stimulus (for example, if the monetary authorities offset the fiscal stimulus).

There are three types of deficit effects. First, the interest on debt issued to finance the tax cut increases spending costs directly. For dynamic studies of budget effects, such as those done in the CBO study, these interest rate effects are already included in initial budgetary costs. Deficits also crowd out investment and reduce the capital stock and thus reduce long run output and taxes on that output — effects that show up as a feedback increasing revenue costs. Deficits also add to budgetary costs because they raise interest rates and increase the cost of debt service.

Some of the same reservations about including stimulus effects also apply to including deficit effects, mainly that deficit effects occur with spending increases as well as tax cuts.

While the effect of deficit finance is probably more certain than the effects on short-run stimulus, there are some major uncertainties. First, if a tax cut is saved rather than spent, it does not have an effect on interest rates or crowding out (nor does it have an effect on stimulating the economy). However, empirical elasticities suggest that even tax cuts that reduce marginal taxes on savings are unlikely to unleash enough savings to offset the deficit effect.

The effects of deficits on interest rates and crowding out of investment can be partially or even fully offset by inflows of capital (which again reduce or eliminate the stimulus effect given flexible exchange rates). If a full offset occurred there might still be an additional cost to revenues because foreign owners of capital do not pay U.S. individual income taxes in most cases, and interest on debt, which is more mobile, is deductible by U.S. firms. (The amount of income available to U.S. citizens would decline, however, because more of the capital stock would be owned by foreigners.)

One other problem with deficits is that, while they can simply be allowed to occur in models that do not rely on long run variables to solve, the deficit must be addressed in order to solve the infinite horizon model or the perfect foresight life cycle model. Deficits running indefinitely cause an explosive growth of the debt which eventually supplants all the capital stock leading to a long run economy with no output. Two issues arise: how long might one wait to resolve the deficit issue and

how should the deficit be corrected? These issues are intertwined with the supply side effects in these intertemporal models and will be discussed in the subsequent section.

Supply Side Effects in the Basic Neoclassical Growth Model

Fundamental supply side effects occur largely through increased labor supply or increased saving (although note that either can be positive or negative due to income and substitution effects). An increase in the labor supply or the savings rate in response to a tax cut would produce additional income and taxes that would reduce the cost of the tax cut. However, increased saving is unlikely to have much effect on federal revenue in the revenue estimating time frame, while labor supply changes can be important. The CBO study has relatively small income and substitution effects that average out to a total elasticity of about 0.1 for an across-the-board wage change. Its neoclassical model yielded negative feedback effects because the labor supply elasticities were small while additions to the debt caused additional interest costs. The JCT study of the House tax cut did not formally report its elasticities (although they are apparently reflective of empirical evidence and therefore modest). The JCT model is not a pure neoclassical model even with an aggressive Fed reaction case, and the estimates reported are only for the effects on revenues. However, its feedback was relatively small, 9.8% in the first five years and 3.6% in the next 10 years. Real output fell in the second five years, presumably because of the temporary nature of the tax cuts affecting wages in the tax bill coupled with some budgetary crowding out.

A simple example can be used to illustrate why labor supply is crucial to effects on output. Empirical evidence on savings elasticities suggests values that range from slightly negative to slightly positive. But even taking the highest of these elasticities, 0.4, a 10% increase in rate of return would lead to a 4% increase in the savings rate. If the capital stock is growing at, say, 3% in real terms, savings would be only 3% of the capital stock. Thus a 4% increase in the savings rate would lead to a 0.12% (0.03 X 4%) increase in the capital stock. Assuming capital income accounts for one quarter of net income, total income would increase by about .03% (0.25 X 0.12%), that is, only 3/100 of 1 percent. This effect does not account for interaction with demand. An elasticity of 0.4 for labor supply would lead to an output effect of 3% with a 10% increase in the wage (again without accounting for demand interaction), an effect 100 times as large. The savings effects will grow over time but will be small initially.

Another way of thinking about this effect is to think of feedback effects, again before considering effects of the production function interaction. If an elasticity is 0.2 then, roughly speaking, the revenue feedback effect is on the order of 20% times the ratio of tax rate to after tax share (see Appendix A). For example, if the tax rate is 0.3, a reduction in wage tax will lead to an offset of about 9% (20% X0.3/(1-0.3)) That effect means that even small labor supply responses can potentially have significant feedback effects. Thus, in order to get an accurate measure of the revenue response, it is crucial to have a good measure of labor supply response. The factor

substitution elasticity, to which little attention has been paid in many models, can also play an important role as it determines both the demand for labor (which interacts with supply to produce a final amount of labor, also derived in Appendix A).

The first section of this part therefore addresses labor supply responses. It is specifically addressed to whether adequate evidence on a point elasticity exists to incorporate labor supply response into a revenue estimate, what such an estimate might be, and whether a range of effects might be considered. The information is presented in the body of the paper in summary form, but details are presented in **Appendix B**. The next sections discuss the factor substitution elasticity and elasticity of savings responses.

Labor Supply Response

Labor supply response is directly incorporated through an elasticity estimate, which may be disaggregated into income and substitution effects and by type of worker in the neoclassical growth models. The labor supply elasticity in inter-temporal models is derived from a particular function and will be discussed subsequently.

The supply of labor can rise or fall with an increase in wages due to opposing income and substitution effects. A rise in wages causes an increase, through the income effect, of consumption of both goods and leisure, which reduces labor supply. This income effect can also arise from changes in average tax rates. The rise in wages also causes leisure to become relatively more costly, inducing a substitution of consumption for leisure, which causes the labor supply to rise. This substitution effect is governed by marginal changes in wages which are affected by marginal tax rates. Thus evaluating labor supply response to tax changes involves knowing the relative sizes of the income and substitution effects as well are the net effect of wage changes on labor supply. Labor supply can also reflect changes in hours, or changes in participation; the latter has particularly been of interest in the case of women's labor supply, since women, because of marriage and children, may not participate in the labor force.

This section begins with a overview of the empirical evidence, followed by a discussion of theoretical problems associated with that evidence, and then by the implications of both for incorporating labor supply response in scoring of tax legislation. The survey of econometric estimates indicates that both positive and negative labor supply responses to wage rate increases can be justified by the empirical evidence, findings consistent with economic theory. Empirical estimates from the literature also likely overstate the elasticities appropriate to dynamic revenue estimating for several reasons.

Empirical Evidence. Empirical evidence on labor supply can be classified into several types: historical patterns, cross section regressions, experimental approaches (natural or otherwise), and even survey data. Appendix B provides a more detailed discussion of the evidence, but the findings can be summed up as follows:

- History suggests a declining or, more recently, relatively unchanging number of hours worked per week despite dramatic changes in real wages, findings consistent with very small and possibly negative elasticities. Participation rates are mixed: participation of older and younger men has declined, participation of prime working age men has been constant, and participation of women has increased (but is now leveling out). Institutional and cultural factors may play an important role in these findings.

- Cross section evidence,[18] which is the most plentiful, suggests small income and substitution effects, with a net *negative*, but small, labor supply response for men (probably of around -0.1). For married women, labor supply response is more likely to be positive and the estimates vary significantly. These studies are fraught with numerous econometric problems. More recent evidence suggests that married women's labor supply response has declined and is converging toward that of men.

- Experimental approaches were of two types. Actual experiments with lower income individuals tended to find small elasticities of mixed signs and "natural experiments" (such as tax changes) tended to find virtually no effect. In the latter case, one study found elasticities of 0.6 to 1 for high income married women although this measure may have reflected only substitution effects and the effects were quite sensitive to controls; other aggregate studies and studies of high income men found essentially no response.

- Survey data asking individuals about their behavioral responses are often held to be unreliable, but they have suggested a small response by affluent men. Survey data on actual knowledge and work experience have suggested that individuals do not know their marginal tax rates (and might not respond for that reason) and that many individuals do not work their optimal hours (which suggests institutional factors may restrict behavioral response).

Theoretical Issues: Why Labor Supply Elasticities Are Probably Small, Can Be Negative, and May Be Falling. Reduced-form empirical estimates of labor supply (estimates that relate outcomes, such as hours worked or participation, to wage rates) suggest small elasticities in most cases. For example, hours of work by men with significantly different hourly earnings actually tend to vary very little. To understand more about the responses, and to prepare for understanding labor supply in intertemporal models, we consider how labor supply responses arise from a more formal model of individual optimization. It is important to understand several theoretical issues: labor supply response is limited by the

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[18] Cross-section evidence compares the hours different individuals work in a given time period and relates these hours to their wages. Cross section evidence can be contrasted to time series evidence which examines changes in average hours as related to changes in average real wages over time.

amount of hours in the day, labor response is limited by the number of potential workers: any labor supply response to wages presents an important dilemma for growth accounting, and institutional factors play a potentially important role in limiting labor supply response, particularly in the short run.

Constraints on Hours. The labor supply elasticity is derived from the substitution between consumption and leisure; that is a reason to expect it might be small. Suppose that we make the assumption that leisure and goods consumed by individuals increase by the same percentage when income increases in a way that does not affect the marginal wage. (Technically, this assumption means use of a utility function for leisure and consumption that is a constant returns to scale utility function, and thus has an income elasticity of one). Also assume that the substitution elasticity between goods and consumption with respect to the marginal wage is constant. (See **Appendix B** for a derivation). We keep the problem simplified by allowing no savings behavior and designate W as the wage rate, H as the hours available, L as leisure, C as consumption, and r as the ratio of non-labor income to labor income. With no non-labor income, we obtain a mathematical expression for the labor supply elasticity of the form:

$$E = (S-1)\, L/H$$

where S is the substitution elasticity.

What value might we expect to find for S? For many types of choices we would think of high substitution elasticities as those above one and low elasticities as those less than one. The more disparate commodities are, the more likely that there is not a lot of substitution between them. If, for example, one considers consumption of goods and leisure to be very different commodities one might not expect them to be easily substitutable.

The S term determines the effect of a rise in wages on increasing work effort through the substitution effect, while the 1 term determines the effect of a rise in wages in reducing work effort through the income effect. Labor supply response can be positive, negative or zero, depending on the size of S. A small labor supply response could be the result of large or small offsetting income and substitution elasticities.

However, as the formula indicates, even if leisure and consumption have a unitary substitution elasticity, the effect of this substitution elasticity on labor supply is smaller, and perhaps much smaller than the substitution elasticity itself because it is multiplied by the ratio of leisure to available hours. This effect makes sense: a person who is working every available minute cannot add to labor supply because his labor supply is constrained by an exogenous amount of time. As discussed in the appendix, this ratio of available leisure that can be diverted to work could be quite small if one allows for other necessary uses of time.

The other point illustrated by this formula is that the labor supply elasticity is not constant even if the underlying income and substitution elasticities with respect to consumption and leisure are. As work increases, the elasticity falls. This point is important, because it suggests that one should not impose a simple labor supply

elasticity across any significant period of time, but (assuming a rise in real wages) should have an elasticity that falls over time (becomes a smaller absolute value if positive and work is increasing and a larger absolute value if negative and work is decreasing). Moreover, it suggests that elasticities are smaller for those working more hours, a reason mentioned by Wilhelm and Moffitt in their study finding little labor supply response by very high income men.[19]

The example of hours response discussed here is meant only to be illustrative, as it is based on a specific form of utility function that includes unitary income elasticities and constant substitution elasticities. Adding non-labor income or requiring a subsistence amount of consumption, other things equal, is likely to increase in the first case and decrease in the second case the likelihood of a positive elasticity and the size of the substitution elasticity. There are many other types of functional forms where elasticities vary across consumption bundles and income elasticities can differ for leisure and consumption. However, the constraints of labor supply exist and those constraints exert limits on elasticities regardless of functional form: people working every available hour can work no more.

Constraints on Participation. Like the amount of hours worked per week, the participation rate is also constrained. The share of people participating cannot fall below zero or rise above one. The almost complete participation of men under 65 in either work or school (and school is largely an investment in future earnings) over time has resulted in little attention to their participation response. However, for married women, who may not participate in the work force, participation response is the most important estimated labor supply response. If the participation response rises for exogenous reasons (e.g. a change in tastes, a decline in marriage or fertility), the elasticity should become smaller, and at some point it should decline if it increases because of wage increases. This point is addressed in the appendix: elasticities, particularly high elasticities, tend to decline when participation rises; indeed, such growth has raised the question of whether women's labor supply elasticities may eventually converge to those of men.[20]

Also discussed in the appendix are survey data which illustrate how close women have now come to male labor supply and how little room for response remains. A positive labor supply response given wage growth cannot continue for long without running out of available workers.

The Labor Supply Response Is Incompatible with Steady-State Growth Unless Elasticities Become Zero. Labor supply analysis is filled with many troubling issues. Why, for example, did the work week decline for 70 years and in an uneven fashion, and then largely stabilize (except for World War II) for the next 60 years at around 40 hours per week? Of course, there were laws adopted that tended to limit hours, but why were they not changed over time? Moreover, a troubling problem for any long term model of the U.S. economy is that a positive or

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[19] Moffitt and Wilhelm, "Taxation and the Labor Supply of the Affluent," In *Does Atlas Shrug?*, Ed. Joel Slemrod, New York, Russell-Sage, 2000.

[20] See Heckman, James J.,"What Has Been Learned About Labor Supply in the Past Twenty Years," *American Economic Review*, vol. 83, May 1993.

negative labor supply response is inconsistent with steady state growth. Growth economists typically model economies as converging to a steady state, with growth rates usually (although not always) exogenous. Some models simply fix labor supply. However, for those that allow endogenous labor supply along with technical progress that increases real wages, such models technically would converge at corner solutions, with people either virtually not working at all, or working every available moment, unless elasticities are zero. Thus a steady state growth model is incompatible with an aggregate labor supply response, and modelers who wish to incorporate technical progress must also impose some arbitrary rule (such as constantly changing preferences that move with the growth rate).

If elasticities are very small (either positive or negative) the change over time might become so small that, for practical purposes, they can be ignored in growth models. However, even small elasticities can lead to significant changes over an extended period of time. For example, a positive elasticity of 0.1 with a current work week of 40 hours plus other constraints on time that result in leisure being half of available hours, and assuming a real wage growth of 0.015 over time would result in projected hours of 43 in 50 years, which would not seem unreasonable. But it would also imply that individuals worked only 34 hours a week 100 years ago, and 28 hours 200 years ago, a finding at odds with history. If the elasticity were 0.3, the implication would be a rise to 49 hours in 50 years, with 23 hours 100 years ago and 11 hours 200 years ago, projections that seem completely unreasonable.

Institutional Issues. Modern work activities are performed in groups and work hours are not easily adjustable for an individual worker. Indeed, as noted earlier, survey evidence indicates that a large fraction of individuals are not working their preferred hours. In the case of taxes, economic theory strongly suggests observations should be bunched at kinks in the budget constraint. But, in fact, they are not. If anything, they are bunched at what appears to be an institutional norm of around 40 hours a week which is an aggregate work week span adopted as reasonable by implication due to the legislation on overtime. In general, one of the arguments for still allowing hours responses is that individuals do have some flexibility in choosing hours by choosing employers and jobs, and some flexibility still remains. However, this type of flexibility is constrained by adjustment costs that present a potential barrier to variation in hours in the short run.

Using Empirical Evidence on Elasticities for Dynamic Scoring Purposes. This section addresses the specific issue of turning to the empirical evidence on labor supply elasticities for purposes of dynamic scoring. In addition to the inherent uncertainties of labor supply response, other issues are: the likelihood that female elasticities are lower as the female participation rate has increased, the need to incorporate cross elasticities between husbands and wives in an aggregate elasticity, and the expectation that short-run responses will be much more constrained by adjustment costs and institutional factors. Overall, the discussion suggests that one cannot necessarily expect a positive labor supply response to tax cuts. Therefore, the presumption of a fixed labor supply for revenue estimating purposes is a quite reasonable assumption.

Variability and Uncertainty in Estimates. The first challenge in seeking an elasticity, or elasticities, to use in dynamic scoring for tax purposes is choosing

one compatible with empirical evidence and economic theory. Not only do labor supply elasticity estimates vary considerably, actually moving from positive to negative, but they are also uncertain because of a number of problems with measurement and specification. These issues are discussed in a number of the survey articles cited in the appendix. Even considering the relatively simple case of male labor supply, there are difficulties in measuring non-labor income (usually from assets), which is used to identify income effects as separate from substitution effects. Progressive tax rates create kinked budget constraints and complicate estimation, although new computer techniques have simplified the mechanics of doing such estimates. Most studies do not adjust for cost-of-living differences that could affect real wages in different localities. And with any econometric studies there are often measurement problems, assumptions of uniformity in certain aspects of the preference function, variations in the choice of other regressors, and variations in functional form that can affect estimated coefficients. In some ways, it may be considered a heroic assumption to posit that the tastes and preferences for work of high income individuals are the same as lower income individuals. But even seemingly minor issues can have effects that could actually change the sign when elasticities are low in the first place. For example, one study found that the use of actual hours rather than desired hours in estimated labor supply equations biased the elasticity upward (in this case by 0.1, i.e., a positive labor elasticity is too large and a negative one should be even more negative).[21]

More serious complications arise in the case of female labor supply. To correct for sample selection bias (individuals working may not be representative) as well as estimate participation response involves including data for non-working individuals where no wage is observed, requiring the inclusion of instrumental variables associated with wage. Many characteristics correlated with wages, such as experience and schooling, may not only directly affect wages but may also reflect tastes for working. Moreover, the dynamics of families are not completely straightforward either: do wives make their choices about working given husbands' choices, or does the couple make a joint utility-maximizing decision, or do they engage in a bargaining solution? The estimation process and the measurement of income will vary substantially depending on what assumption is made.

A recent survey of economists, which included a survey of the views of 65 labor economists on their best estimates of labor supply elasticities for prime age men and women, is suggestive of the existing professional disagreement and lack of consensus about the sign of labor supply response for men and the magnitude for women.[22] Details are presented in **Appendix B**.

Using Out-of-Date Estimates. Most estimates of labor supply are based on data from the sixties, seventies or at best the eighties. Even a more recent study published in 1998 (Pencavel) used data from the early seventies to the mid nineties

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[21] Shulamit Kahn and Kevin Lang, "The Effect of Hours Constraints on Labor Supply Estimates," *The Review of Economics and Statistics*, vol. 75, November 1991, pp. 605-611.

[22] Victor R. Fuchs, Alan B. Krueger, James M. Poterba. "Economists Views about Parameters, Values and Policies: Survey Results in Labor and Public Economics," *Journal of Economic Literature*, vol. 36, September 1998.

and thus tends to reflect on average the early eighties. As discussed earlier, elasticities are expected to change over time, so there is always a question of relying on existing estimates. In particular, the larger elasticities associated with female labor participation should be falling, perhaps substantially, particularly if one weights elasticities by current wage shares (which reflect increased participation rates for women). Female labor participation increased from about 43% in 1970 to 52% in 1980 to 58% in 1990. Moreover, because the elderly population share was growing during this time (for example, the elderly share of the over 15 population grew by about 5 percentage points between 1980 and 2000 for women), the participation rate among those able to work grew even more. There is also some direct evidence of a decline in supply response. Of course, the perceptions of labor economists reported above may reflect acknowledgment of the higher participation rates.

Cross Income Elasticities. A simple weighting of male and female elasticities by their respective wage shares is an incomplete measure, since there are cross elasticities between husbands and wives which should be negative. That is, the income effect may not only affect your own labor, but also your spouse's labor. In models that treat women as the secondary earner, such a response would be confined to wives. As shown in Appendix B, elasticities derived from weighting male and female wage elasticities would be reduced by between 0.05 to 0.10 if this effect were accounted for.

Short-Run Elasticities Should be Smaller, and Asymmetrically So, Than Long Run Ones. There are several reasons why the short-run response is likely to be smaller than the long run (the effect measured in cross section studies), and this is particularly true for changes that induce a positive rather than a negative labor response.

First consider hours. A large share of the currently employed labor force has no direct control over hours; surveys suggest that many individuals would like to work more or fewer hours than they now do. Economists recognize these constraints but generally presume that individuals do have hours choices by changing employers and jobs (and perhaps even professions). This presumption is reasonable in the long run, which is the basis of most cross section studies. But in the short run, even over several years of the estimating horizon, these adjustments cannot easily be made. While self-employed individuals or individuals whose pay is closely tied to performance may work more to earn higher wages or salaries, some self employed individuals may still follow group norms, such as standard hours of opening for retail businesses. Individuals wishing to expand labor hours through a second job find this choice to be discrete, and perhaps not yielding the same pay. But even given these options, it should be clear that the hours elasticity should be smaller, perhaps much smaller, in absolute value, in the short run.

A similar argument applies to a participation response, but applies asymmetrically with respect to expansion versus contraction. Entering the labor force requires, at a minimum, some amount of job search, and may also require some additional period of education and training. Child care arrangements must be made in many cases and require some period of search. Deciding to enter the labor force, and being able to do so at a desirable salary and with desirable working conditions, is a much more challenging process than an original decision made when young to

stay in or leave the work force. For an individual who has retired, such a re-entry may be especially difficult and unlikely, in part because of health and in part because a very short time might remain to work in any case. However, exiting the labor force is relatively easy.

The Production Function and Factor Substitution Elasticities

In the long run, workers tend to create their own capital, but in the short run, the capital stock is fixed or relatively fixed. As a result, dynamic feedback effects can be quite sensitive to assumptions regarding the substitution between capital and labor in production (which determines the degree to which the labor demand curve slopes). Despite the importance of this effect, some modelers have paid little attention to the production function and whether the assumptions (often including use of a unitary factor substitution elasticity) are appropriate.

Consider first the total effect on labor used, which is due to the interaction of labor supply and labor demand. The formula for the percentage increase in the labor supply divided by the initial percentage increase in after tax wage due to a tax change is ES/(aE+S) where E is the labor supply elasticity, S is the factor substitution elasticity and a is the share of income received by capital (see Appendix A). To convert this value to output effects, the percentage change must then be multiplied by the labor income share (1-a). Thus if labor income is two thirds of the output share, the percentage change in output will be two thirds of the percentage change in labor employed.

The elasticity of labor quantity actually used as a function of the labor supply elasticity and the factor substitution elasticity is shown in Table 1. The large factor substitution elasticities are shown not so much because they are likely to be realistic, but rather because they illustrate the pattern of effects.

Table 1. Percentage Change in Labor Employed with a Percentage Change in Tax (Fixed Capital Stock)

Labor supply elasticities	Factor substitution elasticities						
	0.2	0.4	0.5	0.7	1.0	1.5	2.0
-0.2	-0.31	-0.24	-0.23	-0.22	-0.22	-0.21	-0.21
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.09	0.09	0.09	0.10	0.10	0.10	0.10
0.2	0.15	0.17	0.18	0.18	0.19	0.19	0.19
0.4	0.24	0.30	0.31	0.33	0.35	0.37	0.37
0.6	0.29	0.39	0.42	0.46	0.50	0.53	0.54

Source: CRS calculations, see text.

It is clear that the production function does not matter very much when elasticities are small positives but for either backward bending labor supply curves

or as positive labor supply responses rise, they can matter significantly. For example, for an elasticity of 0.1, the amount of labor employed with a factor substitution elasticity of 0.1 is 91% of the effect that would occur with a elasticity of 1.0, while for an elasticity of 0.6 the effect is 66%.

Many modelers have not devoted much attention to the choice of production function and a number of them use a simple form (called the Cobb-Douglas) which has an elasticity of 1.0. The major macroeconomic modelers (ISLM models) use a unitary elasticity as do all of the models in the CBO study. However, three of the nine modelers in the 1997 JCT Symposium used lower elasticities (of 0.2, 0.3, and 0.8, although the modeler using 0.2 (Jorgenson) has recently increased this value to 0.5 to 0.7[23]).

Most empirical estimates of elasticities fall under the value of 1.0, in some cases well under that value. In a survey of estimates from numerous studies, Chirinko suggests a value of about 0.4, approximately the same value he recently estimated with two co-authors in a working paper using a long panel data set.[24] Note also that this choice could matter more if one is averaging a high female elasticity with a negative (and small in absolute value) male elasticity and the markets are largely segregated (i.e. if women work at different occupations). Moreover, the elasticity could be smaller in the short run, when technology combining capital and labor cannot easily be changed, than in the long run.

Savings Responses

Neoclassical models have savings rate elasticities that usually combine income and substitution effects and thus can be either positive or negative. Studies of direct savings elasticities are generally based on aggregate times series data, but few have been done recently because of the growing interest in more sophisticated intertemporal models discussed in the next section. Most studies report results that are very small and can be negative; in general, an elasticity of 0.4 would be considered relatively high.[25] Certainly a model that simply held the savings rate constant would reflect a central tendency based on this evidence. However, even large elasticities would have little impact . Using the 0.4 elasticity in a simulation that eliminated the income tax entirely (and replaced it with a consumption tax), the

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[23] The most recent version is presented in detail in Dale W. Jorgenson and Kun-Young Yun, *Investment: Volume 3: Lifting the Burden: Tax Reform, the Cost of Capital and U.S. Economic Growth*, Cambridge: The MIT Press, 2001. Other modelers have written books presenting their models in detail. See, Alan Auerbach and Laurence J. Kotlikoff,, *Dynamic Fiscal Policy*, Cambridge, MIT Press, 1987 and Don Fullerton and Diane Lim Rogers, *Who Bears the Lifetime Tax Burden*, Washington, DC, The Brookings Institution, 1993.

[24] See Robert S. Chirinko, "Corporate Taxation, Capital Formation, and the Substitution Elasticity between Labor and Capital," *National Tax Journal*, Vol. 55, June, 2002, p. 339-354; Robert S. Chirinko, Steven M. Fazzari, and Andrew P. Meyer, "That Elusive Elasticity: A Long-Panel Approach to Estimated the Capital Labor Substitution Elasticitiy," Working Paper, October 2002.

[25] See Jane G. Gravelle, *The Economic Effects of Taxing Capital Income*, Cambridge: MIT Press, 1994, pp. 27 for a brief summary of this work.

capital stock increased by less than 2% after 10 years, and output increased by only 0.4%.

Conclusion

The analysis in this section is suggestive that the labor supply elasticity, the main response that matters for a neoclassical model in the short run, is so small and so close to zero that a serious question arises as to whether it is worth incorporating in a dynamic scoring effort. Based on a review of the cross section data, the estimates are highly variable, although the central tendencies are very small. At the least, elasticities derived from the body of econometric studies should be adjusted to take account of the following considerations when used for revenue estimating:

- Participation elasticities, which are the main contributors to positive response to wage increases, are largely out-of-date and the dramatic rise in participation since these studies were made suggests lower elasticities; the higher the initial elasticity, the more it should have fallen today.

- A simple weighting of elasticities of men and women does not take into account cross elasticities for wives; if this effect were averaged in it could easily transform a small average positive response to a small negative one.

- The response in the short run is likely to be much smaller than the long run permanent response reflected in most econometric studies because of institutional constraints and adjustment costs.

- A given positive labor supply elasticity in the short run will have a more modest effect after interaction with demand in the short run if the initial elasticity is large, especially if the model uses the small demand elasticities that are probably more appropriate to the short run, when capital and labor substitution is less likely.

Intertemporal Models

Intertemporal models are much more complex and formalized than models relying on reduced form effects. These models are based on consumers choosing how much to work and save by optimizing over a long period of time. Savings and labor response derive from fundamental parameters in the individual's utility function (a mathematical representation of the value received from consumption).

There are three important issues to consider when evaluating these models:

- Are these models realistic representations of individual behavior? There are reasons to expect that they might not be.

- Many behavioral features of these models, particularly when they occur over a long period of time, have not been tested empirically. But certain relationships that can be derived from these models can be directly compared with econometric estimates. Are these responses consistent with empirical evidence?

- Can models that are so dependent on unspecified policies to deal with the government budget constraint be useful for dynamic revenue estimating?

Are Intertemporal Models Realistic Representations of Behavior?

The formal structure of intertemporal models is consistent with economic theory depicting individuals making rational decisions over time, and those theoretical aspects have made them popular in the classroom and the academic journals. But whether the responses derived from these models constitute a realistic depiction of actual behavior is a question that has largely not been tested empirically. That is because, although certain types of empirical estimates are used to construct these models, the results rely strongly on a variety of other assumptions, including the mathematical form of the utility function, the motivation for bequests, and assumptions that individuals are well informed and capable of making precise allocations over a long period of time.

These models basically depict an individual as having to make a choice, given a projection of potential lifetime wealth (which includes the present value of future wage earnings, and any assets on hand or expected to be inherited), choosing how much consumption goods to purchase and how much leisure to enjoy (that is, how much to work). The allocation of consumption and leisure over time depend on the after tax wage rates in different periods and the after tax rates of return. As in the basic neoclassical model, income and substitution effects offset each other. One important difference from typical neoclassical models is that changes in rates of return can have a dramatic effect on labor supply response as individuals shift leisure between the present and future, in those models that treat labor supply as endogenous. This effect is often the most powerful supply side response in the short run, and yet one that would probably be greeted skeptically by many economists.

There are two basic forms of inter-temporal models:

- Infinite horizon models which represent all of the individuals in the economy as a single, infinitely lived representative investor.

- Overlapping generations models, which consider individuals of different ages optimizing over their own remaining lifetimes. As the economy moves through time, new generations are born and older generations die.

Infinite horizon models may seem bizarre, but can theoretically be justified by intergenerational altruism — that individuals include in their own welfare the welfare

of their children, their grandchildren, and, indeed, all future generations.[26] Many economists have reservations about this assumption, given evidence that many bequests do not appear to arise from altruistic motives and that many individuals leave little in the way of bequests or have no children. Moreover, the model cannot be applied to heterogenous classes of individuals (e.g. in different permanent income classes or subjected to different tax regimes, such as differing national or state or local taxes).

Life cycle models may appear more realistic, but even in these models individuals tend to be optimizing over a long period of time.[27] (Note that life cycle models can have perfect foresight about future prices which is required of infinite horizon models, or they can be myopic, where individuals assume that current pre-tax wage and interest rates will continue). Are these models, which assume an enormous amount of information and planning skills, representative of actual behavior (given, for example, that individuals often do not know their marginal or average tax rates)?

Even if one does imagine individuals actually making lifetime plans for savings and consuming that respond to changes in taxes and interest rates, there are a variety of institutional constraints. These models presume that individuals are free to borrow and lend at the same interest rate and that no individuals are liquidity constrained. Moreover, although some models assume labor supply (and leisure) are fixed, others treat labor as a choice variable. When modeling leisure (and thus labor supply), models presume that individuals can easily change hours of work or that individuals can periodically leave and enter the labor force on a voluntary basis due to changes in interest rates as well as wages. Thus, they do not account for the fact that wage rates and earnings may depend on past employment history. Practically speaking, most people cannot easily plan a lifetime working career with periodic deliberate periods of unemployment. And many economists may doubt that the interest rate affects most worker's employment decisions.

Moreover, although some of the behavioral responses in the model can be based on empirical estimates, the functional form of the models force some particular relationships (for example, that consumption in periods far apart have the same intertemporal substitution effects as those close together and that these effects are based on expectations and planning.) While it is possible to estimate profiles of behavior over time, the best type of data (panel data) still falls short of a lifetime, and

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[26] This type of model, also called a Ramsey model, underlies a theory referred to as Ricardian equivalence (and also causes the model to be referred to as a Barro-type model, after the economist who wrote about Ricardian equivalence, Robert Barro). Ricardian equivalence means that deficits never matter because individuals, knowing that they will have to be repaid in the future, will save enough to make up for the debt plus interest and leave those amounts to their children as bequests. This theory precludes any stimulus effect or crowding out effect. Intertemporal models always converge to the same long run steady state equilibrium and basically involve an infinite long-run savings elasticity.

[27] Bequests in the life cycle model must be motivated by something other than intergenerational altruism. One can assume no bequests (although such a model is hard to calibrate to the economy), fixed bequests, bequests that are treated as, or similarly to, a last period of consumption (joy of giving), or bequests that occur because individuals need a hedge against living too long.

the assumption must be made that these patterns reflect the execution of plans that were carried out in anticipation of lifetime prices and incomes.

Correspondence to Empirical Evidence

There are four basic measures that influence the behavioral response in these models (along with a variety of mathematical assumptions):

- The intratemporal substitution elasticity.
- The intertemporal substitution elasticity.
- The factor substitution elasticity.
- The ratio of leisure to hours available to work.

Corresponding to these parameters are the direct estimates of elasticities from statistical studies discussed in the previous sections. They include the labor supply elasticities estimated from cross section studies which are composed of offsetting income and substitution effects, each of which tends to be quite small on average (perhaps in the neighborhood of absolute values of 0.1 to 0.3). These labor supply elasticities depend on functional form, the intratemporal substitution elasticity and the ratio of leisure to hours available. These elasticities also include the factor substitution elasticity whose average value is often estimated to be less than 0.5.

There have also been attempts to estimate some of the intertemporal responses, as discussed in **Appendix C**. They include attempts to directly estimate the intertemporal substitution of consumption with respect to rates of return; these estimates have produced a range of returns, but with most studies falling well under 0.5. Modelers in the 1997 JCT Symposium used values of 0.25, 0.3, a range of 0.15 to 0.5, and 1.0, although the last measure has now been reduced by the modeler to 0.4.[28] The CBO models used 0.5. (The JCT has not formally provided elasticities but its elasticities are apparently consistent with other models) Although these values are often estimated using short panels reflecting close together periods, as applied to intertemporal models, which measure the response to long periods apart (even infinitely far apart), they can produce very large savings responses.

Another set of estimates is the intertemporal substitution of labor supply with respect to changes in the wage rate over time, which tend to be very small, typically averaging about 0.2, and often not statistically significant. This elasticity must be derived from the intratemporal elasticity, the intertemporal elasticity and the leisure shares of hours available.

In general, as discussed in further detail in Appendix C, the labor supply responses in current intertemporal models appear to be high (and in the case of CBO much higher than in their neoclassical models), in large part because the functional form drives models towards income elasticities for leisure with respect to wages to 1, which requires a correspondingly high substitution elasticity to avoid large backward bending labor supply curves. These elasticities drive both parametric labor supply elasticities (responses to a proportional change in wages in each period)

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[28] Jorgenson and Yun, *Investment*, op. cit.

making income and substitution effects quite large (as large as 0.6 in some models), and the intertemporal labor supply elasticity. Most models probably set this latter elasticity far higher than suggested by the intertemporal substitution estimates, because they have such a high share of leisure in available hours. Not all models provide sufficient detail to calculate these derived elasticities, but they appear to be about 0.76 in the Auerbach-Kotlikoff model and about 1.1 in the CBO models (see **Appendix C**). Thus the CBO implicit intertemporal elasticities are over five times the size of most empirically estimated elasticities (estimated at around 0.2 as summarized in Appendix C). The JCT's estimates are slightly below 0.2 and are in line with the econometric evidence on both intratemporal and intertemporal labor supply response). The Treasury initially began at 0.75 for one model and 0.5 for another, but is now at 0.4. Consumption also theoretically responds to changes in wages over time, although those elasticities have not been estimated directly and tend to be small in most models. Because of the leisure share of income, the intertemporal substitution of labor supply with respect to the interest rate is actually *larger* than the intertemporal substitution of consumption in many models — about 0.375 in the Auerbach-Kotlikoff model and about 0.75 in the CBO model.

The easiest way to cause these elasticities to reflect empirical evidence is to set the leisure share of hours quite low (an approach taken by JCT), but this parameter is one that has attracted little attention in most cases.

The particular form of utility chosen to allocate consumption throughout the life cycle (or throughout infinity) also plays an important role in determining the behavioral response because it leads to equal substitution elasticities between time periods. But since the price of future consumption is $(1/(1+r))^T$ where T is the time period, the elasticity of savings with respect to the interest rate can be very large because of the far apart periods (see discussion in Appendix C).

In 1997, three of the modelers who participated in the JCT study presented a paper that tested the sensitivity of a tax change to various parameters, based on revenue neutral tax changes (substituting a flat rate income tax with a consumption tax and a wage tax).[29] Both substitutions would eliminate the tax on new investment and increase the rate of return. They found the first would have only a negligible effect on the wage rate, but the second would have a significant effect. In both cases there are no aggregate income effects in the model although in a life cycle model a switch to a consumption tax imposes higher taxes on the elderly and lower ones on the young and a switch to a wage tax does the opposite. They used a base case of a standard infinite horizon and life cycle model reflecting the parameters of the then existing Auerbach Kotlikoff model: the intertemporal substitution elasticity set at 0.25, the intratemporal elasticity set at 0.8, the factor substitution elasticity set at 1.0 and the ratio of leisure to hours available 0.6. Because the intratemporal substitution elasticity is set at 0.8 and the income effect is 1, these effects imply an income elasticity of labor supply to a proportional change in the wage of 0.6, a substitution effect of 0.48 and an overall backward bending labor supply elasticity of -0.12.

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[29] Eric Engen, Jane Gravelle, and Kent Smetters. "Dynamic Tax Models: Why They Do the Things They Do," *National Tax Journal*, vol. 50, September 1997, pp. 657-682.

These are very high offsetting effects, although the net elasticity is in the empirical range. Most of the effects in the model are driven by interest rate effects, however.

Some of the important findings of these explorations for the intertemporal models (referring to the consumption tax substitution and looking at the first five years) were:

- Results are sensitive to model type. Positive effects of a switch to a consumption tax in the life cycle model were larger in absolute size than those in the infinite horizon model for the consumption tax change, but a large part of that probably reflects the return of retirees into the work force due to the lump sum tax on old people that is imposed by a shift from income to consumption. Effects are also about 20% larger in a life cycle model with myopia as compared to perfect foresight (both fixed labor models). However, effects were reduced by about 50% in this myopic fixed labor model when uncertainty was introduced.

- Although capital expands faster than in the case of the neoclassical growth model when taxes on capital income are eliminated with little effect on the wage, the predominant effect is the labor supply response. The output results for the model with endogenous labor were about 3½ times the effects for models with fixed labor.

- The savings response was enormous. Eliminating the tax on the return to capital in these simulations caused the rate of return to initially rise by about 25% (although the effect was eventually smaller as the capital stock adjusted). In a myopic life cycle model (individuals expect pretax wages and rates of return to persist) with fixed labor, where the rate of return can be treated as fixed and the 25% number holds, savings increased by 127% in the first year, implying an elasticity of about 5. This response is huge by any standards and would have been even greater if labor had been endogenous (in the perfect foresight models, the savings response in the first year was 60% larger in the infinite horizon model and 26% larger in the life cycle model, when labor was made endogenous, as individuals increase work to produce savings to finance future leisure). By contrast, the percentage increase in the neoclassical growth model was only 9.5%. Thus the savings rate was over 13 times as large as that in a neoclassical model.

- Results are sensitive to elasticities. In the infinite horizon model, increasing the intertemporal substitution elasticity from the base of 0.25 to 0.5 increased the average output effect over the first five years by about 80%. Lowering it to 0.05 reduced the effect by 90%. (These effects were smaller, 30% and 45%, in the life cycle model). Because the wage tax rate changed very little, sensitivity analysis to the intratemporal substitution elasticity is not as meaningful. Nevertheless, because effective taxes on wages went up, at least in the short run, changing the intratemporal elasticity to 0 increased

output by 13%. Reducing the factor substitution elasticity to 0.5 reduced the effect by about 20%. Even the introduction of depreciation reduced net output increases by 12%.

- Results are quite sensitive to available labor. If the leisure/hours ratio is set at 0.2 rather than 0.6 to conform them more closely to empirical estimates of labor supply, the effect fell by 53%.

- Effects can be considerably reduced (by about a half) when uncertainty is introduced.

The study also indicated significant differences in model type with a shift to a wage tax, where taxes on wages went up significantly. The life cycle model produced significant negative effects in the short and the long run, while the infinite horizon model produced small initial negative responses and positive long run effects. The short-run effects were positive but smaller in the fixed labor models. In the life cycle model, reducing the intertemporal elasticity to 0.05 caused the negative effect to triple, while increasing it to 0.5, turned a negative output effect to a positive one.

These results suggest a great deal of variability can be expected in the results of intertemporal models depending on the model type and the elasticities and parameters used. Moreover, this exploration is limited to comparing simple, one-sector, closed economy models with relatively simple utility functions. There are many other features that can alter behavioral response, such as requiring a minimum subsistence level of consumption in each period, introducing many sectors and allowing an open economy with perfectly mobile capital.[30] (Note, however, that an open economy is not possible for the infinite horizon model.)

Sensitivity to Method Used to Address the Balanced Budget Constraint

Intertemporal models with perfect foresight cannot be used to solve the short-run effect of a stand alone tax cut because the model relies on long run steady state solutions to be solved at all. While life cycle models can assume individuals behave as if current rates of return and wages will persist and only taxes change (these are often called myopic models), these models tend to produce even more unrealistic savings responses (because they do not account for the eventual fall in the pre-tax rate of return as the capital stock expands in response to a reduction in taxes on capital income). Any model with expectations must rely on some other assumed policy. Policies that retain the income effect (such as assuming that government spending will be cut) will have a smaller effect on labor supply and savings than policies that eliminate most or all of the income effect (such as lump-sum tax changes). Yet a different effect would derive from eventually raising marginal tax rates, which would lead to a temporary rather than permanent intertemporal shift.

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[30] These features are also discussed in Gravelle, "Behavioral Responses to a Consumption Tax," op cit.

The recent CBO study demonstrated the dramatic differences in the results of intertemporal models when different choices are made.[31] For the infinite horizon model in the first five years, choosing to cut government spending resulted in a budgetary feedback effect of 3% (i.e. the deficit was 3% less than expected) while imposing a lump sum tax resulted in a feedback of 15%. In the second five years, these effects are -4% (an increase in budgetary costs) and 17%. With a life cycle model (closed economy) effects were -6% and 7% in the first five years, -15% and 5% in the second five years. The CBO study could have closed the budget balance by introducing a future tax increase; such a change probably would have produced very small effects since it would have eliminated the power of interest rate changes to induce large short-run labor supply responses to higher rates of return.

The JCT study also used two methods: spending increases and marginal rate increases; its feedback effects were 3% for the first case and 2.6% for the second. However, the method of closing the deficit was not as important to its study because of the temporary nature of tax cuts.

Summary of Issues

This section has outlined a variety of problems associated with intertemporal models. The interest in these types of models arose from the growing development of interest in rational expectations and in modeling the economy as agents concerned with forward looking behavior Many economists doubt that such complex and sophisticated models can actually describe the behavior of most individuals. The models produce behavioral responses that are quite large and are governed not only by estimated parameters that are uncertain in magnitude, but also by functional forms and assumptions that are somewhat arbitrary. They produce results that are difficult to believe and that are not supported by the statistical literature. They may propose elasticities that seem reasonable but may produce factor supply responses outside the range of empirically estimated results, a point stressed by Charles Ballard who was the discussant of the intertemporal models in the JCT Symposium. Ballard urged modelers to try to fit their models to empirical estimates. He also pointed out that there is no empirical evidence to support the notion that labor supply responds to the interest rate and that anyone who builds such a response in a model is "shooting in the dark." Yet this particular behavioral response is one of the most important ones in affecting short term response in intertemporal tax models because it produces both labor supply and savings.

As mentioned in the introduction, there are many other features of these models that can influence the results. But certainly one of the most troublesome ones is that intertemporal models with foresight cannot be solved unless some assumption is made about addressing exploding deficit effects. Thus, no study of a stand alone tax cut can be made using these models.

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[31] See Congressional Budget Office. *An Analysis of the President's Budgetary Proposals for Fiscal Year 2004*, March 2003.

The Effects of Different Models and Assumptions: A Summing Up

Different types of models will yield substantially different results, depending on the form of model and the behavioral responses built into the model. These effects have been demonstrated in a variety of studies that consider the same policy including the JCT studies published in 1997 and the 1997 study by Engen, Gravelle and Smetters. The JCT comparisons had first year effects on output of replacing the income tax with a consumption tax ranging from -2.3% to 7.8% (reflecting both model differences and elasticity differences). After four years, the effects ranged from -12.5% to 14.5%. Eliminating the most negative and most positive studies resulted in a smaller, but still significant range of -1.8% to 5.8% in the first year and -0.8 and 4.2% after four years. These differences reflected a range of model types and a range of elasticities used by the nine modelers.

A series of comparisons was done by the Congressional Budget Office for the President's budgetary proposals. In the initial (2003) study, for the two models with unemployed resources, one model led to a reduction in revenue costs of about 30% that began at 27% and rose slightly over six years until it reached 33%. The other model began with a 16% reduction which declined and eventually led to a 28% increase in cost, for an average additional cost of 9%. These models reflect all three effects (short-run stimulus, deficit, and supply side), and part of the effect is that a rise in inflation increases nominal revenues and improves the deficit because of an assumption that appropriations will not be affected by price levels (i.e. a real decline in government spending).

In the neoclassical model, which incorporated labor supply elasticity (averaging about 0.1, with a 0.2 substitution effect and a -0.1 income effect) consistent with the cross section empirical evidence, the feedback effects increased the revenue cost by 6% in the first five years and by 11% in the next five years.

The infinite horizon model led to a reduced revenue cost by 3% or an increased cost by 4% if lower government spending is used to close the deficit gap. Higher lump sum taxes led to a reduced revenue cost of 15% and 17%. These latter numbers reflect the relatively large factor supply responses built into the model which are not offset by income effects when the budget deficit is closed by lump sum taxes.

In addition to versions of the life cycle model with different ways of closing the deficit gap, the CB0 study also considered closed and open economies. For the lower government spending option that leaves income effects intact, feedback would increase costs by 6% in the closed model and 10% in the open model in the first give years and by 15% and 5% in the second five years. For the lump sum tax closure that eliminates some income effects, costs are reduced by 7% in the closed and 6% in the open economy models in the first five years, and by 5% to 8% in the second five years.

Overall, the study shows a large range of effects. If supply side responses are modest and multipliers are small or nonexistent, the eroding effects of the budget deficit lead to an increase in revenue costs. These supply side effects can be small

when the elasticities themselves are modest (as in the neoclassical model) or substitution elasticities are small enough to be largely offset by income effects (as in the life cycle models). However, when multipliers are large or when supply side effects are large because of large substitution elasticities that are not offset by income effects, the revenue cost can be decreased substantially.

Of course the CBO studies do not capture the full range of factor supply elasticities which can quite reasonably fall in the zero or negative range, so that while the upper limit of a feedback that reduces revenue may be reflected in its results, the upper limit of a feedback that increases revenue probably is not. Some sensitivity analysis, including setting of the elasticities in CBO's intertemporal model to correspond more closely to empirical evidence and to the assumptions used in its neoclassical growth model, and allowing for alternative budget and macro assumptions regarding how the deficit is closed (e.g. marginal tax rate increases) and how the monetary authorities might respond would provide a more complete picture of the range of effects that one might find in these models. Of course, such analysis would likely increase an already broad range of effects that vary from a reduction in costs of 30% to an increase in costs of 15%, largely by expanding the latter.

The first JCT study in 2003, while examining only revenue effects from a temporary tax cut, also showed a wide range of effects from a 2.6% revenue feedback to a 23.4% one. Variable effects have persisted in later studies and in the Treasury's studies.

The discussion of the various studies that provided sensitivity analysis in this section and in the previous section on intertemporal models points to two important caveats about dynamic revenue estimating: it is very difficult to obtain a good estimate because of uncertainty about behavioral responses and very difficult to study a tax cut without making some sort of assumption about accompanying policies. Moreover, if the analysis is restricted to supply side effects as some might suggest, a reasonable estimate of the results based on empirical evidence is likely to be a negligible effect, reflecting the very modest factor supply elasticities of uncertain sign.

Appendix A. Revenue Feedback

Revenue Feedback Effect: Partial Equilibrium

Consider a labor tax at a proportional rate t. The revenue from the tax is tWl, where W is the wage rate and l is the labor supply. With a small change in t, the revenue cost is dtWl. The feedback effect is tWdl. The after tax wage is W(1-t). Holding W constant, the change in the after tax wage is -Wdt, and the percentage change is -dt/(1-t). Since the elasticity is defined as percentage change in labor divided by percentage change in wage, dl = -ElWtdt/(1-t). Therefore, the revenue feedback percentage is -Et/(1-t).

Revenue Feedback Effect: General Equilibrium, Short Run

If we denote Q as output, K as the capital stock, W as the wage rate, R as the rate of return, with the tax rates and elasticities defined as above. The production function results in (where the ˆ refers to a percentage change):

(1) $\hat{Q} = (1-a)\hat{L} + a\hat{K}$

where a is the capital share of income and a ˆ refers to a percentage change.

The first order conditions of the production function result in:

(2) $\hat{L} = \hat{K} + S(\hat{R} + \hat{T} - \hat{W})$

where S is the factor substitution elasticity. In these equations, $\hat{T}$ refers to the change in tax divided by (1-T).

The percentage change in price is a weighted average of the wage rate and the rate of return:

(3) $\hat{P} = (1-a)\hat{W} + a(\hat{R} + \hat{T})$

Finally, define the numeraire as a fixed price:

(4) $\hat{P} = 0$

In the short run, a labor demand function can be derived from these equations, assuming that the capital stock is fixed:

(5) $\hat{L} = -(S/a)(\hat{W})$

Note however, that the wage rate can change; in order to solve for the wage rate, introduce the labor supply elasticity, such that:

(6) $\hat{L} = E_S(\hat{W} - \hat{T})$

Combine (5) and (6) to solve for $\hat{W}$ so that:

(7) $\hat{W} = -[aE_S/(aE_S + S)]\hat{T}$

which results in

(8) $\hat{L} = -[E_S S/aE_S + S)]\hat{T}$

In turn, total output is:

(9) $\hat{Q} = -[E_S S/(aE_S + S)]\hat{T}$

Appendix B. Labor Supply Response

Empirical Evidence

Historical Trends. While it is difficult to use time series to estimate regressions (because of the endogeneity of the wage rate) the patterns are nevertheless instructive. Historically, the average hours worked by those in the labor force has declined over time, from 40.3 hours per week in 1947 to 34.2 in 2001. Some industries have had virtually no change (manufacturing hours were 40.3 in 1947 and 40.7 in 2001, with very little fluctuation). Since both of these time periods were associated with rising real wages, they are suggestive of an aggregate zero or negative response in hours. However, they may also have reflected differing hours of changing participants in the work force and may also reflect kink points that arise from institutional constraints on the work week, in particular the overtime pay requirements for workweeks in excess of 40 hours in many jobs.[32]

Participation rates have changed over time but not in ways that are especially meaningful with respect to a wage effect. Male labor force participation rates for those 15 and over have been declining (falling from 86.1% in January of 1948 to 74.1% in June of 2002). Female participation has been increasing (rising from 32% in January of 1948 to 59.7% in June of 2002). The decline in the former may reflect in part the aging of the population as well as some earlier retirement and extended schooling. Female participation rate increases were especially pronounced in the seventies and eighties as baby boomers entered the workforce, but their increased participation may reflect efficiencies in household technology, changes in social norms, later marriage and declines in fertility. This period was, in fact, not a period of overall wage growth, although cause and effect cannot be separated (i.e. wage growth may have slowed because of new entrants).

Over a longer period of time, however, there is a clear fall in labor hours; indeed, many of the labor disputes in the 19th century and early 20th century involved movements for shorter work days and work weeks; hours fell from 70 hours a week in 1856 to 40 hours in 1940.[33] During the 1930's, legislation to mandate a 30-hour week was debated. Hours rose during World War II, but then fell after the war. Some of the further decline in the workweek may have come as a result of more part time jobs in the retail and service industries, reflecting the end of blue laws requiring Sunday closing.

These observations about work weeks and participation suggest that there are powerful institutional factors that may constrain a labor supply response in the short run. In general, the time series evidence on average workweek does not support a

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[32] For covered employment, payment for overtime is time and a half. Employers thus find it costly to have workers work in excess of 40 hours (and they might also find that worker's productivity declines eventually). At the same time, they may be reluctant to employ part time workers because of fixed benefits costs (e.g. health insurance). These effects make the 40-hour work week a kink point that may likely be chosen by employers.

[33] See "The Workweek in American Industry 1850-1956," *Monthly Labor Review*, January 1958.

positive labor supply response to higher wages, while participation rates provide a mixed message.

Cross Section Evidence. A second form of evidence, and the one that receives the most attention from economists, is based on cross section statistical studies. Indeed, because wages vary across individuals, labor supply has been a fertile field for econometric studies and the advancement of econometric techniques.

These studies typically compare the labor supply of individuals with different wage rates. In general the overall elasticities for male labor supply (percentage change in hours worked divided by percentage change in the wage) are relatively small and span zero. Indeed, there is a fair amount of reason to believe that the labor supply elasticity for men is negative: higher wages result in lower work as the income effect dominates the substitution effect. Pencavel, in his summary of empirical studies in 1986, reports a wage elasticity for men that ranges from 0.06 to -0.29.[34] He reports the central tendency as between -0.17 and -0.08, and the simple average as -0.12. In a survey confined to a limited number of articles that explicitly included taxes, Hausman reports similar results.[35] The finding of small and possibly negative responses to wages is confirmed in some later studies.[36]

An important issue for tax analysis is whether these small elasticities are the result of offsetting large or small income and substitution effects. Most studies have found them the result of small offsetting elasticities, which suggests small supply side effects from changes in tax rate progressivity. A study by Hausman found larger offsetting income and substitution effects that suggested a more important role for tax policy; that study has been subject to some criticism and more recent studies have tended to find small offsetting effects.[37]

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[34] John Pencavel, "Labor Supply of Men," in *Handbook of Labor Economics*, vol. 1, Ed.Orley Ashenfelter, New York, Elsiever, 1986.

[35] Jerry Hausman, "Taxes and Labor Supply," *Handbook of Public Economics*, vol. 1, Ed. Alan J. Auerbach and Martin Feldstein, New York, North Holland, 1985.

[36] See Richard Blundell and Thomas MaCurdy, "Labour Supply: A Review of Alternative Approaches," *Handbook of Labor Economics*, vol. 3, Ed. Orly Ashenfelter and David Card, Elsiever, 1999 where three additional U.S. studies using panel data and a piecewise budget constraint found elasticities between 0 and 0.05. Some later studies tended to find higher positive elasticities but Pencavel argues that those studies are actually picking up intertemporal substitution elasticities (which are expected to be positive). Pencavel finds a negative elasticity which becomes more negative with more schooling. However, elasticities can vary depending on specification. Overall he finds an elasticity of -0.12 for white men and -0.08 for black men. See John Pencavel, "A Cohort Analysis of the Association between Work and Wages Among Men, *Journal of Human Resources*, spring 2002, vol. 37.

[37] The study finding large offsetting effects used kinked budget constraints and the criticism involved statistical restrictions placed on the estimates. In addition to Blundell and MaCurdy, and Jerry Hausman, cited above, see Thomas MaCurdy, David Green and Harry Paarsch, "Assessing Empirical Approaches for Analyzing Taxes and Labor Supply," *Journal of Human Resources*, vol. 25, summer 1990. A more accessible article is Thomas MaCurdy,

(continued...)

The estimation of responses for women is much more complicated and has been the subject of more attention. While a large majority of men of primary working age participate in the labor market, a significant fraction of women (at any age) do not participate, and that was particularly true in earlier years of the 20th century. A concern that greatly preoccupied econometricians was that estimates of labor supply response based on women in the labor force would be biased because these women are not randomly selected (they are self-selected). This aspect of women's labor supply creates significant econometric problems which researchers have struggled to address. In addition, part of the response to wage changes can be not only in hours of those working, but also in changes in the number of individuals who work.

Considering only those studies (mostly of married women) that have corrected for selection bias, the range of elasticities is extremely large, ranging from -0.90 to 14, and there are enormous variations even within studies based on methods used.[38] A smaller range of effects was found in the smaller number of studies that included taxes: -0.3 to 2.30.[39] A critic of these studies argued that certain methodological choices tended to bias the estimates upward and concluded that the hours response was actually similar to that of men.[40] Two additional studies since that time found elasticities of around 1, with 70 to 80% of the response a participation response.[41] One of these studies also estimates the response of married women to changes in husband's wages (which is negative) finding that the hours response is as large (i.e. a proportional change in all wages would leave hours unchanged) and that an increase in the husband's wage slightly reduces participation as well.[42]

A recent study that examined changes in women's labor supply response indicated that the elasticity of married women's labor supply had declined substantially in the past two decades, from an estimated 0.8 or 0.9 in 1980 to 0.6 in

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[37] (...continued)
"Work Disincentive Effects of Taxes: A Reexamination of Some Evidence," *American Economic Review*, vol. 82, May 1992.

[38] Mark Killingsworth and James Heckman, "Female Labor Supply: A Survey." In *Handbook of Labor Economics*, Vol. 1, Ed. Orley Ashenfelter , New York, Elsiever, 1986.

[39] Hausman, "Taxes and Labor Supply," op. cit.

[40] Thomas A. Mroz, "The Sensitivity of an Empirical Model of Married Women's Hours of Work to Economic and Statistical Assumptions." *Econometrica*, vol. 55, July 1987.

[41] Richard Blundell and Thomas MaCurdy, "Labour Supply: A Review of Alternative Approaches," op cit.; John Pencavel, "The Market Work Behavior and Wages of Women." *The Journal of Human Resources*, vol. 33, fall 1998. Curiously, this latter study also included single women and found a larger participation response for them than for married women, which is difficult to reconcile with theory. During this period the wages of married women as well as their participation rates increased, and it is possible that the results are reflecting social trends rather than wage response because the data are from repeated cross sections and thus capture a time dimension.

[42] Pencavel, "The Market Work Behavior and Wages of Women," op. cit.

1990 and 0.4 in 2000.[43] The study also found a decline in response to the husband's wage, from -0.3 to 0-0.4 in 1980 to -0.2 in 2000.

Experiments: Natural and Otherwise. A third type of measure uses data to compare the response of different individuals to a particular change. In the late 1960s and early 1970s a series of experiments with negative income taxes (where some households were given the benefit and some were not) resulted in estimates of elasticities for men that also tended to be small and either positive or negative.[44] There was also some evidence of a significant withdrawal from the workforce due to the income effect for married women and a smaller, but still significant effect for female household heads. There were many problems with these studies, however, and they relate only to lower income individuals, although they do accord with cross section data that suggest women are more responsive than men.[45]

Another type of study that has received increasing attention is the "natural experiment," which examines labor supply response to tax changes by comparing how individuals with different tax rate changes changed their behavior. Most of these studies have not indicated any response of labor supply to tax changes (for aggregate labor income, labor supply of men, or labor supply of high income men), although one study of the response of very high income women to the 1986 tax reform act suggested an elasticity of 0.6 to 1.[46] About half of the response was due to participation response, less than is usually thought the case. However, these elasticities are not comparable to the ones cited above: as noted by the author, they are more likely to represent the compensated elasticities which reflect only substitution effects. Uncompensated estimates (such as those discussed above) which reflect both income and substitution effects would be smaller, but it is difficult to know what adjustments to make.

Natural experiments face their own problems, and in particular could reflect trend and cycle effects. For example, women with higher educations increased their participation rates relative to less educated women towards the end of the 20th century, which most people agree could have reflected many other factors than wages. The paper above tried to control for these effects by comparing women whose family income placed them in the 99th percentile, with those who are in the 90th or the 75th percentile. Surprisingly, the elasticities were larger with the former

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[43] Blau, Francine D. and Lawrence M. Khan. "Changes in the Labor Supply Behavior of Married Women: 1980-2000" NBER Working Paper No. 11230 (2005).

[44] Pencavel, "The Labor Supply of Men," op. cit.

[45] Hausman, "Taxes and Labor Supply," op cit.

[46] See a review and analysis in Nada Eissa," Tax Reforms and Labor Supply," *Tax Policy and the Economy*, Ed. James M. Poterba, Cambridge, MIT Press, 1996. In addition to the work reviewed by Eissa, a working paper by Martin Feldstein (The Effect of Marginal Tax Rates on Taxable Income: A Panel Study of the 1986 Tax Reform Act, National Bureau of Economic Research Working Paper 4496) found no clear pattern of response of wage and salary income (using tax data) to the rate changes in the 1986 act. A detailed study of labor supply response to the 1986 act focusing on high income men also found essentially no effect; see Robert A. Moffitt and Mark O. Wilhelm, "Taxation and the Labor Supply of the Affluent," In *Does Atlas Shrug?*, Ed. Joel Slemrod, New York, Russell-Sage, 2000.

comparison than the latter. Because of trend and cycle effects, one might feel more sanguine about the results of natural experiments if the results held for a tax increase as well as a decrease. The 1993 tax increase was an obvious choice as another study episode; unfortunately studies of the labor supply effects of this change have not been made.

Studies of social security retirement age changes and earnings tests have also suggested labor supply responses (more early retirement and less work during retirement).[47]

Surveys. Economists have usually been hesitant to rely on survey data. However, a number of years ago several surveys of affluent men were made, which included questions about the effect of taxes on work effort. Again, this evidence suggested a small response for men.[48]

Some related survey evidence is also interesting: surveys of whether individuals actually know their average and marginal tax rates and surveys that indicate most individuals cannot choose their optimal hours.

There is some evidence that marginal tax rates are not reported with much accuracy.[49] In that case, individuals may not respond, particularly to changes in marginal tax rates. Changes in average tax rates may be more likely to elicit some effect (or at least their consequences on wages become known, since changes in average tax rates would be reflected in paychecks).

Survey data also indicate that a large fraction of individuals report that they are not currently working their optimal hours (some would prefer more hours and some less), which suggests they are not easily free to make small changes in hours in their current positions.[50]

Theoretical Issues

This section of the appendix presents the mathematics for several topics discussed in this report, including the characteristics of derived participation and hours elasticities.

The Elasticity for Hours of Work and the Hours Constraint. To obtain the formula for elasticity:

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[47] Hausman, "Taxes and Labor Supply," op. cit.

[48] Ibid.

[49] See Steven M. Sheffrin, "Perceptions of Fairness in the Crucible of Tax Policy," in *Tax Progressivity and Income Inequality*, Ed. Joel B. Slemrod, New York, Cambridge University Press, 1994.

[50] Shulamit Kahn and Kevin Lang, "The Effect of Hours Constraints on Labor Supply Estimates," *The Review of Economics and Statistics*, vol. 73, November 1991.

$$(10)\quad \text{Max}^{[(1-a)C^{(1-1/S)}+aL^{(1-1/S)}]^{1/(1-1/S)}}$$

Subject to C = W(H-L) + Y

where C is consumption , L is leisure, W is the wage, Y is nonlabor income, H is hours available and S is the substitution elasticity.

The first order condition is:

$$(11)\quad L/C = [(1-a)/a]^{S} W^{-S}$$

Now by substituting in the budget constraint, differentiating and making further substitutions, and denoting hours of labor as l and r as the ratio of non-labor to labor income, the elasticity can be derived as:

$$(12)\quad (dl/l)/(dW/W) = [S(1+r)-1][L/H][1/(1+r[H-L]/H]$$

Or denoting E as the elasticity and setting r = zero:

$$(13)\quad E = [S-1][L/H]$$

Even for typical work weeks, this ratio could be quite small. Available hours, however, are not all that straightforward to measure. If one just took a 40 hour work week and a seven day, 24 hours a day available hours, the ratio would be about three-fourths. However, all hours are not available. For example, there is the biological necessity for sleep. If one allowed eight hours of sleep per night, about 60% of available hours would be spent in leisure, and thus a unitary elasticity would fall to a 0.6 elasticity. But even that elasticity is too high. There are certain minimum requirements for working, that include at least some amount of travel to work, often a lunch period embedded in the work day, as well as preparation time for personal hygiene (shaving, bathing, etc.). If we allow, say, two hours per work day and add it to work, we get a ratio of 55%; if three hours, we get a ratio of 50%.

A study of time allocation for men in the United States indicated that in 1981 men worked 44 hours, commuted for 3.5 hours, slept for 57.9 hours and spent 10.3 hours on personal care.[51] If commuting is assigned to work, these findings suggest a ratio of about between 0.48 and 0.52, depending on whether personal care is added to work, or excluded from available hours. Moreover, there are many other uses of time that are highly constrained by necessary household chores or other needs (eating, shopping, paying bills) or family responsibilities (spending time with spouse and kids), so that this ratio could be even smaller. Some individuals may also not to work on particular days for religious reasons (and consider those constraints to be

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[51] F. Thomas Juster and Frank P. Stafford, "The Allocation of Time: Empirical Findings, Behavioral Models and Problems of Measurement," *Journal of Economic Literature*, vol. 29, June 1991.

strict). Thus, one would expect to find low labor supply elasticities (for hours) not only because of netting of income and substitution but also because each of these effects is small. These observations also make the initial findings of high offsetting income and substitution elasticities using kinked budget constraints to seem somewhat implausible.

The other point illustrated by this formula is that the labor supply elasticity is not constant even though the underlying income and substitution elasticities with respect to consumption and leisure are. As work increases, the elasticity falls. This point is important, because it suggests that one should not impose a simple labor supply elasticity across any significant period of time, but (assuming a rise in real wages) should have an elasticity that falls over time (becomes a smaller absolute value if positive and work is increasing and a larger absolute value if negative and work is decreasing). And, as mentioned earlier, it suggests that elasticities are smaller for those working more hours, a reason mentioned by Wilhelm and Moffitt for the lack of a labor supply response by very high income men.[52]

The example of hours response discussed in this section is meant only to be illustrative, as it is based on a specific form of utility function that includes unitary income elasticities and constant substitution elasticities. Adding non labor income or requiring a subsistence amount of consumption, other things equal, is likely to increase in the first case and decrease in the other case the likelihood of a positive elasticity and the size of the substitution elasticity. There are many other types of functional forms where elasticities vary across consumption bundles and income elasticities can differ for leisure and consumption. However, the constraints of labor supply exist and those constraints exert limits on elasticities regardless of functional form: people working every available hour can work no more.

Participation Responses: Example of the Logit Formula. The effects of constraints on participation can be most easily seen in the case of the logit formula. For the logit case, high elasticities tend to decline when participation rates rise due to wage increases, but low elasticities could rise. The larger the initial elasticity, the more quickly the elasticity is likely to fall over time. Participation responses are also constrained and the growing participation rate of women should lead to lower elasticities; indeed,

The logit form of the participation response can be manipulated mathematically to illustrate what one might expect as participation rates change:

$$(14) \quad P = \frac{e^{bx}}{(1+e^{bx})}$$

where P is the probability of being employed, bx is a series of regressors and their coefficients, including w, and e is the natural constant.

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[52] Moffitt and Wilhelm, "Taxation and the Labor Supply of the Affluent," op. cit.

Differentiating this equation, and denoting b_w as the coefficient for wages provides a slope of form:

$$(15)\quad dp/dw = \frac{b_w e^{bx}}{(1+e^{bx})^2} = b_w WP(1-P)$$

and the elasticity of participation

$$(16)\quad Ep = \frac{b_w W}{(1+e^{bx})} = b_w W(1-P)$$

If the change in P is the result of non wage factors, the elasticity should fall as P rises. In the change in P is the result of wage changes, the elasticity may either rise or fall. Differentiating equation with respect to W, and substituting from (5), results in $dEp/dw = b_w(1\text{-}P)(1\text{-}b_w PW)$. Since the sign of the second term can be positive or negative, the elasticity can either fall or rise as W rises. One can calibrate this relationship by the relationships between estimated elasticities, participation rates and wages, from (7) and eventually the elasticity must fall.

How close have women have come to male participation rates and how much room is there fore further response? Consider the reasons for not working.[53] For those between 15 to 19, about 54% do not work, and 87% of those do not work because they are attending school. (About 3% of those who do not work can't find a job, about 2% have a temporary or chronic disability, about 2% are taking care of children, about 2% are not interested in working and about 2% have other reasons). For those over 65, 85% do not work and 92% of those cite either retirement or disability as a reason.

The prime working years of 20 to 64 are where the differences in the sexes emerge. In those groups, about 14% of men do not work, while 27% of women do not. Most of that differential (about 10 percentage points) reflects differences in child care responsibilities (or care of others). In each case about 2% are looking for a job or laid off, almost 5% have chronic disability (and about 1% have a temporary disability), about 2% are in school. Less than 5% of prime age males are not working for other reasons; over half of these are retired. Except for minor retirement, virtually all prime age men are either in the labor force, can not be in, have not succeeded in entering the labor force, or are preparing to be in the labor force.

About 18% of women are not working for reasons other than these, and over 10% are not working because they are taking care of children or others. Slightly under 1% are not working because of pregnancy or childbirth, which may or may not be a voluntary absence. Slightly under 3% indicate a lack of interest in working and

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[53] See Mai Weismantle, "Reasons People Do Not Work," 1996, U.S. Census Bureau, Issued July 2001. Data on labor force non-participants from this study were compared with population data from the March 1996, Current Population Survey.

slightly under 3% are retired (the remainder fall into the "other" category). The vast majority of women who indicate that they are caring for children (or others) are married. The increase in the ratio of women working over time is partly due to less marriage and partly due to fewer children or more women with children working.

It may be difficult to expect a significant increase in labor supply from participation response with these levels of participation. If real wages were to grow at 2% a year, the real wage would increase by 10% in five years. If there were an average elasticity of one over that time, there would need to be an increase in female workers of over 8% of the population. If drawn proportionally from all categories except the already retired, half of mothers caring for children would have to re-enter the work force.

There are two other types of participation responses that might be considered, but both are ambiguous in their effects. First, wages may affect retirement decisions, but there might, again, be income and substitution effects from higher or lower wages over a lifetime. Most attention to retirement decisions has focused on the larger effects of pensions and Social Security. In any case, the fraction of the workforce over 65 and the fraction of the under-65 workforce not participating because of retirement is very small (3% in the former case and 2% in the latter in 1996). The second issue is the choice between spending more time on schooling versus more time on work. Teenage workers are a small but significant fraction of the workforce and young adults may also not be working because of schooling. However, the effect of higher wages may be to increase schooling as the returns increase. Higher wages also increase the part of the cost of schooling that is in the form of forgone earnings, but not the direct costs. Thus, one might expect higher wages to increase schooling and in fact schooling has increased over the years.

Application to Revenue Feedbacks

Uncertainties About Responses. Many of the articles discussed above contain extensive commentary on the econometric problems encountered in studying labor supply response, in particular the response of women.

A recent survey of 65 labor economists asking for their best estimates of labor supply elasticities for prime age men and women is suggestive of the existing professional lack of consensus about the sign of labor supply response for men and the magnitude for women.[54]

For men, the mean was 0.10, a little higher than the evidence that generally suggests a backward bending labor supply. The median was zero and the standard deviation was 0.27; hence a standard confidence interval would fall well into the negative range. (The estimate was zero at the 25th percentile and 0.10 at the 75th percentile, but as a confidence interval, this is a narrow range.) Compensated

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[54] Victor R. Fuchs, Alan B. Krueger, James M. Poterba. "Economists' Views about Parameters, Values and Policies: Survey Results in Labor and Public Economics," *Journal of Economic Literature*, vol. 36, September 1998.

elasticities had a mean of 0.22 and a median of 0.18, with a standard deviation of 0.18 (0.08 at the 25th percentile and 0.28 at the 75th percentile).

For women the values were a 0.45 mean and 0.30 median, with a larger standard deviation of 0.57 (a range that would fall into the negative). The 25th and 75th percentiles were 0.10 and 0.70. Compensated elasticities were a 0.59 mean, a 0.43 median, and a 0.44 standard deviation. The 25th and 75th percentiles were 0.20 and 0.80. The values for women were lower than much of the empirical evidence for married women, which may reflect an adjustment for single women (who would be expected to have lower elasticities) and perhaps the growth in participation rates over time that should move women's elasticities closer to those of men.

The large standard deviations are suggestive of a great deal of uncertainty in the measurement of labor supply. Moreover, a significant fraction of respondents did not answer the question (15% for men's elasticities and one third for women's). The inescapable conclusion is that if the sign of the elasticity matters, we cannot say with confidence based on the informed judgement of labor economists that it is positive.

One should not make too much of this type of survey data. Labor economists specialize in particular areas outside of labor supply and many may not be familiar with all of the literature. Backward bending labor supply curves present certain difficulties with modeling of business cycles, and economists focused in these areas may tend to think of labor supply elasticities as positive (otherwise, the survey seems at odds with the findings of a backward bending labor supply response of men).[55] But the survey data do tend to accord in a general way with the assessment made of the literature: elasticities are probably small but there is a great deal of uncertainty about them and about whether they are significantly different from zero.

Using Out-of-Date Estimates. Most estimates of labor supply are based on data from the sixties, seventies or at best the eighties. Even a recent study published in 1998 (Pencavel) used data from the early seventies to the mid nineties and thus tends to reflect on average the early eighties. As discussed earlier, elasticities are expected to change over time, so there is always a question of relying on existing estimates. In particular, the larger elasticities associated with female labor participation should be falling, perhaps substantially, particularly if one weights elasticities by current wage shares (which reflect increased participation rates for women). Female labor participation increased from about 43% in 1970 to 52% in 1980 to 58% in 1990. Moreover, because the elderly population share was growing during this time (for example, the elderly share of the over 15 population grew by about 5 percentage points between 1980 and 2000 for women), the participation rate among those able to work grew even more. Of course, the perceptions of labor economists reported above may reflect acknowledgment of the higher participation rates. As noted above, recent evidence has suggested lower elasticities for women,

[55] It is also possible that some respondents forgot to put down minus signs even though they were reminded in the question.

and CBO has reduced elasticities in the neoclassical and short-run models (but not their intertemporal ones).[56]

Cross Income Elasticities for Married Couples. One would expect cross section income elasticities (effects of husband's income on wife's work effort) to be negative and at least one study found them to be significant, with a magnitude of -0.5.[57] An aggregate elasticity constructed for the economy based only on own elasticities should be an overstatement of the true elasticity for purposes of across the board changes.

With initial small elasticities, this correction could reverse the sign of the aggregate supply response. With a composite elasticity of 0.1, the median values for men and women in the survey results with men weighted at 60% and women at 40% (to reflect both women's slightly smaller numbers and the female to male wage ratio of 0.7). If we look back on the empirical evidence for U.S. women, we find a value for the income elasticity of about -0.20 from the survey of the wide range of largely cross section elasticities,[58] an average of -0.28 from the survey of studies incorporating taxes,[59] and a value of -0.33 from a later panel study.[60] These are a little higher than the mean and median elasticities for all women (computed by subtracting the Hicksian demand from the Marshallian demand elasticities) from the survey of labor economists mentioned above, which are -0.13 to -0.14 but it is commonly thought that married women have more elastic responses in general. A range from -0.13 to -0.33 seems to reflect a reasonable assumption about these elasticities. Based on married women's participation and wages, they would receive a weight of about 0.25. However, since these weights were corrected for a gender wage gap, it is appropriate to multiply the elasticities by 1/.7: this yields a range of -0.19 to -0.47 to reflect the effects of husband's proportional wage changes. Multiplying these numbers by 0.25 suggests that any aggregate elasticity computed by weighting men's and women's responses would be reduced by 0.05 to 0.12. At the lower end, this change would cut the elasticity in half, from 0.10 to 0.05. At the upper end, this change would transform the 0.10 positive elasticity to a -0.02 (negative elasticity).

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[56] Congressional Budget Office, *The Effect of Tax Changes on labor Supply in CBO's Microsimulation Tax Model*, April 2007.

[57] Pencavel, "The Market Work Behavior and Wages of Women," op. cit. This study examined cohorts and is thus not strictly a cross section study; as noted earlier, it is not clear that controls for social and other changes were incorporated. The estimate is at the high end of the values discussed subsequently below.

[58] Averaged over negative values excluding zeros and positives. See Killingsworth and Heckman, "Female Labor Supply," op. cit.

[59] Hausman, "Taxes and Labor Supply," op. cit.

[60] This is the 1990 study of Triest, summarized in MaCurdy and Blundell: "Labour Supply: A Review of Alternative Approaches," op. cit.

Appendix C. Intertemporal Models

Empirical Evidence

Empirical evidence relative to this model includes the evidence on labor supply response in a cross section study which examines the supply response across individuals, as discussed above. This evidence largely suggests relatively small income and substitution effects. The evidence regarding the factor substitution elasticity, again being relatively small, is also directly applicable to intertemporal models.

Another type of econometric evidence that is relevant to the intertemporal models is the substitution elasticity across time. These studies have in some cases employed macroeconomic data, and in others panel data on individuals. There are two types of evidence. In some studies the change in consumption over time is estimated as a function of changes in the interest rate. In others, changes in labor supply are estimated over time as a function of changes in the wage rate. The first set of studies is relatively straightforward as a direct estimate of the intertemporal substitution elasticity in a model where labor is fixed or for a combination of leisure and consumption with certain functional forms (such as those frequently used in tax models). The intertemporal labor supply elasticity with respect to wage changes has an interpretation that depends on functional form, discussed below.

Intertemporal Substitution in Consumption

In an early paper on the business cycle, Prescott[61] chooses a value of around 1; he reports three studies that range from 0.5 to 1. The real business cycle model he was pursuing requires a large substitution elasticity to be viable, however. Indeed, growing questions about these elasticities have led to skepticism about real business cycle theories. Auerbach and Kotlikoff[62] report the results of nine different studies which ranged in value from less than 0.1 to more than 1. The median value was around 0.3 and a weighted average of eight of them using the mid-point of each range (and excluding a study by Mankiw, Rotemberg and Summers in which it is clear the authors were not very satisfied with the model) yielded an estimate of 0.39. Elmendorf[63] undertakes a survey of the studies most commonly cited and obtains a weighted average of 0.37; he uses 0.33 in his work. More recent studies were mostly consistent with these general results, namely that the elasticity is probably below 0.5.[64]

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[61] Edward C. Prescott, "Theory Ahead of Business Cycle Measurement," In *Carnegie-Rochester Conference on Public Policy*, vol. 24, pp. 11-44, 1986.

[62] Alan A. Auerbach and Laurence J. Kotlikoff, *Dynamic Fiscal Policy*, New York: Cambridge University Press, 1987, p. 50.

[63] Douglas W. Elmendorf, "The Effect of Interest-Rate Changes on Household Saving and Consumption," Federal Reserve Board, June 1996.

[64] Annette Vissing-Jorgenson, "Limited Asset Market Participation and the Elasticity of Intertemporal Substitution," National Bureau of Economic Research working paper 8896,

(continued...)

Studies of the Intertemporal Labor Supply Elasticity with Respect to Wages

Intertemporal substitution elasticity estimates of labor supply with respect to wages have been very small. These studies which generally look at patterns of labor over time as wages change (the time profile of earnings) and small elasticities are perhaps not surprising given the greater difficulty of shifting labor across time periods. Pencavel's 1986 survey[65] reflected a median value of 0.26 and an average of 0.21, with some results not statistically significant. Adding an additional study reported by Auerbach and Kotlikoff along with three referred to in Ham and Reilly[66] and one additional study[67] yielded a similar average of 0.20. French [68] also reports

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[64] (...continued)
April 2002 found an elasticity less than 0.1 in aggregate. Ogaki Masao and Carmen M. Reinhart, "Measuring Inter-temporal Substitution: The Role of Durable Goods, " *Journal of Political Economy*, vol. 106, no. 5 (October 1998), pp. 1078-1098 found an elasticity of 0.2-0.4. Abdullahi O. Abdulkadro and Michael R. Langemeier, "Using Farm Consumption Data to Estimate the Intertemporal Elasticity of Substitution and Relative Risk Aversion Coefficients," *Agricultural Finance Review*, vol. 60, 2000, pp. 61-70, found 0.158-0.351. Other studies that confined their analysis to food also found low elasticities. Motohiro Yogo, "Estimating the Elasticity of Intertemporal Subsitution when Instruments are Weak," *Review of Economics and Statistics*, v. 86 (August 2004), pp. 797-810, found an elasticity less than one that was not statistically significant across eleven deceloped countries. Pierre-Olivier Gourinchas and Johnathan A. Parker find elasticities ranging from 0.7 to almost 2 (depending on certain weights used) in "Consumption over the Life Cycle," *Econometrica*, v. 70, (June, 2002), pp. 47-89, but this approach presumes powerful precautionary savings effects. Two unpublished studies have included nuances in mesuring the discount rate. Jonathan Gruber, *A Tax Based Estimate of the Elasticity of Intertemporal Subsitution*, National Bureau of Economic Research, Working Paper 11945, January 2006, finds a very high elasticity when using the marginal tax rate on interest, but stresses the need for further work. Fuad Hasanov, in his dissertation (University of Texas), *Residential Housing, Household Portfolio, and Intertemporal Elasticity of Subsitution*, finds an elasticity of 0.15 to 0.30 when including housing returns in the portfolio for measuring interest rates. Studies that try to determine this parameter by fitting it to a single aggregate value are not referred to here because such calibration approaches can be extremely sensitive to model features. See Owen Evans, "Empirical Tests of the Life Cycle Model: Comment," in *American Economic Review*, vol. 84, March 1984, pp. 254-257, for a discussion.

[65] Pencavel, *The Labor Supply of Men*, op. cit. Taking medians of ranges, the studies reported values of 0.26, 0.31, 0. 32, and 0,10.

[66] Auerbach and Kotlikoff, *Dynamic Fiscal Policy*, op. cit. rely largely on a study by Ghez and Becker that had an elasticity of 0.28. John C. Ham and Kevin T. Reilly, "Testing Intertemporal Substitution, Implicit Contracts and Hours Restrictions Models of the Labor Market Using Micro Data," *American Economic Review*, vol. 92, September 2002, pp. 905-927 refer to Altonji (1986), Ham (1986) and French (2000), all with elasticities below 0.1 Their own tests reject the intertemporal model.

[67] Chul-In Lee, "Finite Sample bias in IV Estimation of Intertemporal Labor Supply Models: Is the Intertemporal Substitution Elasticity Really Small?" *Review of Economics and Statistics*, vol. 83, no. 4, November 2001

[68] Eric Fench, "The Labor Supply Response to (Mismeasured but) Predictable Wage (continued...)

some other studies whose values were not clear from their studies but, according to French, fell below 0.5. French also summarizes some specialized or event studies that found widely varying results. Looney and Monica examined hours for both women and men and found no effect.[69]

Theoretical Issues

The intratemporal substitution elasticity is the parameter governing the substitution of consumption and leisure within a period. It also governs the response to an equal percentage change in wages in all time periods, thus becoming the lifetime analog of the basic substitution elasticity that is reflected in the labor supply equation presented earlier. Moreover, most models use functions that set income elasticities to one, so the wage elasticity of labor supply elasticity is given a proportional change in wages across all periods and ignoring capital income on hand is (L/H)(S-1), where L is leisure, H is hours available, and S the intratemporal substitution elasticity. (This formula is somewhat modified in the intermediate term for those who have already accumulated non labor income; the substitution effect will be slightly larger and the income effect slightly smaller).[70] If the elasticities are not set to yield a steady state growth, which means that aggregate labor supply cannot respond to wage growth, some assumption must be made in the model to correct for it. For that reason, it is difficult to justify a very small or very large substitution elasticity. To keep the income and substitution elasticities in line with empirical evidence from cross section labor studies, the ratio of leisure to hours available should be set quite low, probably around 0.2. It often is not, leading to very large labor supply elasticities that are inconsistent with evidence.

A similar problem can arise with conforming to the relatively low intertemporal substitution elasticities for labor with respect to wage rate changes. The effects depend on the functional form of the model, but in the nested utility functions that are commonly used in tax models, the intertemporal substitution elasticity is a weighted average of the intertemporal and intratemporal substitution elasticities, γ and ρ (new notation is chosen to conform to a reference equation) multiplied by the share of leisure over labor, or:

(17) $[L/(H-L)][\gamma a + \rho(1-a)]$

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[68] (...continued)
Changes." Federal Reserve Bank of Chicago, Working Paper No. 2000-08, August 2000.

[69] Adam Looney and Monica Singhal, "The Effect of Anticipated Tax Changes on Intertemporal Labor Supply and the Realization of Taxable Income," Finance and Economics Discussion Series, 2005-44. This study that used the loss of a dependent to identify an expected change in the marginal tax rate and found no change in labor supply (either in participation, or in hours worked by existing participants). The study did find a curious increase in labor income of men, which is not easily explained, although it is possible that there was a shifting of income over time periods or a shift to fringe benefits, or perhaps an increase in work intensity.

[70] The substitution elasticity is (1+x)S*L/[H(1+x)-xL] where x is the share of nonlabor income. The income elasticity is L/[H(1+x)-xL)].

where L is leisure and a is the share of total consumption spent on leisure (wL/(c+wL)) where w is the wage rate and c is expenditure on goods). This formula can be derived from the transition equation for leisure in equation 3.12 of the Auerbach and Kotlikoff's book, *Dynamic Fiscal Policy*, making use of 3.11 and 3.9. (Note that 3.12 has an error, which is that v_t/v_{t-1} should not be raised to the power $-\rho$ and note also that equation 3.11 has an error in that the term α should be raised to the power ρ rather than being multiplied by it.)

This formula would also require leisure to be a relatively small part of hours (and small relative to labor) in order to keep the intertemporal labor elasticity with respect to wage relatively low. For example, in the CBO model, γ is 0.5, ρ is 1.0, a is 0.53 and L/(H-L) is 1.5 because leisure is 60% of hours available. That result is 1.1, but if the leisure were set at 20% (which would change a to 0.2 and L/(H-L) to 0.25), it would be 0.225, in the neighbor hood of the empirical estimates. A reduction in the intertemporal elasticity itself would reduce it even further.

In these nested functions consumption over time is also affected by available wages, but in this case, the elasticity is (derived from equation 3.10 in Dynamic Fiscal Policy):

(18) $(\rho-\gamma)\, a$

which in the CBO model would be about 0.265. Making the change in leisure would reduce it to 0.1, and changing the intertemporal elasticity to 0.25 would change it to 0.15.

The final set of substitution elasticities is the change in consumption and leisure with respect to the interest rate. This value is estimated directly but not always over a long period of time. This elasticity rises as periods become farther apart because of the compounding of interest and the percentage change in current consumption r- the percentage change in consumption T years in the future is equal to:

(19) $-\gamma T(r/(1+r))$

If r is .05 and γ is 0.5, the one period apart, the elasticity is -0.024, for two periods apart, -0.048, for ten 0.24, and for 50 -1.19. However, if we convert it to an elasticity of substitution between savings in each period, which has a magnitude more closely corresponding to the reduced form savings estimates, the elasticity should be divided by the savings rate, which is usually well under 0.10. Using 0.06 as an example, the percentage change in savings today minus the percentage change in savings in the future would be 0.40 for times one period apart, 4 for 10 years apart and 20 for 50 years apart. Thus, the implied elasticities of savings with respect to the interest rate are very large.

There is also substitution elasticity for leisure over time which leads to an intertemporal labor supply response to the rate of return. In this case, it's size also depends on the ratio of leisure to labor; thus it is larger that the substitution between consumption in many models because it is multiplied by leisure over labor. If leisure over labor is 1.5 as in the CBO model it is 50% larger; however, a much lower

substitution elasticity could be obtained by reducing the leisure share, and also by reducing the intertemporal elasticity itself.

Note that the income effects are more complicated in these models. There is an offsetting income and substitution effect that affects the price of future consumption goods so that if the intertemporal substitution effect were unitary these effects would offset each other. With an intertemporal substitution elasticity of less than 1, these types of income effects would result in more consumption with a rise in the interest rate because future consumption is discounted at a higher rate. However, an increase in the interest rate also reduces the present value of human wealth, and this latter effect would reduce consumption and increase savings. At the same time, there is existing income from capital in the model that can be affected. Therefore, how these effects occur depends on a variety of factors in the model and what fraction of the tax cut affects average versus marginal rates of interest. crsphpgw