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MACROECONOMIC VOLATILITY IN GENERAL EQUILIBRIUM

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MACROECONOMIC VOLATILITY IN GENERAL EQUILIBRIUM*

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Abstract

In this paper we explore the concept of excess volatility in general equilibrium. We show there is a fundamental tension between household efforts to smooth consumption and attempts by firms' to smooth investment in the presence of convex adjustment costs in capital formation. Adjustment costs substantially diminish the ability of households to smooth consumption. As a result, consumption volatility will be significantly higher in the presence of adjustment costs than would be expected from the permanent income model alone. Moreover adjustment costs can cause consumption and asset prices to change discontinuously at the moment of implementation of a previously anticipated event, a phenomenon that does not occur in models without adjustment costs.

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Introduction

Two of the most important influences on modern macroeconomics are the permanent income model of savings[1] and the adjustment cost model of investment[2]. Both are intimately familiar to most economists and form the core of the macroeconomic theory presented in modern graduate textbooks.[3] Yet the most well-known implications of the models (particularly those that are the basis of most empirical tests) are true only in partial equilibrium. In general equilibrium, the permanent income hypothesis and the adjustment cost model are actually in direct conflict. Permanent income consumers would like to use saving to smooth out consumption in the face of fluctuations in income. Saving, as a result, should be quite volatile. The adjustment cost model of investment, on the other hand, implies that firms would like to avoid excessive spikes in the investment rate, which raise adjustment costs. Thus, other things equal firms would prefer to have less volatile investment.

In a closed economy, both of these objectives cannot be met simultaneously: if consumers smooth income fluctuations, that will cause savings and investment spikes which will lead to adjustment costs. At the same time, the only way to minimize adjustment costs would be to reduce the volatility of investment, but that would mean increasing the volatility of consumption.[4]

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[1] We will refer to the model as the permanent income hypothesis (Friedman, 1957) but our argument applies equally to the life-cycle hypothesis (Modigliani, 1971).

[2] The adjustment cost model of investment is an extension of the Q theory of investment first proposed by Tobin (1969). Contributors include Eisner and Strotz (1963), Lucas (1967a,b), Gould (1968), Treadway (1969), Uzawa (1969), Abel (1979) and Hayashi (1982). For a recent survey of the empirical literature on adjustment costs in labor demand and investment, see Hamermesh and Pfann (1996).

[3] For example, Blanchard and Fisher (1989), Azariadis (1993), Barro and Sala-i-Martin (1995), Mankiw (1994) and Romer (1996).

[4] This is consistent with the empirical findings of Campbell (1987), who used aggregate data to argue that the permanent income hypothesis failed in a way that should be interpreted as “insufficient variability of saving”.

We show that the outcome of this conflict is that consumption will be much more volatile (and investment less volatile) that one would expect from a partial equilibrium model, or from a general equilibrium model that excluded adjustment costs. In particular, we show that in the presence of adjustment costs, consumption will jump discontinuously at perfectly anticipated changes in income. To put this point more sharply, consumption jumps at the moment of an anticipated change in income even though there is no change in the information set. This contradicts the familiar partial equilibrium notion that consumption should jump only when new information arrives and not at the implementation of previously anticipated events.[5]

Our result has implications for research in several areas where the permanent income hypothesis and the adjustment cost model of investment meet. First, it suggests an explanation for why empirical tests often reject the permanent income hypothesis at the aggregate level, or indicate that it holds only if a substantial fraction of consumers are liquidity constrained.[6] When adjustment costs are present, consumption will be more strongly correlated with temporary changes in income than the partial equilibrium version of the permanent income hypothesis would predict, even when no consumers are liquidity constrained.[7]

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[5] The notion that consumption changes only when the household's information set changes is deeply embedded in the literature. For example. it is a cornerstone of Hall (1978), a pioneering empirical test of the permanent income hypothesis, and many subsequent papers.

[6] Well known examples of rejections include Flavin (1981), and Deaton (1987). Moreover, Deaton argued that consumption is actually excessively smooth relative to inferred changes in permanent income. Mankiw and Campbell (1990) found that consumption was consistent with the theory only if 50% of households were liquidity-constrained. Our results extend Michener (1984), who showed that partial equilibrium tests of the permanent income hypothesis, in which interest rates are taken to be constant, are biased in favor of rejection.

[7] This suggests a reconciliation between the empirical results of microeconomic studies that find few households are liquidity constrained, such as Hall and Mishkin (1982) or Mariger (1987), and aggregate studies, such as Campbell and Mankiw (1990), which find large numbers of constrained agents.

Second, our result is consistent with Cochrane (1991, 1996), who showed that asset prices are much more closely related to physical returns on assets (including the effects of adjustment costs) than to the evolution of aggregate consumption. Consumption-based methods of asset pricing rely on the Euler equation linking consumption in one period to the next. Our finding that consumption can change discontinuously at a perfectly anticipated event implies that the Euler equation does not, in fact, hold at that instant.[8] Thus, if changes in income are ever expected in advance, it is not surprising that consumption-based approaches do not perform well.[9]

Finally, our result suggests that adjustment costs play an important role in distributing aggregate income shocks between changes in consumption and changes in investment. Thus, it has a potentially important role to play in real business cycle models.[10]

Our paper builds on the seminal work of Abel and Blanchard (1983), who constructed an intertemporal general equilibrium model of saving and investment and used it to study the effects of technology shocks and fiscal policy. We generalize their model and draw out the previously

[8] We will return to this point below. In the mean time, one way to understand why the Euler equation fails to hold is that the instantaneous interest rate is momentarily undefined at the time of an anticipated change in income. Another way to look at it is that adjustment costs cause a kink in the household's intertemporal budget constraint at the moment an anticipated change in income occurs.

[9] Another explanation for the failure of consumption-based asset pricing has been advanced by Grossman and Laroque (1990), who showed that transactions costs in the purchases of durable goods will cause consumption to be unresponsive to small changes in wealth. The key difference between our approach and theirs is that in our model, adjustment costs arise in investment within firms rather than in consumption. As a result, we find that consumption should be relatively *more* responsive to short term fluctuations in income than the permanent income hypothesis would suggest, while their model suggests the opposite. Moreover, our results also predict that wealth itself should be more volatile than changes in permanent income.

[10] Adjustment costs are not a routine part of real business cycle models; see, for example, Backus, Kehoe and Kydland (1992). A recent exception is Ravn (1997).

overlooked implication that consumption is discontinuous at anticipated changes in income[11]. We begin by presenting a very general Ramsey-style model of a centralized economy in order to emphasize that our results arise from adjustment costs, not from some sort of coordination failure or other interaction between agents. We then illustrate our results numerically using a simple model of a decentralized economy loosely calibrated to the United States.

The Ramsey Model with Adjustment Costs

The general equilibrium effect of combining the permanent income hypothesis and the adjustment cost model of capital accumulation can be seen clearly in a simple closed-economy Ramsey growth model with adjustment costs. Suppose households can be modeled by a representative agent with the following intertemporal utility function:

$$U=\int_0^\infty G(c(t))e^{-\rho t}dt \tag{1}$$

where *c(t)* is consumption at time *t*, ρ is the rate of time preference and *G* is a function giving instantaneous utility, or “felicity”. We will assume the first derivative of *G* is positive and the second is negative. The representative household maximizes *U* subject to several constraints. Total output, *q*, is a function of *k* and the level of technology, *a*:

$$q = F(k,a) \tag{2}$$

[11] Abel and Blanchard (1983) p. 688 note this possibility for a specific functional form however they do not pursue the implications of this result.

The capital stock accumulates according to the following equation, where i is the rate of investment and δ is the depreciation rate:

$$\frac{dk}{dt} = (i - \delta)k \tag{3}$$

This specification is convenient but a little unusual: since i the investment rate, investment itself, in the sense of new capital goods installed, will be given by ik. The total cost of investing at rate i when the capital stock is k will be given h, which is determined by the following function:

$$h = H(i,k)k \tag{4}$$

This form of the adjustment cost model follows Uzawa (1969). In a model with no adjustment costs, $H(i,k)$ would be equal to i and h would equal ik. We will assume the cost of investment depends positively on how much investment is done:

$$H_i > 0 \tag{5}$$

where H_i is the derivative of H with respect to i. Adjustment costs are present when the following is true:

$$H_{ii} \neq 0 \tag{6}$$

The usual adjustment cost assumption is that this derivative is positive but all that is necessary for our argument is that it be nonzero. Finally, the household is subject to an overall budget constraint in which the sum of consumption and investment must equal total output:

$$q = c + h \tag{7}$$

Notice that investment enters gross of adjustment costs.

Maximizing the household's utility function subject to the four constraints above is an optimal control problem. Setting up the Hamiltonian and taking first-order conditions yields the following:

$$G_c H_i = \mu \tag{8}$$

$$\frac{d\mu}{dt} = \mu(\rho + \delta - i) - G_c(F_k - H) + G_c H_k k \tag{9}$$

$$F(k,a) = c + H(i,k)k \tag{10}$$

$$\frac{dk}{dt} = (i - \delta)k \tag{11}$$

where μ is the multiplier associated with the capital stock.

Equation (8) has a clear interpretation: μ is the marginal value of increasing the capital stock by one unit and $G_c H_i$ is marginal cost of doing so in terms of foregone consumption. In the absence of adjustment costs H_i is unity and the left hand side is just the marginal utility of a unit of consumption. When adjustment costs are present H_i will be greater than one and the consumption cost of increasing the capital stock by one unit will be greater than G_c. Similarly, equation (9) extends the conventional Ramsey model by adding the effect of adjustment costs, in this case through the term in H_k. If having a larger capital stock reduces adjustment costs (that is, if H_k is negative), integrating (9) shows that μ will be larger as a result.

Now consider what happens at the moment of implementation of an anticipated change in a. The change could be a shift in technology or, more abstractly, a change in exhaustive government spending. Since the change is anticipated, there will be no jump in μ at the instant of implementation.[12] There will also be no change in the capital stock. The relationship between the change in a and consumption can be seen by totally differentiating (8) and (10) holding μ and k constant. This produces the following expressions:

$$G_{cc}H_i dc + G_c H_{ii} di = 0 \tag{12}$$

and

$$F_a da = dc + H_i k di \tag{13}$$

Eliminating dc and rearranging gives:

$$\frac{H_i k di}{F_a da} = \frac{1}{1 - \Gamma} \tag{14}$$

where Γ is given by:

$$\Gamma = \frac{G_c H_{ii}}{G_{cc} H_i^2 k} \tag{15}$$

The left hand side of (14) is the ratio of the change in investment expenditure, $H_i k di$, to the change in the household's income, $F_a da$. Unless the ratio is exactly equal to one, the change in investment spending will not match the change in income exactly. This implies that consumption will jump at the moment of the shock unless the right side of (14) is precisely equal to one, which would require that Γ equal zero. However, a necessary condition for Γ to be zero for an arbitrary felicity index G is that H_{ii} be equal to zero. In other words, consumption is certain to jump at the moment of implementation unless there are no adjustment costs. Because of this jump,

[12] The lack of change in the multiplier at the moment of an anticipated event is a familiar result and can be seen from equation (9). Because the right hand side of (9) will be finite at the moment of implementation for reasonable functions F, G and H, derivative of μ with respect to time at that instant will be a well-defined finite number.

adjustment costs mean consumption will be more volatile than one would expect from the partial equilibrium version of the permanent income hypothesis.

As an example, consider a shock *da* that increases *F*. Suppose that $H_{ii} > 0$, which is the conventional cost of adjustment assumption. In that case, Γ is negative and the ratio in (14) is strictly less than one. This means that when the shock arrives, investment does not fully offset it and there will be a discontinuous upward jump in consumption. Another way to put this point is that when adjustment costs are present in capital accumulation, the usual Euler equation giving the derivative of consumption with respect to time will not hold at the instant an anticipated event takes place.

The effect of adjustment costs can be seen clearly in the model's phase diagram in (K,C) space. To make the discussion somewhat more concrete, suppose the felicity index *G* and the production function *F* take the forms below:

$$G(c) = \ln(c) \tag{16}$$

$$F(k,a) = Ak^{\alpha} - a \tag{17}$$

where *A* and α are parameters, α is strictly less than one and *a* is an exogenous in-kind tax imposed by the government.[13] In addition, suppose the investment cost function takes the form:

$$H(i,k) = i(1+\varphi i) \tag{18}$$

where φ is a parameter. This form of *H* is roughly similar to the quadratic specification widely used in the investment literature.[14] When $\varphi = 1$, *H* implies significant but not enormous

[13] The tax represents exhaustive government expenditures, such as the military, not transfer programs.

[14] This specification is common in the investment literature (see Summers (1982) for example) although there is considerable evidence that adjustment costs are more complex. In particular, adjustment costs are probably not symmetrical. See Hamermesh and Pfann (1996) for a more complete discussion.

adjustment costs: if the gross investment rate *i* were 10%, adjustment costs would add 10% to the firm's cost of new capital (that is, the firm would have to invest at a rate of 11% to get a 10% increase in the capital stock). This is near the lower bound of empirical estimates of adjustment costs, which range from 12% to 30%.[15]

Figure 1 is a phase diagram showing the effect on this economy of an immediate, temporary increase in tax *a* if there are no adjustment costs (φ=0). The trajectory has conventional features: a downward jump in consumption when the tax appears at time 0, gradual evolution up and to the left during the period of the tax, no jump when the tax is removed at time *T*, and then gradual evolution back to the steady state along the stable path. When adjustment costs are present, however, the phase diagram takes the form shown in figure 2. The difference is immediately apparent: there is a discontinuous jump in the trajectory when the tax is removed at time *T*.[16]

The Decentralized Case

So far we have considered the effect of adjustment costs in a single-agent Ramsey model. We now examine the decentralized case in which households and firms are separate optimizing agents interacting through markets. Consumption, investment and capital accumulation will be identical in the decentralized and Ramsey models. In the decentralized version, however, it is also possible to observe short and long term interest rates and the value of the firm.

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[15] Hamermesh and Pfann (1996).

[16] It is important to remember that the jump is in consumption, not in the model's true costate variable μ. If one were to plot the phase diagram in (k,μ) space there would be an initial jump upward in μ in year 0 but no jump in year 10.

Suppose the representative household maximizes the following intertemporal utility function:

$$U = \int_t^{\infty} \ln(c) e^{-\rho(s-t)} ds \tag{19}$$

It will be subject to the lifetime budget constraint shown below:

$$\int_t^{\infty} c(s) e^{-R(s)(s-t)} ds = W(t) \tag{20}$$

where $R(s)$ is the long term interest rate:

$$R(s) = \int_t^{s} \frac{r(v)}{s-t} dv \tag{21}$$

and $W(t)$ is household wealth at time t, which is equal to the present value of dividends to be paid by the firm:

$$W(t) = \int_t^{\infty} D(s) e^{-R(s)(s-t)} ds \tag{22}$$

The first order conditions for this problem can be rearranged to give the familiar expression below showing how consumption in time t is related to wealth:

$$c(t) = \rho W(t) \tag{23}$$

Equation (23), which is familiar from the partial equilibrium version of the permanent income hypothesis, hints at the results to come. Since (23) holds at all points in time, it must hold immediately before and after implementation of an anticipated event. Since we have shown that in the presence of adjustment costs, consumption will jump at implementation, it must be the case that wealth jumps as well. Since the path of earnings before and after the tax change is known with certainty in advance, the only way for wealth to jump is for there to be a discrete jump in the long run interest rate. To see why that occurs, consider the firm side of the model.

Suppose the firm, for its part, maximizes the present value of its dividend stream:

$$\int_0^{\infty} D(s) e^{-R(s)s} ds \tag{24}$$

where dividends $D(s)$ are equal to output less taxes (a) and investment spending (h):

$$D = k^{\alpha} - a - h \tag{25}$$

As before, we assume that adjustment costs mean the firm must buy more capital goods than it will actually be able to install. Using the quadratic investment cost function from above, the cost of investing at rate i is:

$$h = i(1+\varphi i)k \tag{26}$$

Finally, the capital stock evolves according to the accumulation equation:

$$\frac{dk}{dt} = (i-\delta)k \tag{27}$$

To illustrate the interaction between adjustment costs and consumption graphically, we constructed a numerical version of the model. The time preference rate, ρ, was set to 0.05; the depreciation rate, δ, to 0.06; the exponent in the production function, α, to 0.3; the production coefficient A, to 2.95; and the adjustment cost parameter, φ, to 1. In addition, the tax parameter a was set to 1.2. These values were chosen so that the model would loosely approximate the 1995 U.S. economy: GDP is about 7 trillion dollars, consumption is 4.6 trillion, and investment is about 1.1 trillion.

Using the numerical model we examined the effects of a temporary 30% increase in the tax *a* lasting for 10 years. The increase was announced and implemented immediately and was known to be temporary. Figure 3 shows the path of consumption over time. The results are normalized so that the base case value of consumption is 100 in each year.[17] For reference, the trajectory that would have applied in the absence of adjustment costs ($\varphi = 0$) is shown. The first path, labeled "No smoothing", shows the path consumption would follow if households were constrained to pay the entire tax by reducing consumption without changing investment. It corresponds to an environment in which households are completely liquidity constrained and are unable to smooth consumption at all.

The second path, labeled "Complete smoothing in partial equilibrium", is the polar opposite. It shows the consumption path predicted by the partial equilibrium version of the permanent income model in which the interest rate is assumed to be unaffected by the household's behavior. It corresponds to complete consumption smoothing: consumption changes once when news arrives at the beginning of the simulation and is constant thereafter. The initial change in consumption is relatively small but consumption is permanently lower because households have to pay interest on the debt run up during periods 0 to 10. This path is not a solution to our model because our interest rate is endogenous but is shown as a benchmark for comparison.

The third path, labeled "General equilibrium without adjustment costs", shows the path of consumption in general equilibrium when the adjustment cost parameter, φ, is zero.[18] This

[17] In other words, in the absence of a shock consumption would remain at 100 in every year. A value of 90 in year 0 under the no-smoothing case, for example, indicates a 10% decline in consumption relative to the base case in that year. Unless otherwise noted, all figures will be normalized this way.

[18] Our numerical results were calculated using the GEMPACK modeling package created by Ken Pearson at Monash University. For more information, see Codsi, Pearson and Wilcoxen (1992).

illustrates the results of Michener (1984): even though there are no adjustment costs, households are unable to achieve the complete consumption smoothing one would expect from the partial equilibrium version of the permanent income model. This comes about because in general equilibrium the rate of return on capital is endogenous. During the period when the high tax rate is in effect (years 0 through 10), households would like consumption to fall much less than the drop in income. However, that would mean allowing investment to drop dramatically. Reducing investment would cause the capital stock to decline, leading to a rise in the marginal product of capital. That, in turn, would raise the return on capital and cause the household to reduce investment less than it would if the rate of return were exogenous. Hence, consumption falls more than in the partial equilibrium case but less than it would if households were liquidity-constrained. In contrast to the partial equilibrium case, over time consumption rises back to its initial level. Also, as predicted, there is no jump in consumption in year 10 when the anticipated end of the tax occurs.

Finally, the fourth case, labeled "General equilibrium with adjustment costs", shows the path of consumption generated by the model when φ is set to one. It differs from the previous path in two respects: the initial drop in consumption is somewhat larger, and there is a discontinuous change in consumption in year 10. The discontinuity is precisely the one predicted above. Overall, the effect of adjustment costs is to make the path of consumption more volatile and more similar to the unsmoothed case. As a result, econometric tests ignoring the presence of adjustment costs in capital accumulation would be biased toward rejecting the permanent income hypothesis or toward concluding that a large fraction of the population is liquidity constrained. In the results shown, for example, one might conclude that since the overall consumption path is about halfway between the liquidity-constrained and partial equilibrium paths, about 50% of households must be liquidity constrained. However, no households are actually liquidity constrained.

Figure 4 shows the path of wealth, which is identical to the value of the firm. The curve labeled “Wealth in partial equilibrium”, is a reference line showing the effect of the tax on wealth if households were able to borrow and save at a fixed interest rate.[19] In general equilibrium, however, changes in savings change the rate of return. Thus, when adjustment costs are zero, the effect of the tax on wealth is as shown in the curve labeled “General equilibrium without adjustment costs”. This emphasizes the fact that endogenous changes in interest rates can cause much larger changes in wealth than would be expected from a partial equilibrium analysis. As a result, in general equilibrium, consumption will be more highly correlated with income than would be expected from a partial equilibrium analysis alone.

The final curve in Figure 4, labeled “General equilibrium with adjustment costs”, gives the path of wealth when adjustment costs are present. It differs from the no-adjustment-cost curve because it is discontinuous at year 10 when the tax reverts to its base case value. This is a striking illustration of the effect of adjustment costs because it shows wealth jumping discontinuously ***at a perfectly anticipated event***. In the absence of adjustment costs, one would expect wealth to be continuous when there is no change in information. Here, however, wealth jumps even though no news arrives in year 10: the path of the tax was known completely and with certainty from year 0.

To understand why wealth is discontinuous in year 10 it is necessary to understand what is happening to interest rates. Figure 5 shows the instantaneous interest rate as a function of time.

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[19] This might be true, for example, for a small open economy with perfect capital mobility.

The two curves show the paths when there are no adjustment costs and when adjustment costs are present. The key point is that in the adjustment cost case r is undefined at the instant the tax changes in period 10 (indicated in the figure by an open circle in the adjustment-cost trajectory in year 10). This is because interest rates are fundamentally determined by consumption behavior, and consumption changes discontinuously at that point.[20]

Another way to look at the interest rate is shown in Figure 6, which gives the term structure viewed from year 0. Each point in this graph shows the long term interest rate $R(s)$ prevailing between year 0 and the period on the x-axis (see equation (21) for a definition of the long term interest rate). When there are no adjustment costs, the rate rises gradually as the term increases because the tax policy has increased short run rates temporarily. For term lengths longer than 10 years, the rate begins to fall since after year 10 short term rates begin falling back to their original levels. When adjustment costs are present, however, rates are fairly low for terms up to 10 years but beyond that the rate rises sharply. The discontinuity results from the fact the instantaneous interest rate is undefined at that point. The effect of this is that the household appears to view total wealth as influenced much more by its near term income than the income it will receive after year 10.[21] To put this another way, adjustment costs in the firm cause households to allocate consumption over time in a manner that appears as though there are discontinuities in the effective long term interest rates households use to compute their wealth.

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[20] Dacy and Thum (1995) also make the point that interest rates are fundamentally determined by consumption behavior. They use an Euler equation approach to infer the implicit interest rate used by consumers from data on aggregate consumption. They refer to this as the “consumption rate of interest”.

[21] If this seems unintuitive, remember that the model’s underlying state variable is the physical capital stock, not wealth. Wealth is the product of the quantity of capital and its asset price, so it is determined as much by what households are willing to pay for assets as by the quantity of capital. What this result says, in effect, is that the price households are willing to pay for assets is determined largely by what will happen in the near term.

Moreover, this phenomenon cannot be adequately captured in empirical work by simply including the short run interest rate as an explanatory variable, as has often been done.

To drive this point home it is useful to consider what happens under the opposite policy, a temporary decrease in the tax rate. In this case, households will want to save most of the extra income. In fact, under the partial equilibrium version of the permanent income hypothesis they would save all but a small fraction about equal in magnitude to their time preference rate. In general equilibrium, however, a sharp increase in saving would push down the rate of return. Moreover, the downward pressure on rates of return is even stronger when adjustment costs are present: firms have trouble investing the burst of savings without a large fraction of it being consumed by adjustment costs. The result is that the increased savings mostly drives up the stock market value of firms and drives down the rate of return. Little of it ends up as productive investment. In the terms used in the financial press, market values would rise above what one would expect from “fundamentals”. Another way to interpret this is that adjustment costs will cause asset prices to be more volatile than one would expect from fundamentals, and are thus potentially a partial explanation of the apparent excess volatility of financial markets.[22]

Numerical results for this experiment are displayed in Figure 7, which shows the value of the firm over time. The temporary increase in income causes a temporary surge in asset prices. When income drops back to its usual value in year 10, however, asset prices drop sharply. This pattern corresponds to the business-page intuition that a sudden increase in savings (due to greater use of 401(k) plans, for example), might inflate asset values and depress rates of return.

[22] There is a large empirical literature investigating whether asset prices volatility is reasonable relative to the volatility of dividends and earnings. See Shiller (1989), for example.

Conclusion

The main contribution of this paper is to point out that there is a direct and fundamental conflict between two of the basic microeconomic models on which much of modern macroeconomics is based. The permanent income hypothesis, on one hand, predicts that households will adjust saving as needed in order to allow consumption to be relatively constant in the face of fluctuations in income. Thus, it predicts that aggregate saving should be highly volatile. The adjustment cost model of capital accumulation, on the other hand, predicts that firms will avoid excessively sharp bursts of investment because it is costly to absorb large influxes of capital quickly. Investment, therefore, should be less volatile than one would otherwise expect. In a closed economy in general equilibrium, the two implications cannot hold simultaneously: if households shift income volatility to saving, investment will be volatile as well; if investment is chosen to maximize the value of the capital stock, saving and investment will be less volatile than income and consumption will have to absorb the excess volatility.

The fundamental result of our paper is to show that combining the two models in general equilibrium implies that consumption will be more volatile and more highly correlated with income than would be expected from the permanent income hypothesis alone. In particular, the model exhibits a behavior that is completely inconsistent with the usual view of the permanent income hypothesis: when adjustment costs are present in firms, consumption will jump discontinuously at perfectly anticipated changes in aggregate income, and in the same direction as the change in income. It is worth emphasizing that this effect stems from the existence of adjustment costs, not from the fact that there is only one asset in our model. Adding more assets would not change the result unless the supply of one of the assets were perfectly elastic in the short run. At the aggregate level, the only case where that might occur would be small open economy that can borrow or lend at a fixed world interest rate.

This finding has several important implications. First, it suggests an explanation for the apparent excess sensitivity of consumption to current income that augments or replaces the role of liquidity constraints. Adjustment costs in capital accumulation have the effect of causing the economy as a whole to behave as though it were liquidity-constrained even if individual agents are not. Failing to account for this effect would bias aggregate estimates of the fraction of liquidity constrained consumers upward. Second, it suggests that asset prices should be much more closely related to investment returns (in the sense of Cochrane 1991 or 1996) than to the evolution of consumption. Moreover, it also implies that a temporary increase in income can lead to a savings boom that is partially consumed by adjustment costs and produces little real investment. Third, it suggests that adjustment costs have a significant effect on the distribution of income shocks between consumption and investment, and hence should play an important role in real business cycle models. Finally, in an open economy that is a large part of world capital markets, domestic adjustment costs would affect the volatility of international capital flows and real exchange rates.

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Figure 1
The Effect of a Temporary Tax Without Adjustment Costs

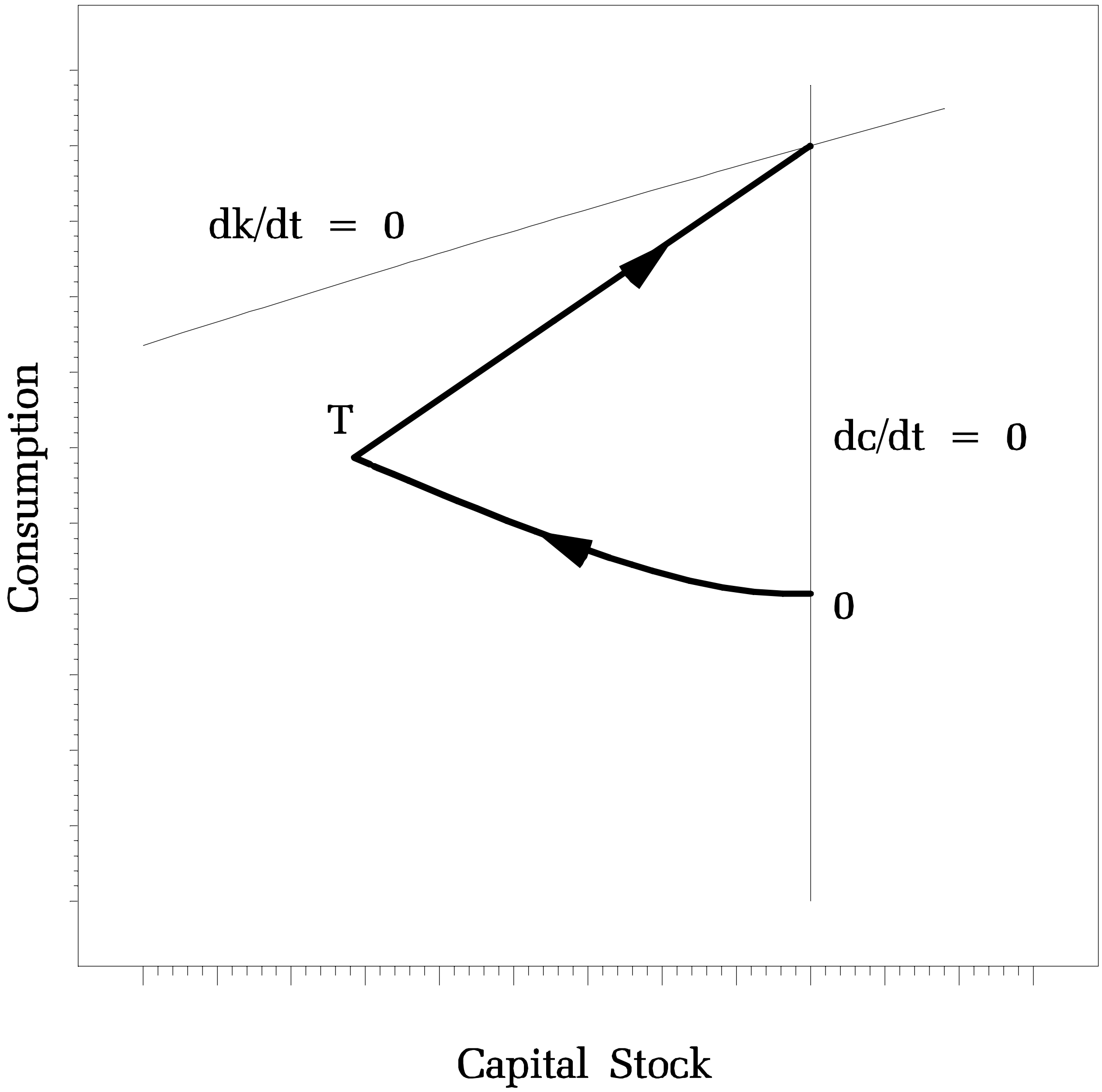


Figure 2
The Effect of a Temporary Tax With Adjustment Costs

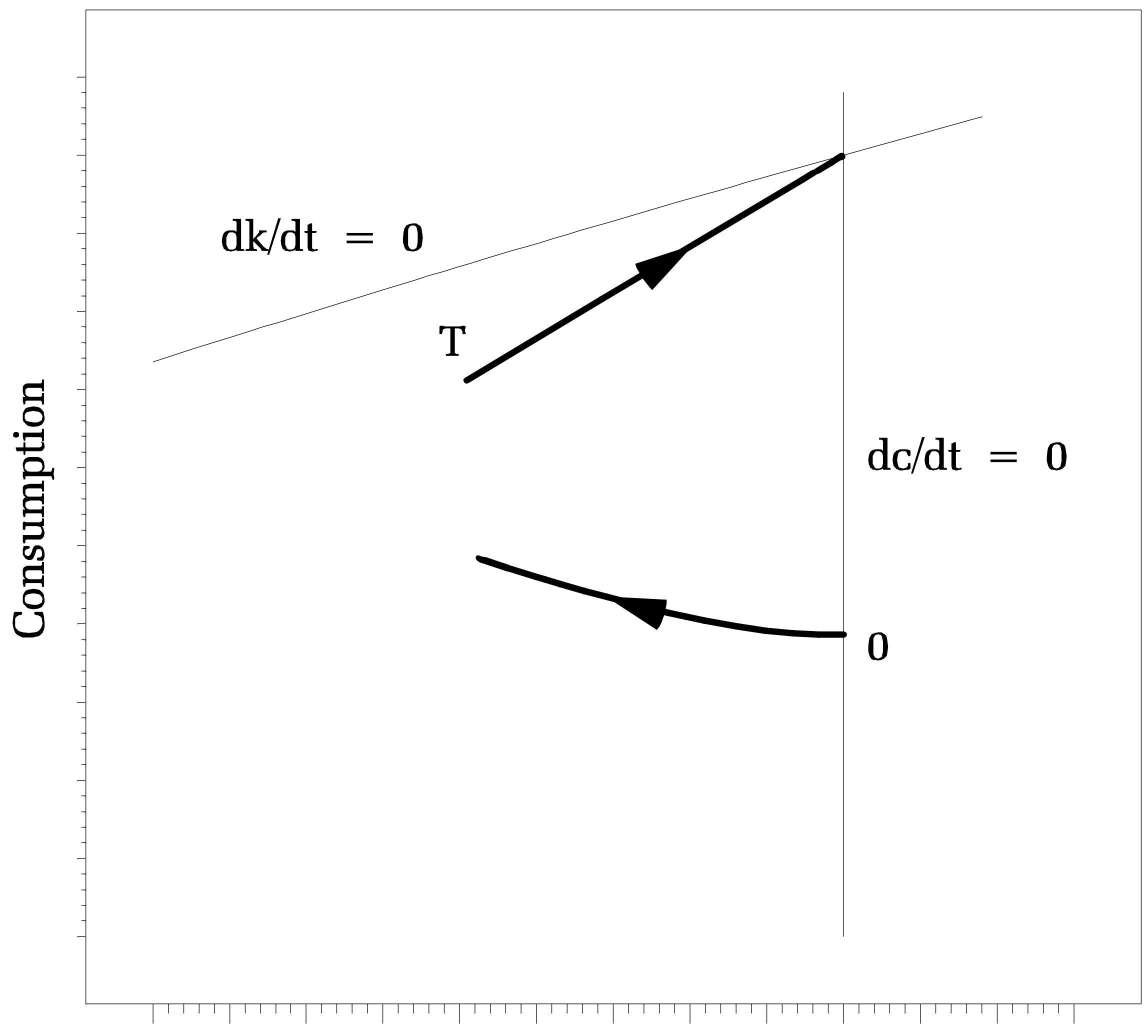


Figure 3
The Effect of the Tax on Consumption

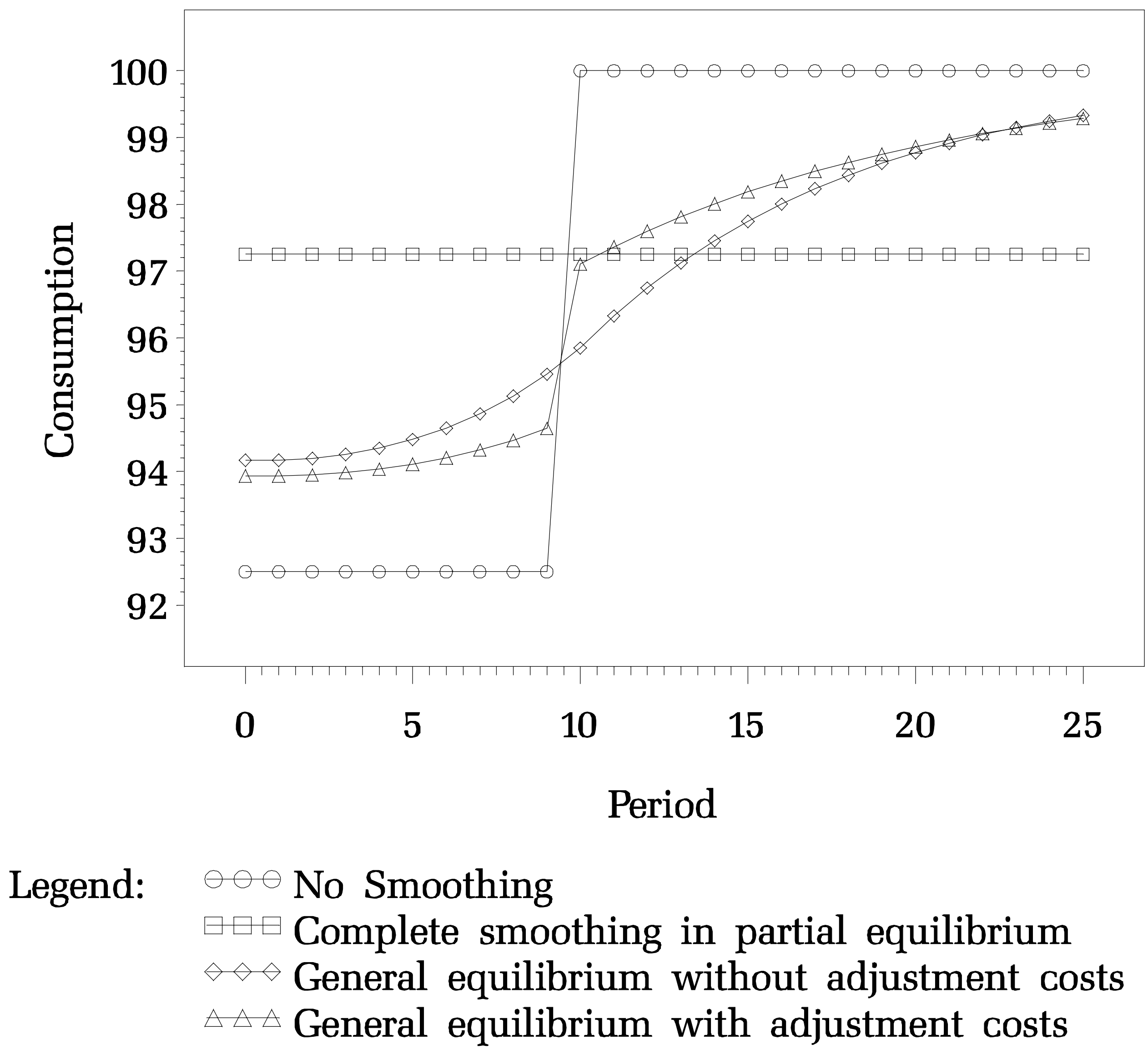


Figure 4
Wealth and the Value of the Firm

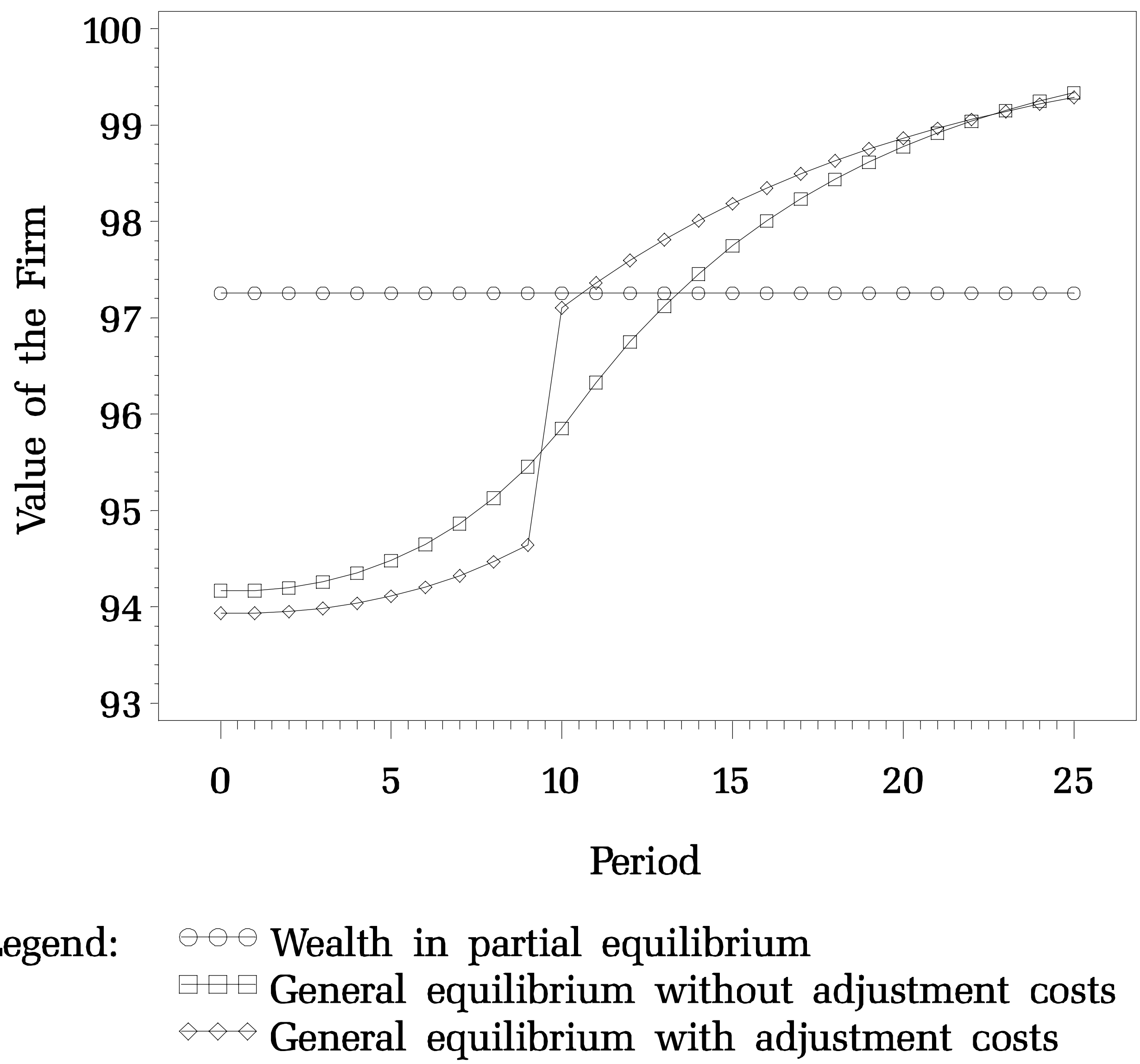


Figure 5
Instantaneous Interest Rate

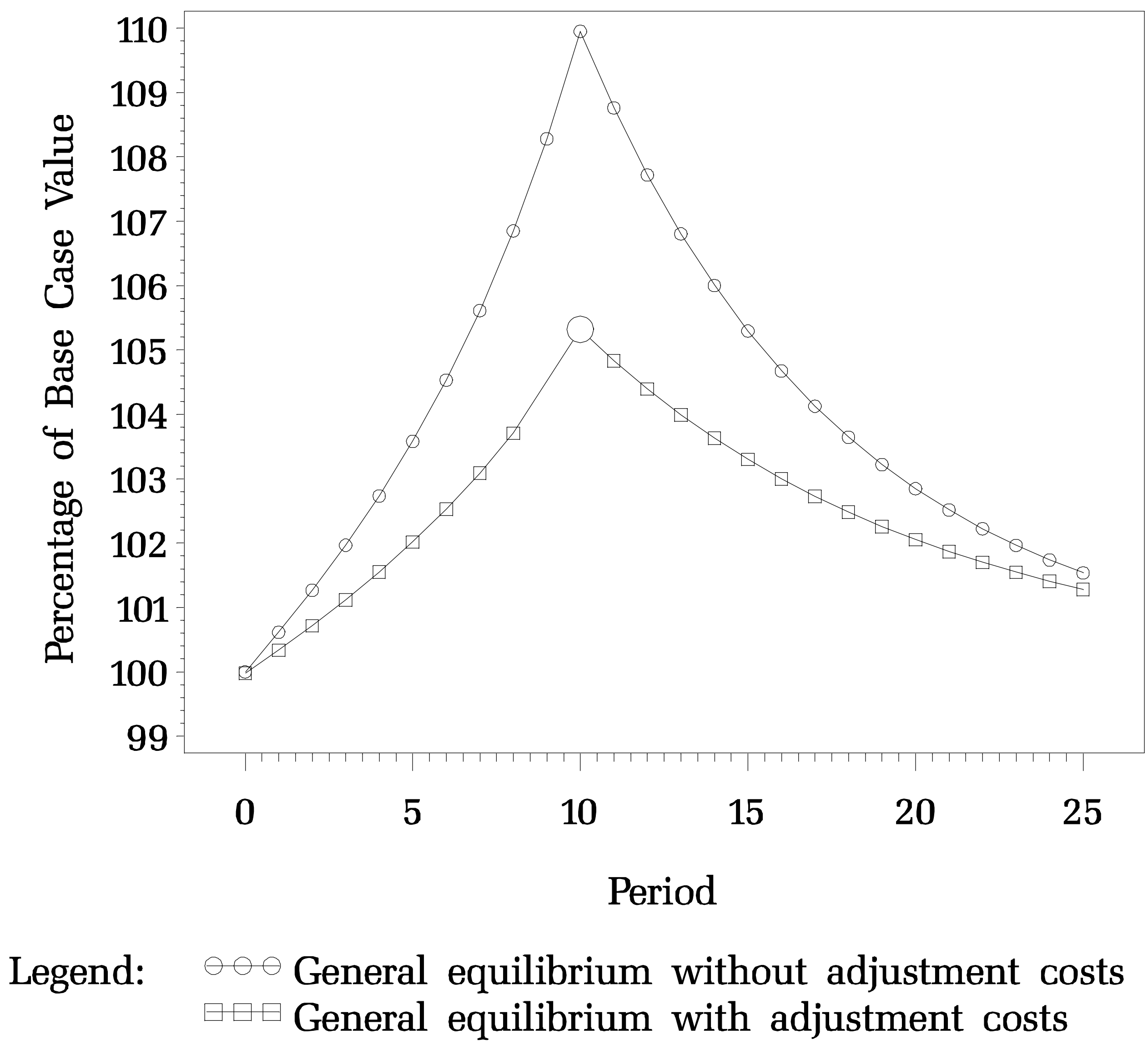


Figure 6
Term Structure of Interest Rates

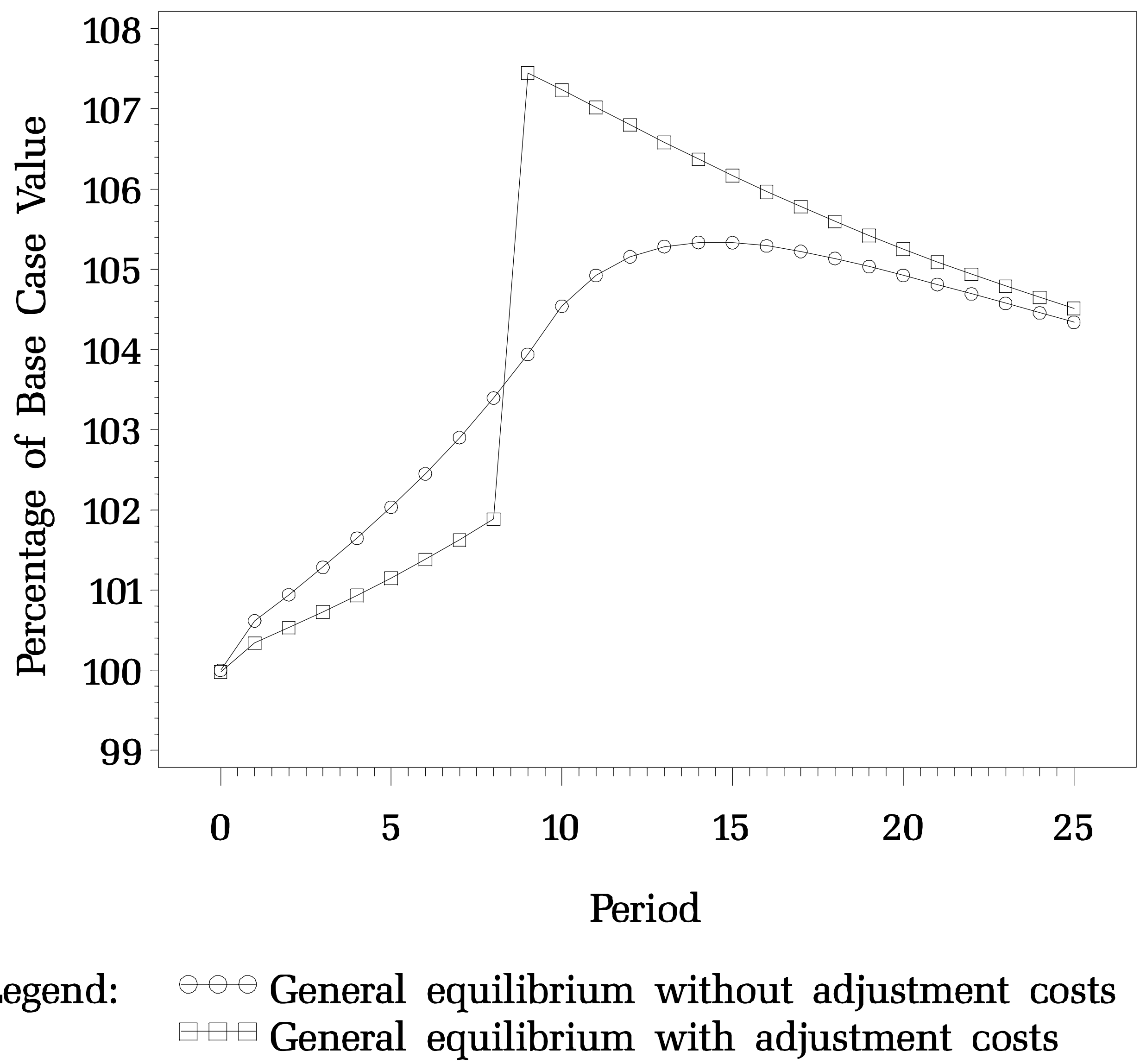
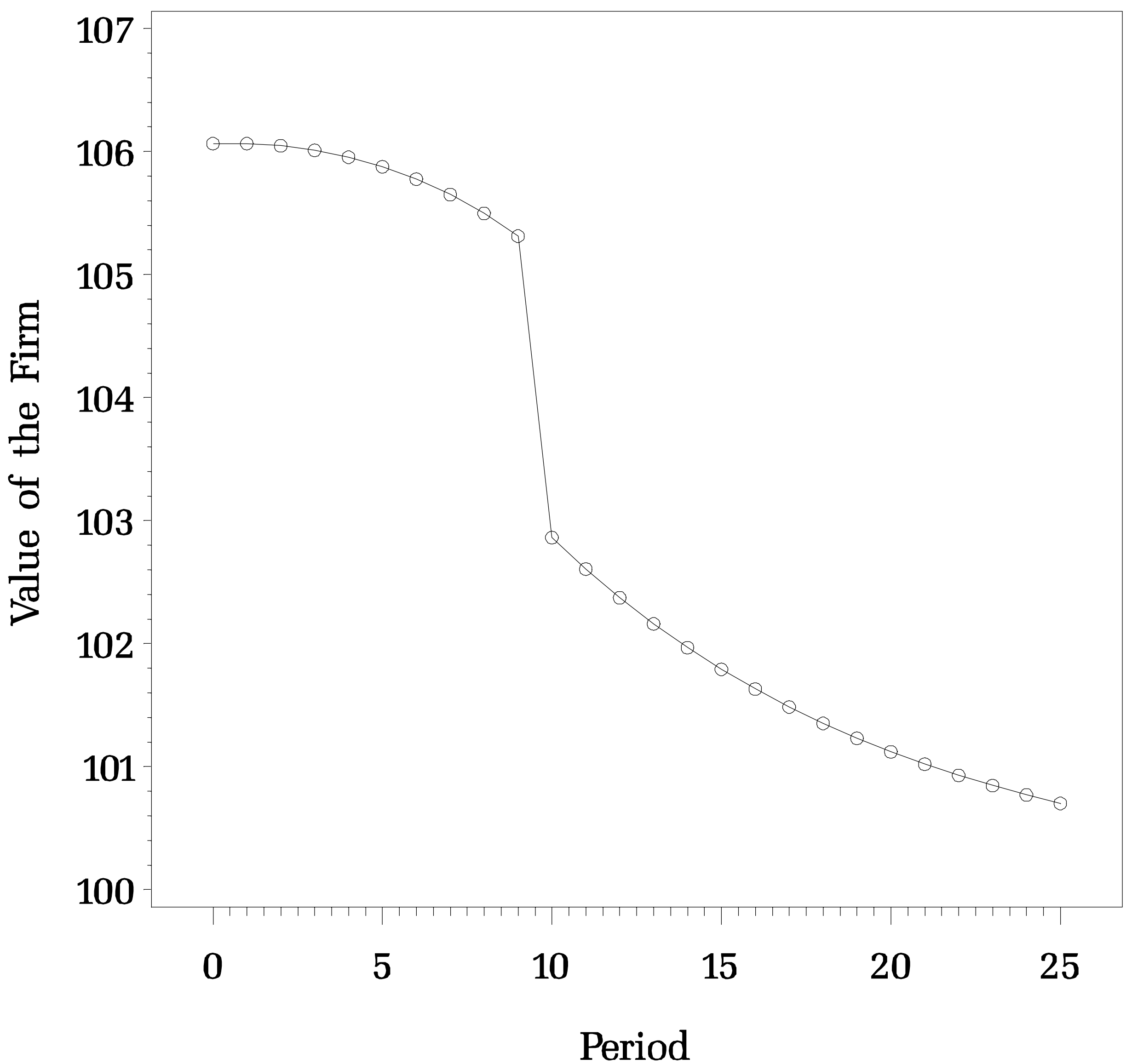


Figure 7
The Value of the Firm Under a Tax Cut



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