working paper 0011

Monetary Shocks, Agency Costs and Business Cycles

by Charles T. Carlstrom and
Timothy S. Fuerst

FEDERAL RESERVE BANK OF CLEVELAND

Working Paper 00-11

Monetary Shocks, Agency Costs and Business Cycles

by Charles T. Carlstrom and Timothy S. Fuerst

Charles T. Carlstrom is at the Federal Reserve Bank of Cleveland.
Timothy S. Fuerst is at Bowling Green State University, Bowling Green, Ohio and is a visiting research associate at the Federal Reserve Bank of Cleveland.
This paper was prepared for the Spring 2000 Carnegie-Rochester Conference on Public Policy.

August 2000

Monetary Shocks, Agency Costs and Business Cycles

by Charles T. Carlstrom and Timothy S. Fuerst

This paper integrates money into a real model of agency costs. Money is introduced by imposing a cash-in-advance constraint on a subset of transactions. The underlying real model is a standard real business cycle model modified to include endogenous agency costs. The chief contribution of the paper is to demonstrate how the monetary transmission mechanism is altered by these endogenous agency costs. In particular, do agency costs amplify and/or propagate monetary shocks?

JEL Classification: E32, E44, E50

Keywords: business fluctuations, financial markets, macroeconomy, monetary policy

Monetary shocks, agency costs and business cycles*

Charles T. Carlstrom[1] and Timothy S. Fuerst[2]

[1]Federal Reserve Bank of Cleveland, Cleveland, OH 44101, USA.
[2]Bowling Green State University, Bowling Green, OH 43403, USA;
and Federal Reserve Bank of Cleveland.

March 15, 2000

Summary: This paper integrates money into a real model of agency costs. Money is introduced by imposing a cash-in-advance constraint on a subset of transactions. The underlying real model is a standard real business cycle model modified to include endogenous agency costs. The chief contribution of the paper is to demonstrate how the monetary transmission mechanism is altered by these endogenous agency costs. In particular, do agency costs amplify and/or propagate monetary shocks?

Keywords and Phrases: Business fluctuations; financial markets and the macroeconomy; monetary policy.

JEL Classification Numbers: E32, E44, E50.

---

* The opinions are solely those of the authors and do not necessarily represent those of the Federal Reserve System. This paper was prepared for the Spring 2000 Carnegie-Rochester Conference on Public Policy.

I. Introduction.

What is the influence of financial factors on business cycle dynamics? This question has a long history in business cycle research (see, for example, the survey by Gertler (1986)). This is ultimately a quantitative question, and one that is difficult to assess empirically because of severe identification problems. In contrast, a recent line of research exemplified by Carlstrom and Fuerst (1996,1997,1998) has explored these issues in dynamic general equilibrium models that can be calibrated to some salient characteristics of the economy and then analyzed quantitatively.[1] The models have the attractive feature that they are otherwise quite similar to the canonical real business cycle (RBC) model so that one can easily see how agency costs alter dynamics in comparison to RBC dynamics. These earlier models were entirely real.[2] The contribution of this paper is to introduce monetary factors into the analysis and explore the role of agency costs in altering the economy's response to a monetary policy shock. In particular, do agency costs amplify and/or propagate monetary shocks?

This paper is essentially the monetary counterpart to Carlstrom and Fuerst (1998). That paper extends the original "investment model" of Carlstrom and Fuerst (1996,1997) in which agency costs arose in the creation of new capital, to an environment in which agency costs are more encompassing and arise in the production of aggregate output

---

[1] These quantitative models build on the seminal theoretical work of Bernanke and Gertler (1989).

[2] Bernanke, Gertler, and Gilchrist (2000) also examine monetary shocks in a theoretical environment closely related to the current paper. Below we will compare and contrast the differing results across the papers. Cooley and Nam (1997), Fuerst (1995) and Gertler (1995) analyzed agency cost models with monetary shocks but these papers utilized the simplifying assumption that entrepreneurs only live for one period so that the effect of agency costs quickly died away.

("output model"). This paper investigates the effect of monetary shocks in both of these models.

The underlying real model is the RBC paradigm. The environment is perturbed by assuming that there are agency costs associated with entrepreneurial production (either investment or output). To finance the deadweight loss of expected bankruptcy entrepreneurial production must sell at a premium over its production cost. In the output model this premium has the interpretation of an endogenous mark-up while in the investment model it is equivalent to an endogenous adjustment cost for investment ("Tobin's Q"). Increases in entrepreneurial production increase both of these mark-ups. In contrast, increases in entrepreneurial net worth lower agency costs and these mark-ups.

The central issue below is the extent to which these time-varying distortions affect the dynamic response to a monetary shock. For example, if net worth is largely constant in the period of the monetary shock, these mark-ups will be procyclical and hence the model will have less amplification on impact than the model without agency costs. Alternatively, if net worth responds instantaneously, monetary shocks may be magnified by a fall in the mark-ups. Questions about persistence are also connected to the behavior of the markups. A markup declining with time (increasing net worth) will lead to increases in persistence.

Money is introduced into the model by imposing a cash-in-advance constraint on household purchases of consumption and investment goods (eg., Cooley and Hansen (1989), Stockman (1981)). Prices are perfectly flexible in the model so that money alters real behavior only via expected inflation effects (although see the discussion below).

We model monetary policy as an interest rate rule. This is the most natural choice for several reasons. First, most central banks conduct policy in terms of directives for the nominal interest rate. Second, as demonstrated by Carlstrom and Fuerst (1995), the nominal interest rate entirely summarizes the distorting behavior of monetary policy in this flexible price environment. Third, Carlstrom and Fuerst (1995) demonstrate that a limited participation monetary model is isomorphic to a flexible price model under the assumption that the central bank is using an interest rate targeting procedure. The limited participation and flexible price models differ only in the money growth process needed to support the real behavior. Finally, in ongoing research, we demonstrate that there exists a comparable isomorphism for models with sticky goods prices. Hence, the monetary environment studied here is relatively general.

The line of research that attempts to quantitatively assess the effect of agency costs in dynamic general equilibrium models is quite young but one key modeling issue naturally arises. Because of agency costs there is a strong tendency for entrepreneurs to accumulate net worth until they no longer need external financing. To keep agency costs operative within the model we need some assumption that will dampen this accumulation. Carlstrom and Fuerst (1996) originally handled this problem by imposing an exogenous death probability, where dying means liquidating your net worth, consuming the proceeds, and exiting the model. Bernanke, Gertler, and Gilchrist (2000) also use this approach. In contrast, Carlstrom and Fuerst (1997,1998) assume that the entrepreneurs optimize their consumption across time but have a higher personal discount rate than do households. In comparison to the “death” assumption, this modeling assumption leads to much more rapid net worth movements in response to shocks. In this paper we explore both possibilities.

The remainder of the paper is organized as follows: The next section describes the model. Section III discusses calibration, while section IV discusses the quantitative ability of the agency cost models to amplify and/or propagate shocks. Section V concludes.

II. The Model.

We start with the behavior of firms. As noted in the introduction, a key issue is the sector in which agency costs arise. We will consider two possibilities: (1) total output (the "output model"), and (2) new capital (the "investment model"). Since the analysis is symmetric, we will present the details for the output model, and then conclude with a brief discussion of the investment model.

Firms

The economy contains a continuum of firms with unit mass. Each firm is owned by an infinitely-lived, risk-neutral entrepreneur (below we will use "entrepreneur" and "firm" interchangeably). Because of informational problems and a limited supply of internal funds, entrepreneurs would like to raise external funds from households but are limited by the premium associated with external finance. The CRS production function of firm i is given by

$$Y_{it} = \omega_{it}F(K_{it},H_{it})$$

where ω_{it} denotes an idiosyncratic productivity disturbance. K_{it} and H_{it} denote the firm-level capital and employment demands, respectively. We assume that ω_{it} is lognormal with a mean of unity, and a standard deviation of σ. Below we will let Φ denote the distribution function and ϕ the density of ω.

The firm uses the funds it receives from external investors (households) as well as its net worth (n_{it}) to finance the firm's input bill. The entrepreneur's net worth or internal funds is the beginning-of-period market value of its accumulated capital stock (z_{it}):

$$n_{it} = z_{it}[(1-\delta) + r_t].$$ [3]

Let w_t and r_t denote the real wage and rental rate, respectively, so that x_{it} denotes the firm's input bill:

$$x_{it} = w_t H_{it} + r_t K_{it},$$

We assume that this input bill must be paid before production commences so that the entrepreneur must partially rely on external finance. After observing the monetary shock but before observing his idiosyncratic shock, ω_{it}, the entreprenuer borrows (x_{it}-n_{it}), the amount of the factor bill not covered by his net worth. After production takes place the entrepreneur privately observes his idiosyncratic shock. This private information creates a moral hazard problem as the entrepreneur may wish to under-report the true value of the shock. External parties can only observe this shock by expending a

[3] To be more precise, net worth must also include an arbitrarily small share of non-capital income so that entrepreneurs that go bankrupt in the previous period have at least some amount of net worth to finance projects in the current period. Since this has no effect on dynamics, we ignore it for simplicity.

monitoring cost that is proportional to the size of the firm's input cost, μx_{it}. This informational structure is the costly-state-verification (CSV) framework of Townsend (1979), Gale and Hellwig (1985), and Williamson (1987).

A standard result of the CSV framework is that the optimal contract between the firm and the external parties is risky debt.[4] The contract is characterized by two values: project size (x_{it}) and a critical ω, denoted by ϖ_{it}. This critical or cut-off ω is the realization that triggers bankruptcy: if $\omega_{it} < \varpi_{it}$ then bankruptcy occurs and the external lenders seize all of the firm's output, while if $\omega_{it} \geq \varpi_{it}$, then the loan is re-paid and the firm keeps the excess output.

Using this notation, it is convenient to define the following functions:

$$f(\varpi) \equiv \int_{\varpi}^{\infty} (\omega - \varpi)\Phi(d\omega) \equiv \int_{\varpi}^{\infty} \omega\Phi(d\omega) - [1-\Phi]\varpi$$

$$g(\varpi) \equiv \int_{0}^{\varpi} \omega\Phi(d\omega) - \Phi\mu + [1-\Phi]\varpi .$$

The functions f and g are the expected shares of the firm's production (after expected bankruptcy costs) that go to the entrepreneur and lender, respectively. Notice that the function f integrates only over values of ω in excess of ϖ, while g integrates over the lower part of the support. The two functions do not sum to one as the contract must cover expected bankruptcy costs: $f(\varpi) + g(\varpi) = 1 - \Phi(\varpi)\mu$.

[4] An important assumption of these CSV models is that both the lender and borrower are risk-neutral. In the current set-up, the entrepreneur is risk-neutral. As for the lender (the typical household), there is risk-neutrality over the period of the contract since (1) idiosyncratic risk is diversified away, and (2) there is no

Since the firm's production function F is CRS these bankruptcy costs imply that the firm's output must sell at a mark-up over production costs, $s_t > 1$. Because of the mark-up, factor prices will be below their marginal products. Equilibrium factor prices are thus given by $w_t = F_L(K_t,L_t)/s_t$, and $r_t = F_K(K_t,L_t)/s_t$, so that $s_t x_t = Y_t$.

The optimal contract between the lender and entrepreneur i is given by the (x_{it},ϖ_{it}) pair that solves:

$$\max s_t x_{it} f(\varpi_{it}) \text{ subject to } s_t x_{it} g(\varpi_{it}) \geq (x_{it}-n_{it}).$$

The constraint arises from the assumption that these are intra-period loans so that the lender must on average recoup exactly his investment. The solution to this maximization problem is defined by

$$s_t = 1/[1-\Phi(\varpi_{it})\mu + \phi(\varpi_{it})\mu f(\varpi_{it})/f'(\varpi_{it})] \quad (1)$$

$$x_{it} = n_{it}\,[1/(1-s_t g(\varpi_{it}))]. \quad (2)$$

A few observations are in order. First, if there are no monitoring costs ($\mu = 0$), then the mark-up disappears, $s_t = 1$. Hence, the agency costs are manifested by an endogenous mark-up over production costs. Second, the contract depends upon the aggregate state of the economy only through the effect of the aggregate state on this mark-up. Third, ϖ_{it} depends *only* upon s_t—it is independent of i. That is, all firms receive the same basic terms on their debt contract. The contracts differ only in size—a firm with

aggregate risk as the contract is intra-period. Hence, the intra-period nature of the loan is useful as it makes the household effectively risk-neutral.

larger net worth simply receives a proportionately larger loan, and thus implements a larger project size x_{it}. This aggregation result is a natural implication of our linearity assumptions: both the monitoring technology and the firm's production function are constant returns to scale. Because of this aggregation, firm-specific subscripts are henceforth dropped.

The existence of agency costs and the resulting premium to internal funds implies that there is a strong tendency for entrepreneurs to accumulate enough net worth so that they are eventually self-financed and agency costs effectively disappear. To see this, consider the effect of the entrepreneur foregoing one unit of consumption. The entrepreneur leverages this extra unit of net worth into a project of size [1/(1-sg)]. The firm keeps share f of this output that is valued at s which gives it [sf/(1-sg)] extra units of net worth at the end of the period. Moral hazard implies that this additional return must be greater than unity.[5] To prevent entreprenuers from becoming entirely self-financing, entrepreneurial behavior must be modified to force them to consume part of their net worth. As noted in the introduction, there are (at least) two logical possibilities:

Euler Equation Entrepreneurs:

The most natural choice is to assume that entrepreneurs discount the future at a higher rate than do households, $\beta\gamma < \beta$. This then implies the following Euler equation for entrepreneurial consumption:

---

[5] Substituting the constraint (2) back into the maximization problem, we have that the optimal contract maximizes [sf/(1-sg)]n. The entrepreneur will invest his resources only if the term in brackets exceeds unity.

$$1 = E_t \beta\gamma[(1-\delta) + r_{t+1}]\{s_{t+1} f(\varpi_{t+1})/[1-s_{t+1} g(\varpi_{t+1})]\}. \qquad (3)$$

The first term in brackets is the market return on capital accumulation. The second term in braces is the additional return on internal funds which as discussed must be greater than unity. We then choose γ to offset this return so that in the steady-state the entrepreneurs partly rely on external finance.

Permanent Income Entrepreneurs:

The obvious alternative to the Euler equation approach to entrepreneurial behavior is to assume that some entrepreneurs die each period, where death entails consuming your accumulated net worth and exiting the economy.[6] The population is held steady by the birth of a new entrepreneur for each dying one. If a constant fraction γ die each period, then this is equivalent to entrepreneurs being permanent income consumers since they are consuming a constant fraction γ of their (end-of-period) wealth each period. Entrepreneurial consumption (e_t) and capital accumulation are thus given by

$$e_t = \gamma F(K_t, L_t) f(\varpi_t) \qquad (4)$$

$$z_{t+1} = (1-\gamma) F(K_t, L_t) f(\varpi_t) \qquad (5)$$

As in the earlier case, we choose γ to ensure that in the steady-state the entrepreneurs partly rely on external finance.

---

[6] One can think of entrepreneurs learning at the beginning of the period whether or not they will die at the end of the period. Those receiving the bad news would therefore have an incentive to consume their assets just before their death.

These differing assumptions on entrepreneurial consumption/savings behavior will have important implications below. Under the Euler equation approach, net worth responds much more sharply to shocks as the entrepreneur changes his savings behavior in response to changes in the return to internal funds. This return is determined by the size of the mark-up, so that the elasticity of entrepreneurial savings behavior to the mark-up will be quite high. Recall that entrepreneurs are risk neutral so that with constant prices this elasticity would be infinite. Thus their savings increases until the rental rate of capital falls and (3) is satisfied.

In contrast, when a constant fraction of entrepreneurs die each period, net worth responds passively and thus much more slowly to changes in the internal return. This sluggishness is of course symmetric, so that if net worth is pushed above normal, it will tend to stay there and only decline at a rate determined by γ. As noted above, the model with constant death is equivalent to assuming that entrepreneurs are permanent income consumers. Our Euler equation and permanent income models are thus two extremes of entrepreneur behavior. In the former they are risk neutral while the latter is roughly consistent with them being extremely risk-averse.[7]

Households

Households are infinitely-lived with preferences over consumption (c_t) and leisure ($1-L_t$) given by

$$\sum_{t=0}^{\infty} \beta^t U(c_t, 1-L_t).$$

[7] Note that if we directly assumed risk-averse entrepreneurs then the debt contract may not be optimal.

The household supplies labor and rents its accumulated capital stock (k_t) to firms at the market-clearing real wage (w_t) and rental rate (r_t). The household budget constraint is given by:

$$M_{t+1}/P_t + c_t + [k_{t+1} - (1-\delta)k_t] = w_t L_t + r_t k_t + M_t/P_t + (G_t-1)M^s_t/ P_t ,$$

where M_t denotes cash held at the beginning of time-t, P_t denotes the price level, and $(G_t-1)M^s_t$ denotes a helicopter drop of new money into the economy ($G_t > \beta$ is the gross money growth rate). Capital depreciates at the rate δ. The household's purchases of consumption and investment are subject to the following CIA constraint:

$$P_t\{c_t + [k_{t+1} - (1-\delta)k_t]\} \leq M_t + (G_t-1)M^s_t. \qquad (6)$$

We are now ready to define a competitive equilibrium for the output model.

Competitive Equilibrium in the Output Model:

A competitive equilibrium of the output model is defined by the first order conditions for the household and the financial contract.

$$U_l(t)/U_c(t) = F_L(K_t,L_t)/s_tR_t \qquad (7)$$

$$U_c(t) = E_t\beta[U_c(t+1)/][(1-\delta) + F_K(K_{t+1},L_{t+1})/R_{t+1}s_{t+1}] \qquad (8)$$

$$s_t[1-\Phi(\varpi_t)\mu + \phi(\varpi_t)\mu f(\varpi_t)/f'(\varpi_t)] = 1 \qquad (9)$$

$$F(K_t,L_t)/s_t = n_t /[1-s_t g(\varpi_t)] \quad (10)$$

$$n_t = z_t[(1-\delta) + F_K(K_t,L_t)/s_t] \quad (11)$$

$$z_{t+1} = F(K_t,L_t)f(\varpi_t) - e_t, \quad (12)$$

$$c_t + e_t + K_{t+1} - (1-\delta) K_t = F(K_t,L_t)[1-\Phi(\varpi_t)\mu], \quad (13)$$

with either (3) or (4) defining entrepreneurial consumption. R_t denotes the gross nominal interest rate on a one-period riskless bond.

The model consists of the familiar Euler equations from a monetized RBC model (7)-(8), along with the financial relationships that determine the endogenous mark-up as a function of net worth and aggregate output (9)-(10). Since cash is required to facilitate the purchases of all goods (both consumption and investment), the nominal interest rate distorts both the employment (7) and savings (8) decisions.

Competitive Equilibrium in the Investment Model:

The fundamental difference between the investment model and the output model is that in the former entrepreneurs are involved in the creation of new capital. In particular, an input of x_t consumption goods yields ωx_t new capital goods. To cover expected bankruptcy costs this capital good sells at a premium, q_t, over its cost of production. Since consumption is our numeraire, q_t denotes the cost of new capital (Tobin's Q). The remaining details of the model follow symmetrically from the output model. With monitoring costs on investment, the market-clearing conditions are now given by:

$$c_t + e_t + I_t = F(K_t, L_t) \tag{14}$$

$$K_{t+1} = (1-\delta) K_t + I_t[1-\Phi(\varpi_t)\mu]. \tag{15}$$

Since agency costs only arise on investment, factor payments are now equal to their marginal products ($s_t = 1$). The cost of capital (q_t), however, will now enter into the financial contract and the intertemporal optimization conditions. Equilibrium in the investment model is thus characterized by the market-clearing conditions and the following Euler equations:

$$U_l(t)/U_c(t) = F_L(K_t, L_t)/R_t \tag{16}$$

$$q_t U_c(t) = E_t \beta U_c(t+1)[q_{t+1}(1-\delta) + F_K(K_{t+1}, L_{t+1})/R_{t+1}] \tag{17}$$

$$q_t[1-\Phi(\varpi_t)\mu + \phi(\varpi_t)\mu f(\varpi_t)/f'(\varpi_t)] = 1 \tag{18}$$

$$I_t = n_t / [1-q_t g(\varpi_t)] \tag{19}$$

$$n_t = z_t[q_t(1\text{-}\delta) + F_K(K_t,L_t)] \tag{20}$$

$$q_t z_{t+1} = q_t I_t f(\varpi_t) - e_t \tag{21}$$

and entrepreneurial consumption is given by either

$$q_t = E_t\beta\gamma[q_{t+1}(1\text{-}\delta) + F_K(K_{t+1},L_{t+1})]\{q_{t+1}f(\varpi_{t+1})/[1\text{-}q_{t+1}g(\varpi_{t+1})]\}, \tag{22}$$

$$e_t = \gamma q_t I_t f(\varpi_t). \tag{23}$$

The investment model is thus symmetric with the output model, consisting of the familiar Euler equations (16)-(17) along with the financial contract. This contract determines the endogenous cost of capital as a function of net worth and aggregate investment. Similarly, the results of the contracting problem yield identical relationships for the cutoff bankruptcy rate, ϖ_t and between the markup in the output model and Tobin's Q in the investment model. Essentially, the differences in the business cycle dynamics of the output and investment agency costs models compared to the monetized RBC model are determined by the endogenous movements in their respective markups.

Monetary policy:

Monetary policy is modeled as an interest rate rule:

$$\tilde{R}_t = \rho \tilde{R}_{t-1} + \varepsilon_t$$

where tildes denote log-deviations from the steady-state, ρ is the autocorrelation coefficient, and ε_t is the nominal interest rate shock.

Note that only the nominal interest rate enters into the equilibrium Euler equations. Given that our focus is on real behavior, the behavior of the price level and money supply process that support this real behavior is absent from our definitions of competitive equilibrium. It is given by the binding CIA constraint (6) and the traditional Fisher equation:

$$\frac{U_c(t)}{P_t} = R_t \, E_t \left[\frac{\beta U_c(t+1)}{P_{t+1}} \right]. \qquad (24)$$

Note also that introducing limited participation would not change the equilibrium real quantities since only the above Fisher equation and thus only nominal quantities are affected.

Using a public finance viewpoint, the nominal interest rate can be interpreted as a distortionary tax on labor (equations 7 and 16) and capital income (equations 8 and 17) with the proceeds being redistributed to the household in a lump-sum fashion. Hence, a persistent decline in the nominal interest rate is isomorphic to a persistent cut in distortionary income taxes. Since these movements entail pure substitution effects (there are no income effects as the taxes are rebated to the household), we should anticipate sharp responses of real activity to these shocks.

Similarly, notice that $1/R_t$ enters the household's employment and savings choice in a manner exactly analogous to the familiar shock to total factor productivity.[8] Hence, changes in $1/R_t$ will be equivalent to a technology shock except the interest rate shock will have no income effects. Because of this absence of income effects, the initial impact of an interest rate shock will be larger than for a similarly sized technology shock. The basic dynamics, however, are the same. This isomorphism exists because the CIA constraint was placed on both consumption and investment, and not just consumption. This equivalence exists for the model with or without adjustment costs.

III. Calibration.

The model is parameterized at the non-stochastic steady state to roughly match empirical counterparts.

Household preferences are given by $U(c,1-L) = \ln(c) + \nu(1-L)$, where the constant ν is chosen so that $L = .3$. We set $\beta = .99$, implying a 4% annual riskless rate of return.

The firm's production technology is Cobb-Douglas with a capital coefficient of .36. The capital deprecation rate is $\delta = .02$. As noted earlier, the idiosyncratic shock is i.i.d. and lognormal, with a mean of unity and a standard deviation of σ.

Monetary policy is given by a steady-state annual nominal rate of 8%, and an autocorrelation coefficient of $\rho = .9$. This latter value is consistent with VAR evidence on the persistence of a nominal interest rate shock.

[8] In a model with sticky goods prices, marginal cost would create a comparable distortion. It is this symmetry that generates the isomorphism mentioned in the introduction.

We are thus left with three parameters: μ, σ, and γ. There is considerable controversy within the literature on the value of μ, ranging from Warner's (1977) estimate of 4%, to Alderson and Betker's (1995) estimate of 36%. For this study, we set $\mu = .15$, a choice roughly in the middle of this range.[9] We treat σ and γ as unobservables, and choose them indirectly to match two measures of risk: an annual risk premium of 187 basis points (the average spread between the prime and commercial paper rates), and a quarterly default rate of .974% (from the Dun and Bradstreet data set). Given ϖ, the interest rate on these intra-period loans is defined by $(1+r_L) = s\varpi x/(x-n)$ for the output model, and $(1+r_L) = q\varpi x/(x-n)$ for the investment model. The bankruptcy rate is $\Phi(\varpi)$. Hence, we choose σ and γ to match $r_L = 1.87\%/4$, and $\Phi(\varpi) = .974\%$.

IV. Simulations.

We use our simulations to highlight the issues raised in the introduction. Do agency costs alter the economy's response to a monetary shock? Is there amplification? What about propagation?

Below we will use the case of $\mu = 0$ (and a zero risk premium) as our benchmark. In both the output and investment model (and with either assumption on entrepreneurial consumption), the model with $\mu = 0$ implies that entrepreneurial net worth and consumption are both zero. Hence, the model without monitoring costs collapses to a monetized RBC model similar to that studied by Cooley and Hansen (1989). An

---

[9] The exact choice of μ does not affect the results that dramatically. The calibration of the risk premium has a much larger affect.

important difference is that in the present context investment expenditures are also subject to the CIA constraint. We will henceforth refer to this $\mu = 0$ model as the benchmark model.

Monetary Policy Shocks in the Output Model:

Figure 1 presents the benchmark model's and output model's response to a one percentage point decline (with $\rho = .9$) in the nominal interest rate. The results are presented for both assumptions about entrepreneurial savings behavior. It is helpful to begin by reviewing the benchmark dynamics. Since the nominal rate acts like a tax on factor income, the decline in the nominal rate stimulates work effort and capital accumulation. The effect is quite large with an initial impact on output of 1.67%. These effects are quite persistent since they deteriorate at rate ρ.

Turning to the output model, a key feature in the simulation is the endogenous behavior of the mark-up. In particular, note from the employment and capital accumulation equations (7)-(8), that if the mark-up (s_t) is held fixed at its steady-state value, then the dynamics of the output model will be the same as the dynamics of the benchmark model. The impact of agency costs thus arises in the endogenous behavior of the mark-up.

Although this is a general equilibrium environment, it is helpful to think of equations (9)-(10) as the partial equilibrium determinant of the mark-up. Equations (9) and (10) imply that the project size (x=Y/s) is proportional to the level of net worth, where the proportionality factor is solely a function of the mark-up. Hence, the mark-up will remain constant (and the agency cost model will mimic the benchmark's dynamics) if and only if net worth responds by the same percentage as the desired project size and hence output. The mark-up will rise (fall) if net worth increases by less (more) than does output.

The principle effect of agency costs is to delay the economy's response to the monetary shock. Since net worth consists of previously accumulated capital, it is essentially fixed in the period of the shock, so that the output rises by more than does net worth. Hence, the mark-up must rise on impact.[10] This increase in the mark-up dampens the economy's initial response to the monetary shock. Under either assumption on entrepreneurial savings, the initial output response is 1.4%.

In the period after the initial shock, net worth rises in response to the higher demand for production. With Euler equation entrepreneurs, (3), the higher return on internal funds (which is proportional to the mark-up) encourages entrepreneurs to sharply increase their savings implying a surge in aggregate investment. In fact, the increase in entrepreneurial savings is so dramatic that the next period's mark-up moves below steady state. Since capital is below steady-state, the marginal product of capital is above steady-state implying that entrepreneurs will accumulate capital until the mark-up is driven below steady-state (see equation 3). The mark-up or the implicit output tax then increases back to its steady state. Thus once output peaks in the period following the shock there

[10] We have experimented with adding capital adjustment costs to the output model so that there is an asset price effect present also. For plausible calibrations, this had little effect on the simulations as entrepreneurs hold a relatively small fraction of the steady-state capital stock.

will be less persistence in the output model with Euler equation entrepreneurs than in the benchmark model.

With permanent income entrepreneurs net worth responds more slowly to changes in the mark-up. The higher mark-up increases the share of output that is paid out to the entrepreneur. He then saves a constant fraction of this income. The effect of this is that the mark-up is driven below steady-state only after six quarters. The declining mark-up implies that there will be more persistence compared to the benchmark model.

In summary, does the output model produce amplification? In terms of aggregate production, the answer is no, the procyclical mark-up necessarily dampens the initial output response. What about propagation? It is unclear how to measure persistence. While the half-life seems like a natural yardstick, the difficulty arises in the starting point. This question is of particular importance in a model that generates a delayed or hump-shaped output response. Should we measure the half-life from the initial impact? Or from the peak impact? Here we choose the former.

Given this definition, the agency cost model enhances persistence. For the benchmark RBC model, the initial output response is 1.67%, with a half-life of 8 quarters. In the agency cost model, the initial output response is 1.4%, with a half-life of 10 quarters. Interestingly, this half-life is unaffected by the assumption on entrepreneurial savings behavior. The increased persistence in the Euler equation model, however, is entirely due to the one-period delay or hump in output.

Monetary Policy Shocks in the Investment Model:

Figure 2 presents the benchmark model's and investment model's response to a one percentage point decline (with $\rho = .9$) in the nominal interest rate. The benchmark dynamics are of course the same as in Figure 1. However, the investment model's behavior generates some key quantitative differences from the output model.

As with the output model, a key feature is the endogenous behavior of the mark-up or "Tobin's Q". From equations (18)-(19), if q_t is held fixed at its steady-state value, then the dynamics of the investment model will be the same as those of the benchmark model. The impact of agency costs thus arises in the endogenous behavior of this mark-up. Viewing equation (19) as the determinant of this mark-up, we note that the mark-up will remain constant (and hence, the dynamics of the investment model will replicate benchmark dynamics) if and only if net worth and investment spending respond by the same percentage.

The previous statement is key in understanding the difference between the output model and the investment model. The mark-up in the investment model (Tobin's Q) responds much more sharply to a monetary shock than the mark-up in the investment model. This is for two reasons. First, and most importantly, investment (the project size in the investment model) responds much more sharply to a monetary shock than does output (the project size = Y/s). The second reason is that increases in the mark-up directly dampen the project size (Y/s) in the output model.

The major difference between the output and investment models occurs with Euler-equation entrepreneurs. In the output model entrepreneurial savings rises so that the mark-up immediately moves back to and actually over-shoots the steady state. In the investment model the mark-up (Tobin's Q) takes much longer to return to steady state.

This occurs as the anticipated decline in this mark-up (an implicit investment tax) deters greater entrepreneurial savings. Hence the initial increase in Tobin's Q is much sharper and longer-lived than the corresponding movement of the mark-up in the output model.

In the investment model this decline in Tobin's Q produces a hump-shaped investment response which in turn produces the peculiar reverse-hump for household consumption. The resulting income effects then produce the resulting hump-shape profiles for labor and output. Carlstrom and Fuerst (1997) note how this sharp hump-shape allows the model to match the positive autocorrelation of GDP growth rates present in the data (a fact that the benchmark model comes nowhere close to matching). In contrast, with permanent income entrepreneurs there is no hump in real behavior.

A well-known problem in theoretical monetary models is the difficulty of generating the liquidity effect of an increase in the money supply growth rate, ie., the VAR evidence suggests that there is a persistent decline in the nominal interest rate in response to an increase in the money growth rate. This VAR evidence also suggests that consumption and other real aggregates display a hump-shaped response to a monetary shock. The Fisher equation, however, suggests a problem. If consumption is hump-shaped in response to a monetary shock, then the real rate must rise on impact. But then how can the nominal rate fall?

The investment model with Euler-equation entrepreneurs suggests an interesting possibility. Note that aggregate consumption is hump-shaped, as in the VAR evidence. However, household behavior is what prices bonds, and household consumption starts high and then falls, implying a decline in the real rate of interest. Hence, we have the tantalizing possibility that the implicit heterogeneity in this agency cost framework may be a step towards understanding the liquidity effect puzzles provided by the VAR evidence.

In closing, does the investment model produce amplification? In terms of aggregate production, the answer is no, the procyclical movement in the cost of capital necessarily dampens the initial output response. What about propagation? For the benchmark model, the initial output response is 1.67%, with a half-life of 8 quarters. In the investment model, the initial output response is 1.1%, with a half-life of 14 quarters. Notice that the investment model nearly doubles the half-life of output! As before, this half-life is unaffected by the assumption on entrepreneurial savings behavior. There is, however, more persistence in the very short-term (a longer "3/4 life") with the Euler equation model (versus the permanent income model) because of the hump associated with the sharp decline in the mark-up in the periods immediately following the shock. Consequently there is less persistence afterwards (or a shorter ¼ life) in the Euler equation model. Given that VAR evidence is much more precisely estimated for the periods immediately following a shock, the Euler equation investment model does a better job of generating persistence.

Adding a Wealth Shock to the Investment Model:

In this section, we explore a different type of monetary shock that is inspired by Irving Fisher's debt-deflation explanation for the Great Depression. In Fisher's view the contraction was particularly severe because of the wealth redistribution from borrowers (entrepreneurs) to lenders (households) induced by the unexpected decline in the price level. Here we consider the converse—an unexpected inflation. The previous makes clear that the investment model is the more interesting of the two possibilities, so in this section we will limit our analysis to the investment model.

This unexpected price movement is a natural experiment under the assumed interest-rate operating procedure. The interest rate policy implies that there is nominal indeterminacy, ie., we can add i.i.d. sunspot movements in the money growth process (and hence the price level) and still support the interest rate target. If all contracts are indexed to the price level then this indeterminacy is entirely nominal. This will not be the case if the loan contract is denominated in nominal terms and is not indexed.

Let us assume that after signing the contract there is an unexpected increase in money or the price level. Since the contract is nonindexed, this effectively lowers the real debt owed to the household, and thus corresponds to a one-time increase in entrepreneurial net worth. To be specific, the loan size is (I-n). For the calibration used above, a price movement of 1% will increase the entrepreneur's end-of-period capital holdings (z) by (.01)(I-n)/z = 1.42%.

Figure 3 presents the response of the economy to such a price shock. We do not present the benchmark model as the absence of agency costs (and thus the presence of the Modigliani-Miller theorem) implies that this small wealth shock is essentially irrelevant.

The wealth shock drives down Tobin's Q in both the Euler-equation and permanent-income models. This decline then spurs investment spending and thus employment and output in both models. Household consumption falls as the household takes advantage of the low cost of capital goods to accumulate more capital.

The difference in the two views of entrepreneurial savings is in persistence. In the case of the Euler-equation entrepreneurs, the fall in Tobin's Q implies that the return to internal funds has also fallen. Hence, the entrepreneur radically lowers savings and increases consumption. This leads to a fairly quick return of Q to the steady-state. This rapid movement upward in Q leads to a greater initial effect on household activity (eg., labor) as the household realizes that capital goods are only temporarily cheap.

In sharp contrast, in the permanent-income model net worth returns ever so slowly to steady-state, implying a long-lived decline in Q. The household responds by increasing labor by less initially, but labor remains above steady-state for a much longer time period afterwards.

Amplification?

A consistent conclusion in the earlier analysis of interest rate shocks is that the existence of agency costs does not amplify the effect of a monetary shock but actually dampens the economy's initial response to the shock. The central reason for this dampening is that net worth does not move by much in the period of the shock as it consists of previously accumulated capital. Net worth does rise because of the higher rental rate and higher Tobin's Q, but these effects are much too small to generate a wealth movement large enough to deliver amplification.

It is thus tempting to integrate the exogenous price shock with the interest rate shock of the earlier section. However, Figure 3 makes it clear that we need a fairly large wealth effect to generate any sort of amplification. The 1% price shock induced a .16% output response in the Euler-equation model, .11% output response in the permanent-income model. Inspection of Figure 2 then implies that we need a price shock in excess of 4-5% to generate amplification relative to the benchmark model. This seems too large to be plausible. The essential problem is that the loan contract is relatively small (9.7% of aggregate output), so that there needs to be a large price shock to generate a significant wealth movement.

In a similar modeling environment, Bernanke, Gertler, and Gilchrist (2000) report amplification of an interest rate shock relative to the corresponding benchmark model. In their model, entrepreneurs store the capital stock intertemporally, and this storage technology is subject to agency cost problems. They assume that the loan contract on this storage technology is not indexed to interest rate shocks that arise in the next period. Since entrepreneurs hold the *entire* capital stock intertemporally, the loan contract is enormous—about six times the size of aggregate output. Hence, there is an enormous wealth effect that results from an interest rate shock. While this modeling device delivers amplification, the assumption of such a large contract is a bit heroic.[11]

[11] Bernanke, Gertler, and Gilchrist (2000) also suggest that their model delivers persistence. This arises because of their differing definition of persistence: "With the financial accelerator included, the initial response of output to a given monetary impulse is about 50% greater….Further, the persistence of the real effects is substantially greater in the presence of credit market factors, eg., relative to trend, output and investment in the model with credit market imperfections after about four quarters are about where they are in the baseline model after only two quarters." (page 1370). Under this definition, amplification automatically delivers persistence. Using the ½ life definition, the model does not deliver persistence.

V. Conclusion.

The chief contribution of this paper is to integrate monetary shocks into the recent class of dynamic general equilibrium models that explicitly incorporate agency costs into the environment. This integration leads to several conclusions.

First, the investment model seems much more interesting than does the output model. This is somewhat surprising since in the output model a larger share of the economy is subject to agency costs. However, investment is much more volatile than is investment, so that exposing this smaller sector of the economy to agency costs delivers much more pronounced effects (compare Figure 1 with Figure 2).

Second, under either Euler-equation or permanent-income entrepreneurs, the investment model delivers substantial propagation to a monetary shock. The chief difference is in the time frame of this propagation. In the Euler-equation model, the propagation comes from the initial hump-shaped dynamics. In the permanent-income model, there is no hump, but the movement back to the steady-state is slowed. Since the VAR evidence is more precisely estimated for the short horizon, the Euler-equation model seems to be a better choice.

Third, and finally, the agency cost model does not deliver amplification. The essential reason is that the endogenous wealth effects that are needed to amplify shocks are much too small. This problem can be "remedied" by imposing non-indexed contracts, but even in this case the size of the wealth shock must be implausibly large to generate amplification. A chief issue in future work is the search for more plausible endogenous wealth shocks.

References

Alderson, Michael J., and Brian L. Betker, "Liquidation Costs and Capital Structure," Mimeo, St. Louis University, 1995.

Bernanke, Ben, and Mark Gertler, "Agency Costs, Net Worth and Business Fluctuations," *American Economic Review* (73), June 1983, 257-276.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist, "The Financial Accelerator in a Quantitative Business Cycle Framework," in *Handbook of Macroeconomics Volume 1C,* edited by John Taylor and Michael Woodford (Elsevier: 2000).

Carlstrom, Charles T., and Timothy S. Fuerst, "Agency Costs, Net Worth and Business Fluctuations: A Computable General Equilibrium Analysis," *Federal Reserve Bank of Cleveland Working Paper 96-02,* May 1996.

Carlstrom, Charles T., and Timothy S. Fuerst, "Agency Costs, Net Worth and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review,* December 1997, 87(5), 893-910.

Carlstrom, Charles T., and Timothy S. Fuerst, "Agency Costs and Business Cycles," *Economic Theory,* November 1998, 12, 583-597.

Carlstrom, Charles T., and Timothy S. Fuerst, "Interest Rate Rules vs. Money Growth Rules: A Welfare Comparison in a Cash-in-Advance Economy," *Journal of Monetary Economics* 36 (1995), 247-267.

Cooley, Thomas, and Kwanghee Nam, "Asymmetric Information, Financial Intermediation, and Business Cycles " *Economic Theory,* November 1998, 12, 599-620.

Cooley, Thomas, and Gary Hansen, "The Inflation Tax in a Real Business Cycle Model," *American Economic Review* 79, 1989, 733-748.

Cooley, Thomas and Vincenzo Quadrini, "Monetary Policy and the Financial Decisions of Firms," University of Rochester Working Paper, 1999.

Fuerst, Timothy S., "Monetary and Financial Interactions in the Business Cycle," *Journal of Money, Credit and Banking* (27), 1995, 1321-1338.

Gale, Douglas, and Martin Hellwig, "Incentive-Compatible Debt Contracts I: The One-Period Problem," *Review of Economic Studies* (52), 1985, 647-664.

Gertler, Mark, "Comment on Money and Financial Interactions in the Business Cycle," *Journal of Money, Credit and Banking* (27), 1995, 1342-1353.

Stockman, Alan, "Anticipated Inflation and the Capital Stock in a Cash-in-Advance Economy," *Journal of Monetary Economics* 8, 1981, 387-393.

Townsend, Robert M., "Optimal Contracts and Competitive Markets with Costly State Verification," *Journal of Economic Theory* (21), 1979, 265-293.

Warner, Jerald, "Bankruptcy Costs: Some Evidence," *Journal of Finance*, May 1977, 32(2), 337-48.

Williamson, Stephen, "Costly Monitoring, Optimal Contracts, and Equilibrium Credit Rationing," *Quarterly Journal of Economics* (102), 1987a, 135-145.

Figure 1: Output Model

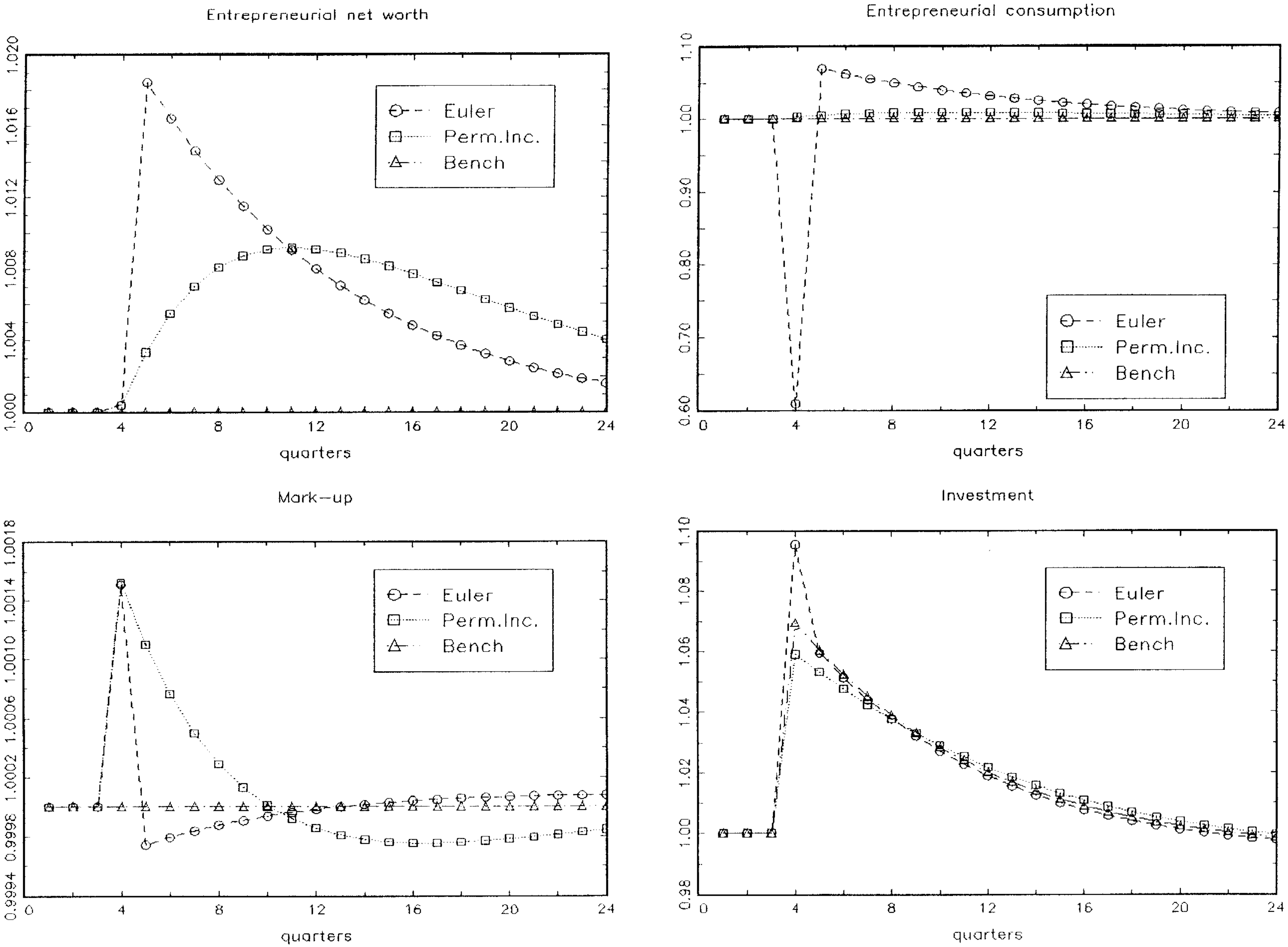

Figure 1: Output Model

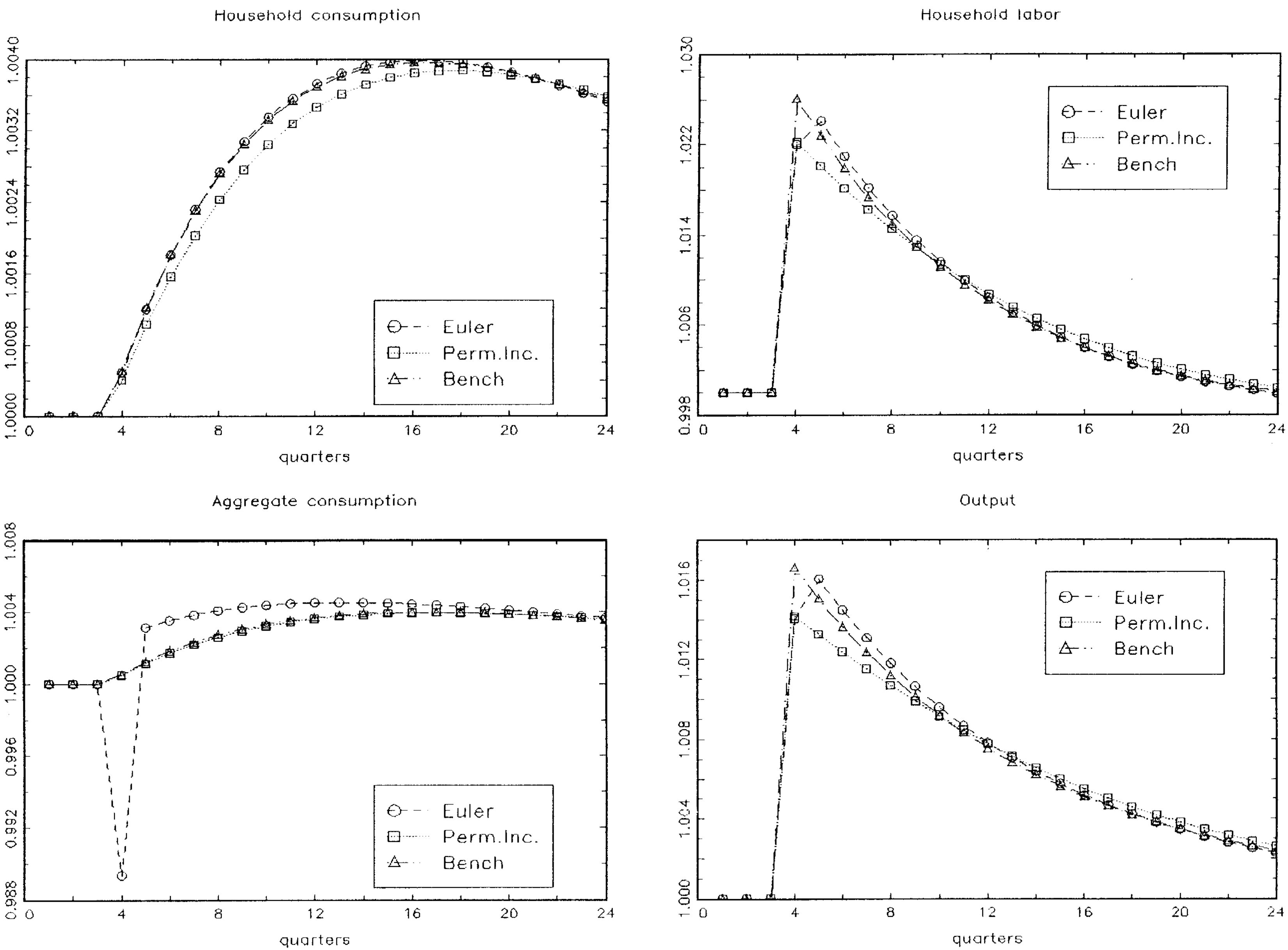

Figure 2: Investment Model

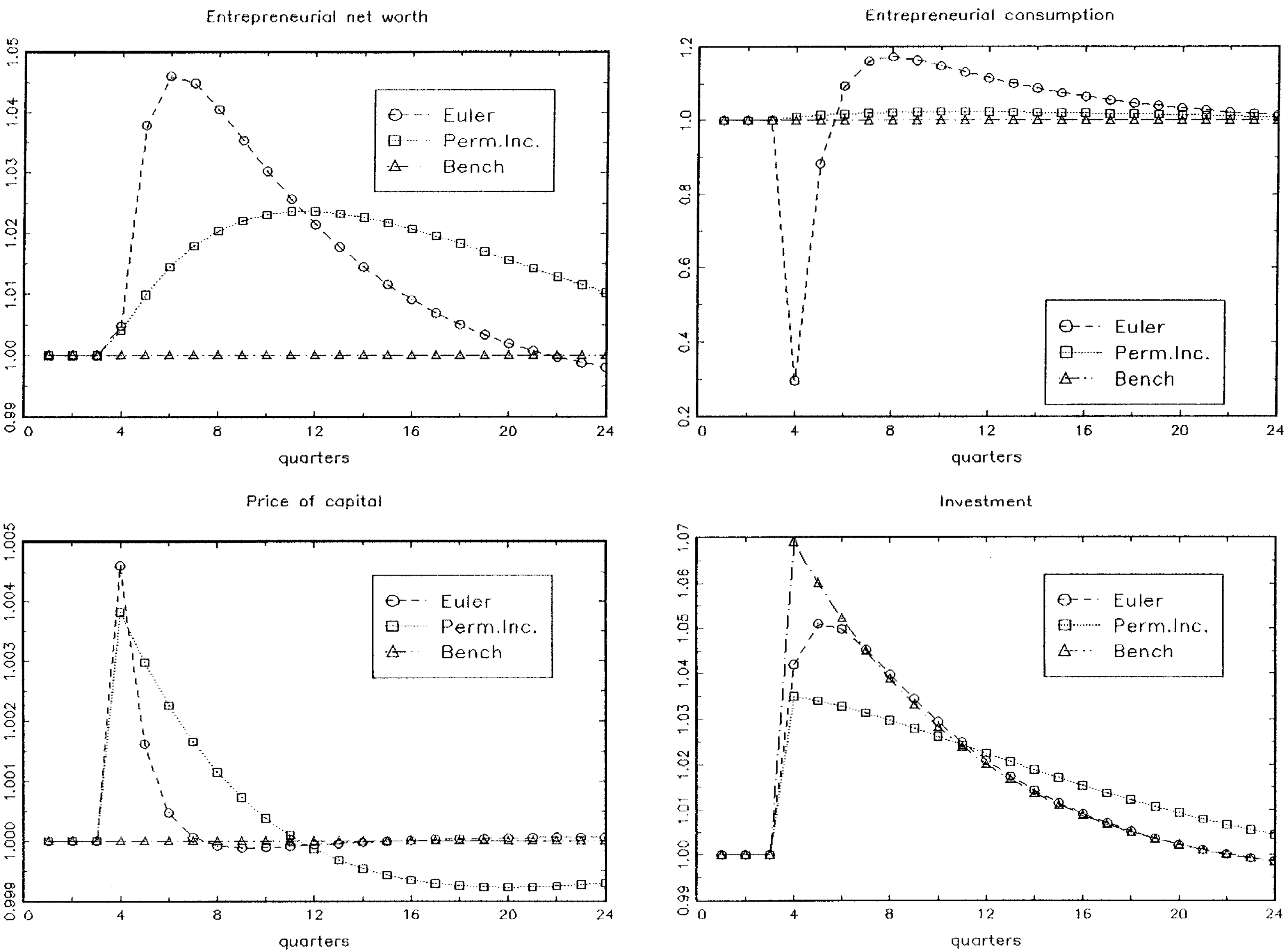

Figure 2: Investment Model

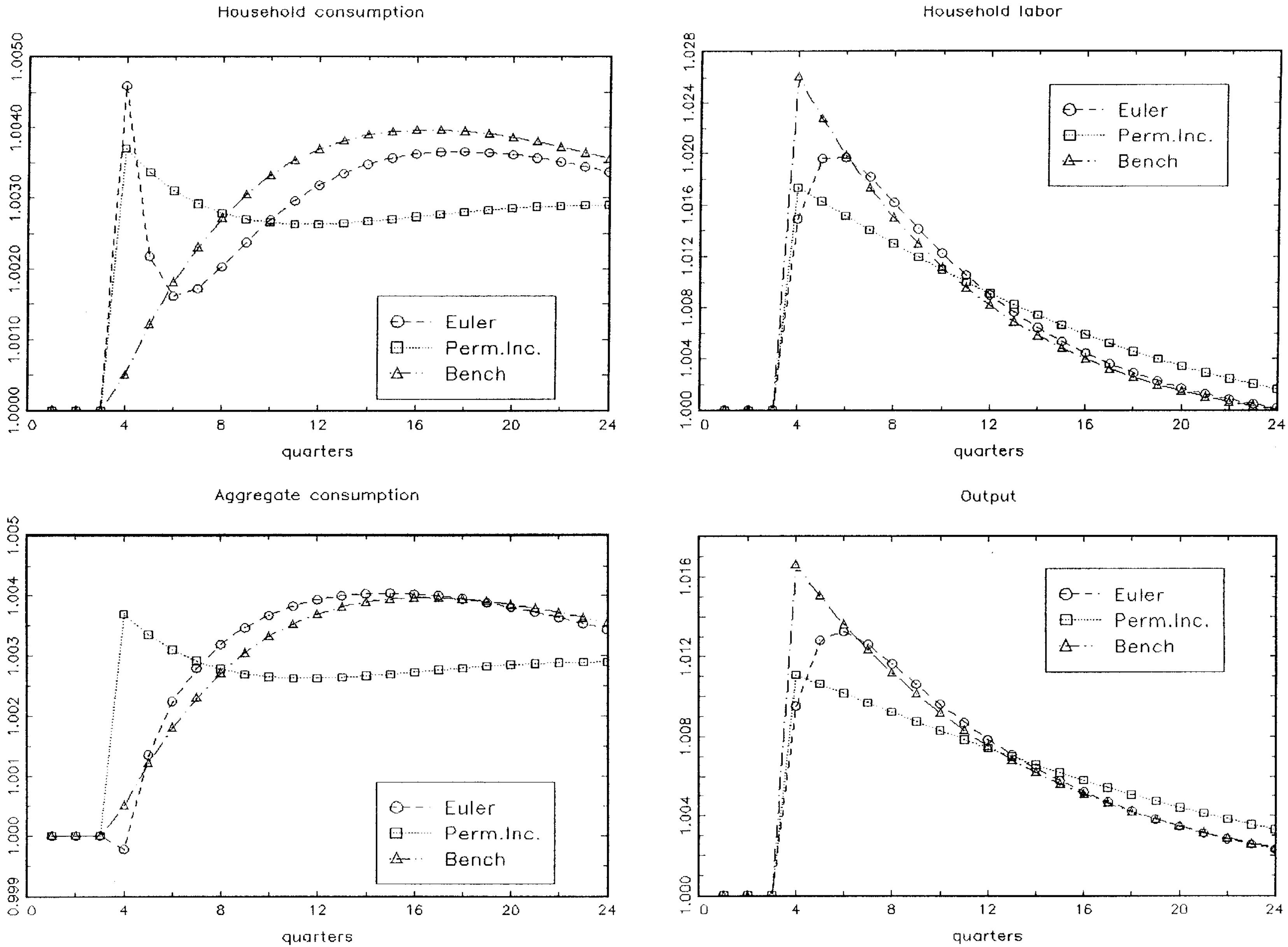

Figure 3: A Wealth Shock in the Investment Model

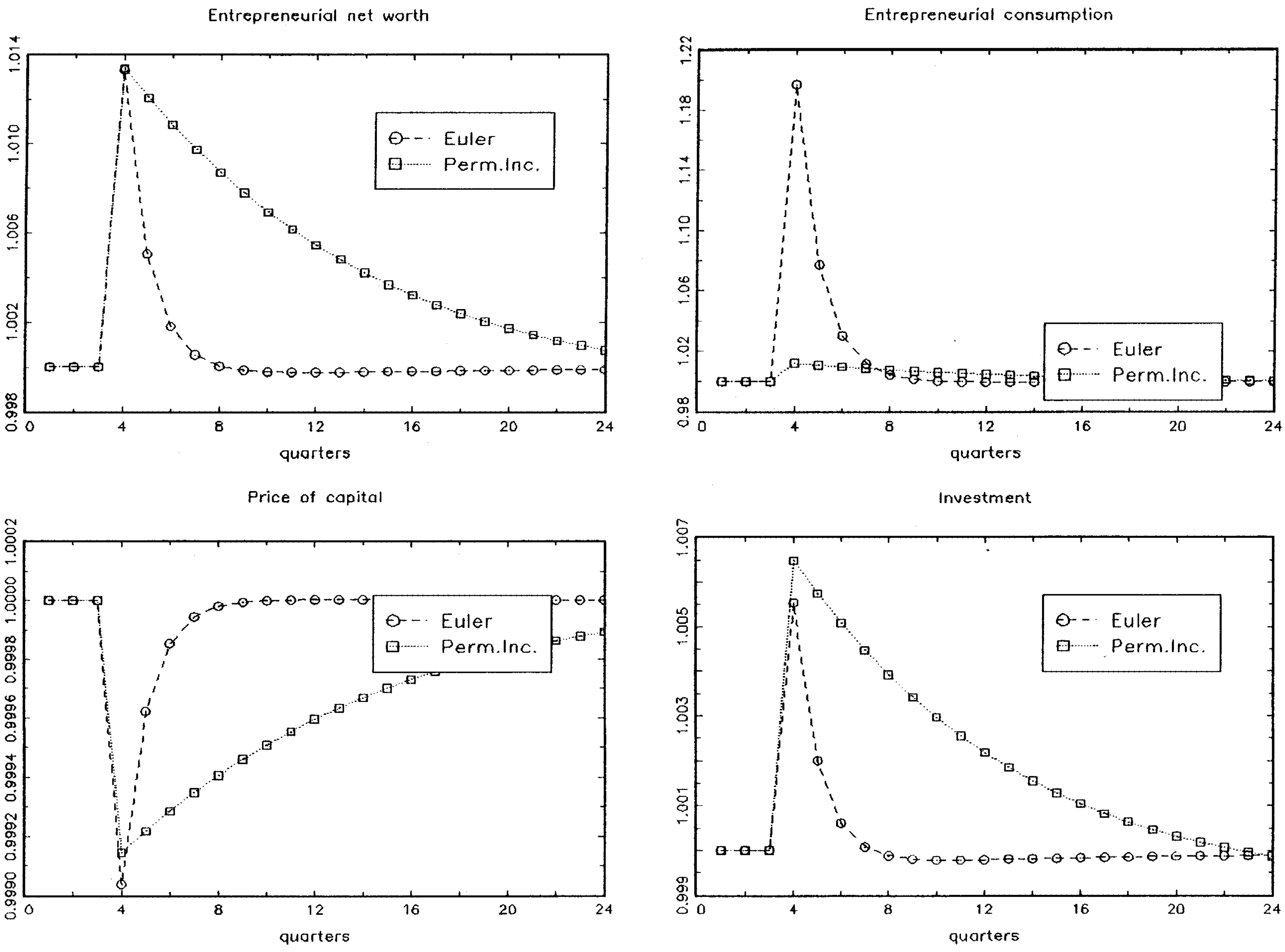

Figure 3: A Wealth Shock in the Investment Model