Macroeconomics of Persistent Slumps *

Robert E. Hall
Hoover Institution and Department of Economics,
Stanford University
National Bureau of Economic Research
rehall@stanford.edu; stanford.edu/∼rehall

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Abstract

In modern economies, sharp increases in unemployment from major adverse shocks result in long periods of abnormal unemployment and low output. This chapter investigates the processes that account for these persistent slumps. The data are from the economy of the United States, and the discussion emphasizes the financial crisis of 2008 and the ensuing slump. The framework starts by discerning driving forces set in motion by the initial shock. These are agency frictions in capital markets resulting in tighter lending standards, higher discounts applied by decision makers (possibly related to a loss of confidence), withdrawal of potential workers from the labor market, and diminished productivity growth. Most of the driving forces are less persistent than unemployment and output. The next step is to study how driving forces influence general equilibrium, both at the time of the initial shock and later as its effects persist. Some of the effects propagate the effects of the shock—they contribute to poor performance even after the driving force itself has subsided. Depletion of the capital stock is one of the most important of these propagation mechanisms. Another is the borrowing power of households. I use a medium-frequency dynamic equilibrium model to gain some notions of the magnitudes of responses and propagation.

JEL E24, E32, G12

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Peak year	*Peak rate*	*Ratio of later unemployment rate to peak rate, by number of years later*			
		1	2	3	4
1975	8.5	0.91	0.84	0.72	0.69
1982	9.7	0.99	0.77	0.74	0.72
1992	7.5	0.92	0.81	0.75	0.72
2010	9.6	0.93	0.84	0.77	0.65

Table 1: Unemployment in the Four Serious Slumps since 1948

Beginning in 2008, output and employment in the United States dropped well below its previous growth path. Seven years later, unemployment is back to normal but output remains below the growth path. Japan has been in a persistent slump for two decades. And many of the advanced economies of Europe are in slumps, several quite deep. This chapter reviews the macroeconomics of slumps taking the American experience as a leading example.

The adverse shock that launches a slump generally triggers a rapid contraction of output and employment, with a substantial jump in unemployment. This phase—the recession—is usually brief. It ended in mid-2009 in the recent case. The recovery from the trough often lasts many years. The slump is the entire period of substandard output and employment and excess unemployment. In the recent U.S. case, the slump lasted from late 2008 until around the end of 2014. Dating the end of a slump is challenging, because some of the state variables accounting for depressed output, notably the capital stock, take many years to return to normal. Output in 2014 was well below its earlier trend path.

Persistent slumps did not begin with the one that originated from the financial crisis of 2008. The Great Depression remains much the deepest and longest slump in the American record since the beginning of national income accounting. Table 1 shows that the persistence of unemployment was about equally high in the four major slumps that occurred after the introduction of the household unemployment survey in 1948. Normal unemployment in the U.S, measured as its average over the period starting in 1948, is 5.8 percent. In all four slumps, unemployment remained above normal three years following the peak of unemployment, and in ony one slump, the milder one associated with the recession of 1990-91, did unemployment drop below normal four years after the peak of unemployment.

Other accounts of persistent shortfalls in output and employment, focusing on the financial crisis and its aftermath, include Kocherlakota (2013), Christiano, Eichenbaum and Trabandt (2013), Christiano, Trabandt and Walentin (2010), Benigno and Fornaro (2015), Petrosky-Nadeau and Wasmer (2015), Gertler, Sala and Trigari (2008), Mian and Sufi (2010), Reifschneider, Wascher and Wilcox (2013), Hall (2013), Hall (2011b), Hall (2014b), and Hall (2012b).

1 The Slump Following the 2008 Financial Crisis

This section provides the factual foundation for the chapter by describing events in the U.S. economy around the time of the 2008 crisis, through to 2014. I provide plots of key macroeconomic variables with brief discussions. The rest of the chapter considers the ideas and models that seem most relevant to understanding those events.

Figure 1 shows that real GDP fell dramatically right after the crisis and remained below its prior growth path even six years after the crisis. Plainly the crisis had a persistent effect on the total output of goods and services. Figure 2 shows that real consumption expenditures behaved similarly to real GDP, with no sign of regaining its earlier growth path over the period following the 2008 crisis. Figure 3 shows persistent shortfalls from the growth path of employment. Figure 4 shows that unemployment rose to a high level and returned to its long-run average of 5.8 percent at the end of 2014, six years after the crisis. The unemployment rate is the only major macroeconomic indicator that returned to normal within the six-year period considered here. Figure 5 shows that the labor force shrank after the crisis, relative to the working-age population, and that no recovery of the labor force occurred during the recovery. Figure 6 shows that average real compensation per household, which had grown briskly through 2000, flattened before the crisis, fell sharply just after the crisis, and only regained its previous level in 2014. Figure 7 shows that the business capital stock—in the sense of an index of capital services available to private businesses—grew much less rapidly than normal immediately after the crisis. Its growth rate returned closer to normal, but left a considerable shortfall in capital relative to trend, as of 2014. Figure 8 shows that private business total factor productivity grew rapidly from 1989 through 2006. A dip in productivity began in 2007. Though productivity grew at normal rates during the recovery, it did not make up for the cumulative decline just after the crisis. Figure 9 shows the index of the share of the total income generated in the U.S. economy that accrues to workers,

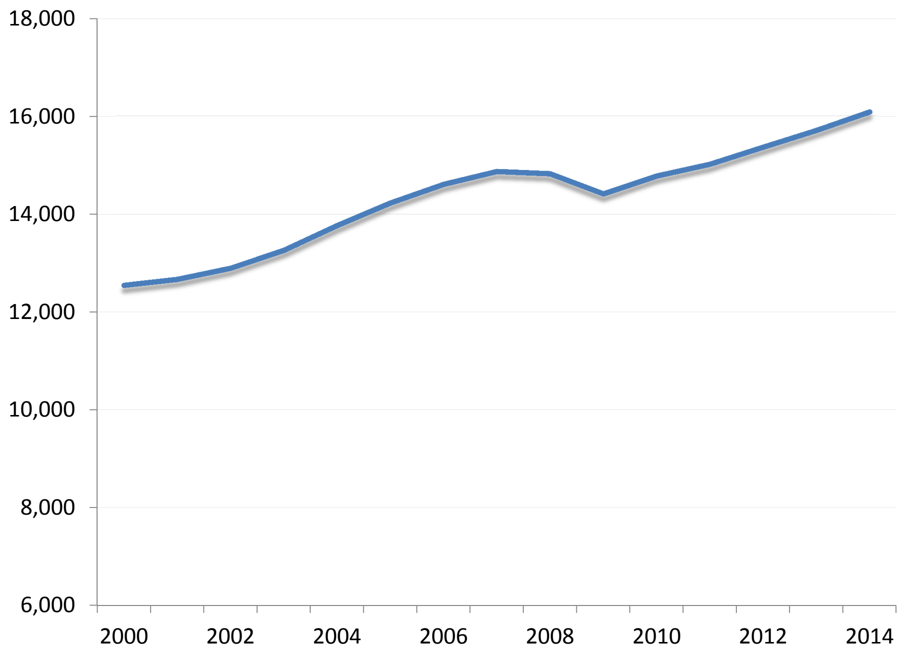


Figure 1: Real GDP, 2000-2014, Billions of 2009 Dollars

including fringe benefits. It tends to have a high level in recession years, to fall during the first half of the ensuing expansion, then rise back to a high level at the next recession. But superimposed on that pattern is a general decline that cumulates to about 10 percent over the period. Like the general declining trend in earnings, the decline in the share seems to have started around 2000.

2 Driving Forces, Shocks, and Propagation

I use the term *driving force* to mean either an exogenous variable or an endogenous variable that is taken as an input to a macro model. An example of the latter case is a rise in the discount rate for investment and job creation, triggered by a financial crisis. There is no claim that the discount increase is exogenous. Rather, the hypothesis is that a process outside the model—say a collapse of house prices—influences the model through a higher discount rate. The same process outside the model may enter the model through more than one driving force. For example, the collapse of housing prices may also affect consumption demand by lowering borrowing opportunities of constrained households.

Various shocks hit the economy unpredictably. Shocks have predictable effects on driving forces. For example, a financial shock may raise the discount rate for a year or two. And

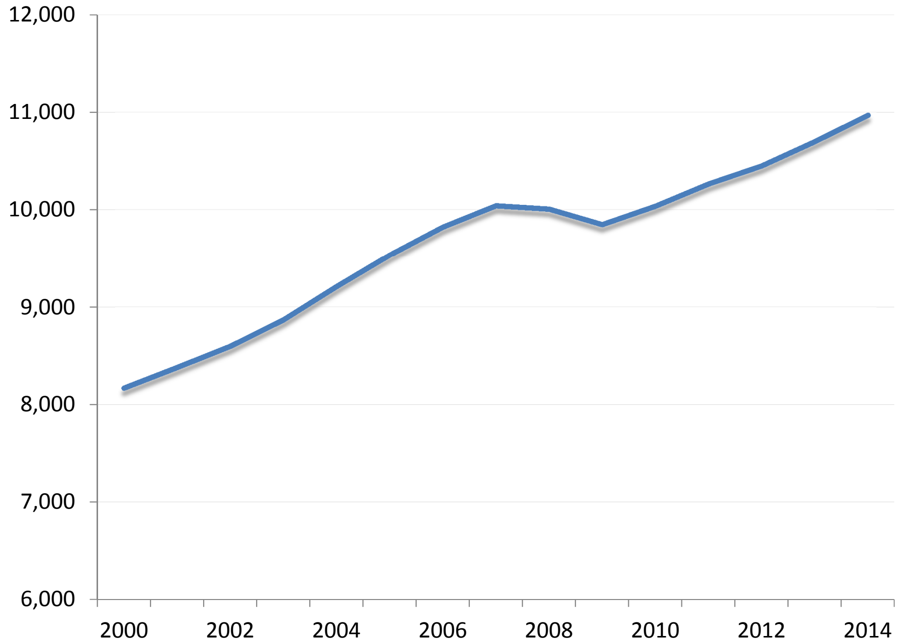


Figure 2: Real Consumption Expenditure, 2000-2014, Billions of 2009 Dollars

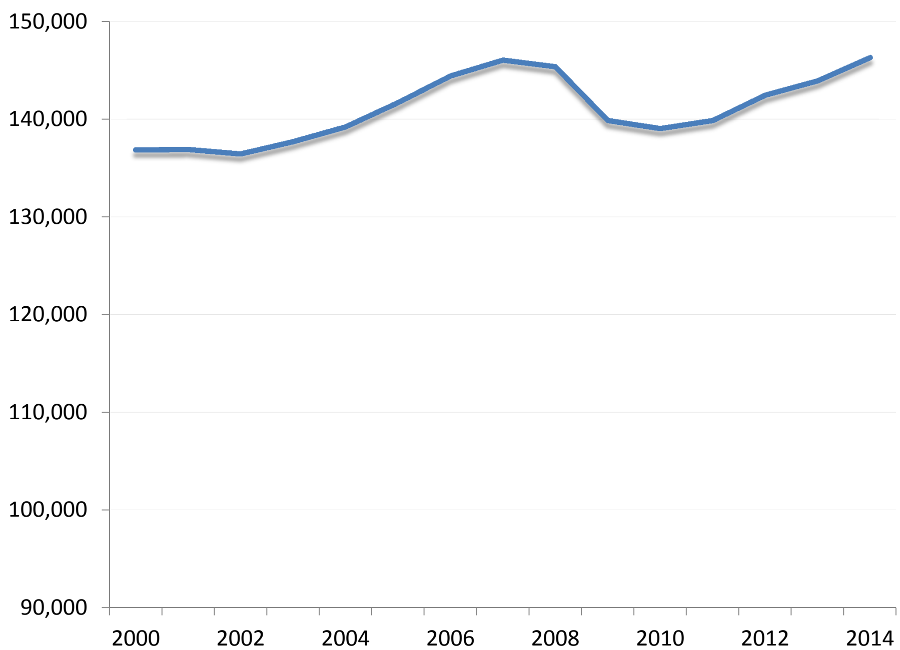


Figure 3: Employment, 2000-2014, Thousands of Workers

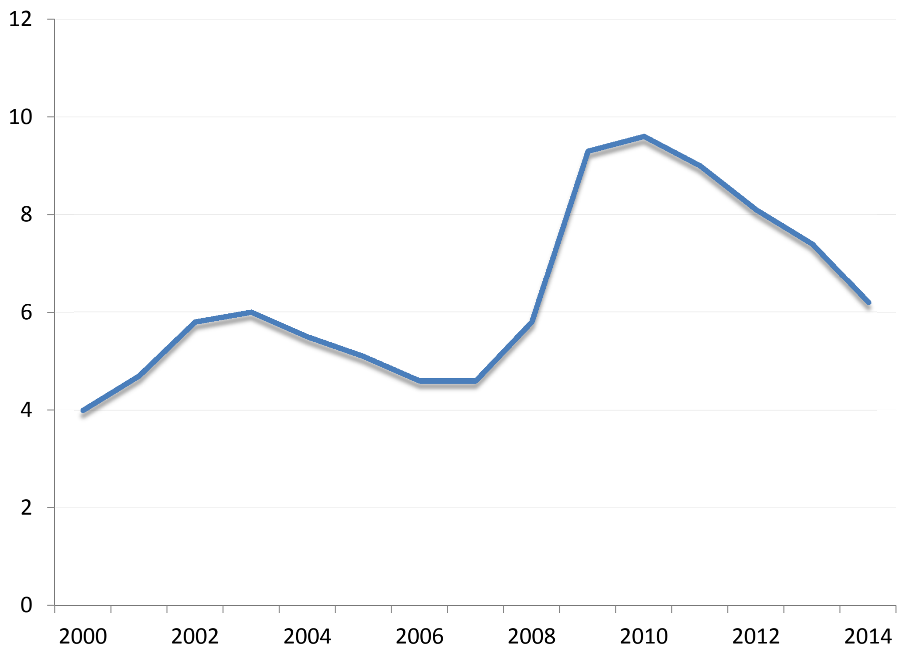


Figure 4: Unemployment, 2000-2014, Percent of Labor Force

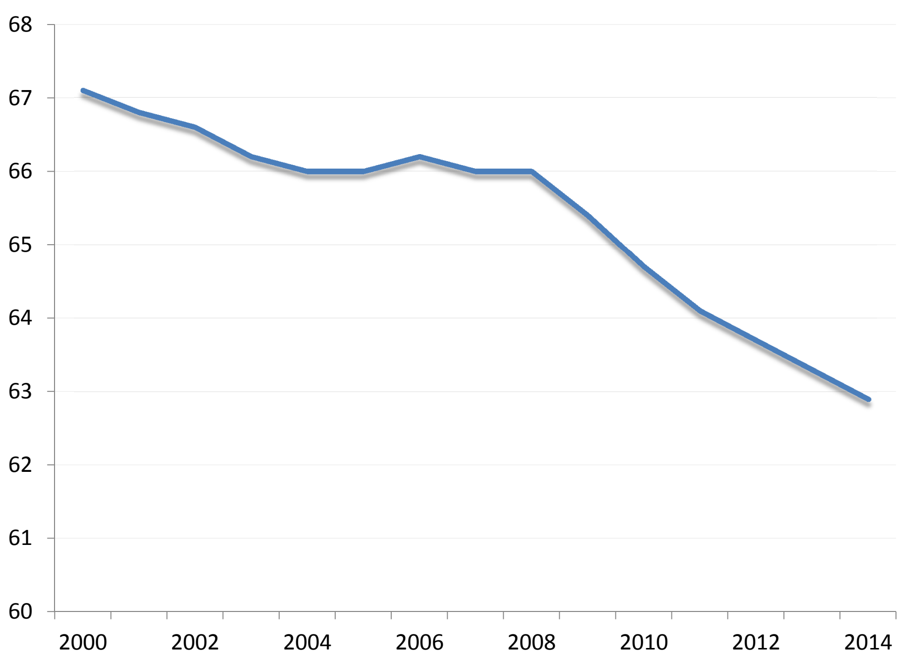


Figure 5: Percent of Working-Age Population in the Labor Force, 2000-2014

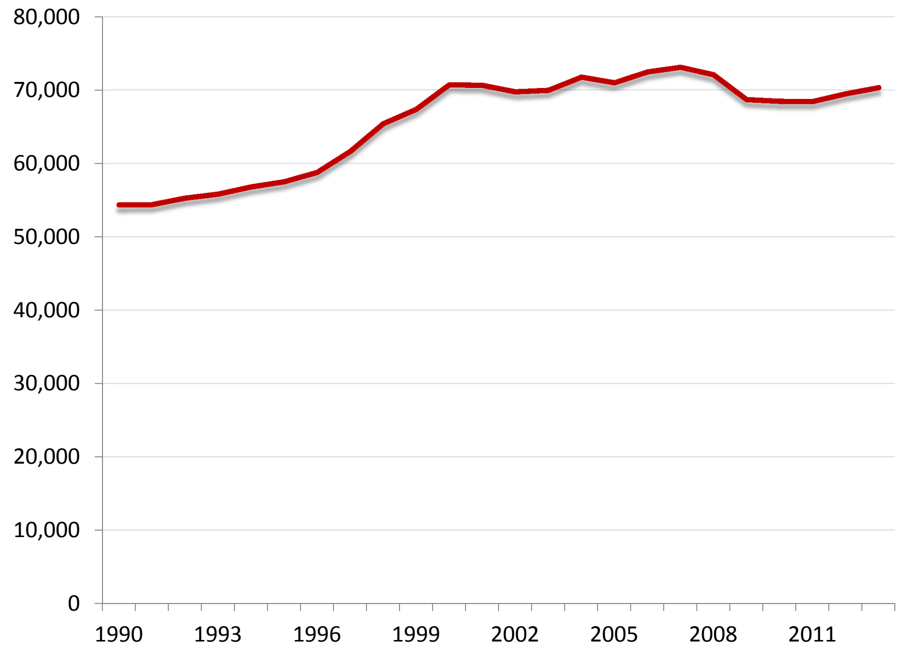


Figure 6: Average Real Earnings per Household, 2009 Dollars, 1990-2014

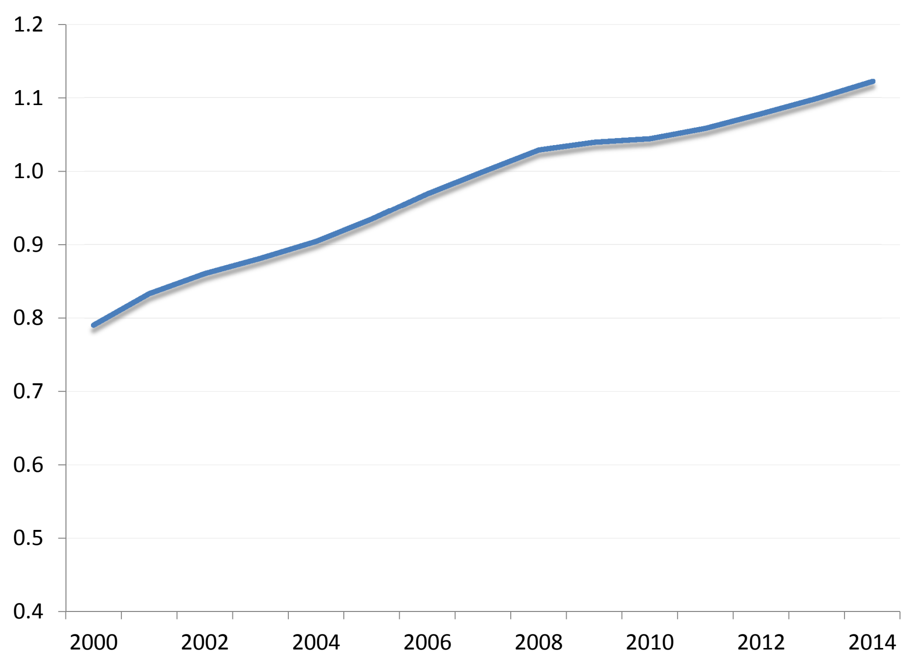


Figure 7: Index of Capital Services, 2007 = 1, 2000-2014

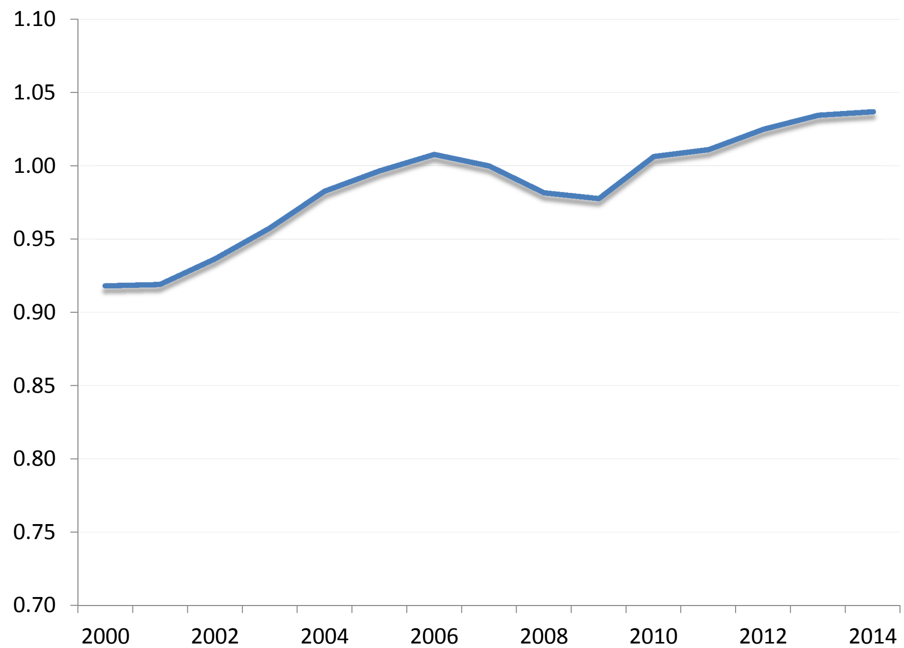


Figure 8: Index of Total Factor Productivity, 2007 = 1, 2000-2014

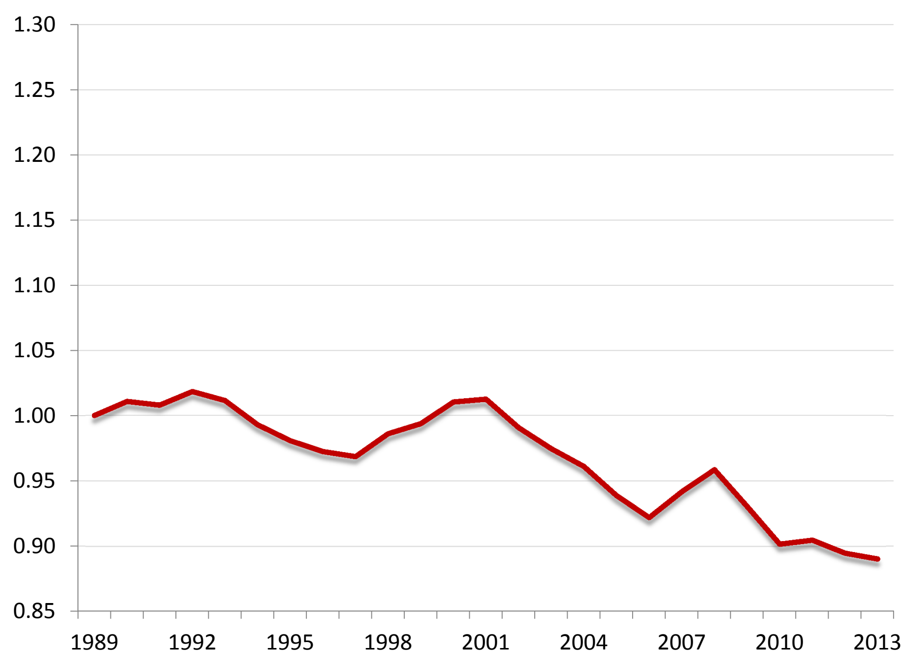


Figure 9: Labor share

driving forces may set in motion longer-lasting movements of output, employment, and other macro variables. *Propagation* is the lag between an induced movement of a driving force and the corresponding movement of a variable. Propagation is a big issue in macroeconomics, because driving forces tend to be much less persistent that the movements of output and employment, including the movements after large adverse shocks that are the subject of this chapter.

The impulse response function is a standard tool of macroeconomics. The impulse response function for a driving force with respect to relevant shock measures the persistence of the effect of the shock on the driving force. The impulse response function for a key variable, say unemployment, with respect to the same shock measures the persistence of the effect of the shock on the variable. The ratio of the IRF for a variable to the IRF for the driving force measures the amount of propagation of the effect of the driving force. If the ratio is constant over lags, no propagation is occurring. A rising ratio indicates propagation.

An alternative definition of propagation uses lag operators. The IRF $\phi(L)$ relates a shock ϵ_t to a driving force d_t as

$$d_t = \phi(L)\epsilon_t + x_{d,t}, \tag{1}$$

where $x_{d,t}$ represents the effects of other shocks and of exogenous variables. The IRF $\gamma(L)$ relates the shock to a variable y_t as

$$y_t = \gamma(L)\epsilon_t + x_{y,t}. \tag{2}$$

The lag function $\beta(L)$ reveals the extend of propagation:

$$\beta(L) = \frac{\gamma(L)}{\phi(L)}. \tag{3}$$

That is, to find the propagation function $\beta(L)$, given the IRFs for the driving force and the variable, $\phi(L)$ and $\gamma(L)$, divide $\gamma(L)$ by $\phi(L)$. If the resulting lag function places no weight on any lags ($\beta(L) = \beta(0)$), no propagation occurs. The mean lag, $\beta'(1)/\beta(1)$ is one useful measure of the extent of propagation.

A major challenge in macroeconomics is that direct measurement of propagation with vector autoregressions tends to find extensive propagation—shocks dissipate quickly but their effects linger for years. On the other hand, models derived from theory tend to have little propagation. Getting theory-based models to match VAR-based IRFs requires some stretching of the theory, in the views of skeptics.

3 Driving Forces and Propagation Mechanisms

Here I provide an informal review of the forces that macroeconomics has identified to account for persistent slumps.

3.1 Driving forces

3.2 Labor-force participation

An important discovery in recent U.S. experience has been the importance of a major decline in labor-force participation. In past slumps, participation remained close to unchanged—the economy has not had a consistent tendency for the labor force to shrink when job-finding became more difficult. As of early 2015, the U.S. labor market has returned to normal tightness, as measured by job-finding and job-filling rates, yet a large decline in participation starting around 2000 has not reversed. The decline in participation is an important contributor to the divergent behavior of output and employment, on the one hand, and labor-market tightness, on the other and. Judged by the latter, the slump triggered by the financial crisis of 2008 is over, yet output and employment are far below the paths expected just prior to the crisis.

Movements in participation not directly tied to labor-market tightness need to be added to the list of phenomena associated with episodic slumps. Even if a major shock did not cause a subsequent decline in participation, if a decline happens to occur during a slump, the shortfall in employment and output will be negatively affected.

Elsby, Hobijn and Şahin (2013) is a recent investigation of the decline in participation. Autor (2011) describes the disability benefits that may be a contributor to that decline.

3.3 The capital wedge

A key fact in understanding the slump following the financial crisis is the stability of business earnings. Figure 10 shows the earnings of private business (the operating surplus from the NIPAs, revenue less non-capital costs) as a ratio to the value of capital (plant, equipment, software, and other intangibles, from the Fixed Assets account of the NIPAs). Earnings fell in 2007 from their normal level of just over 20 percent, but recovered most of the way by 2010, when output and employment remained at seriously depressed levels.

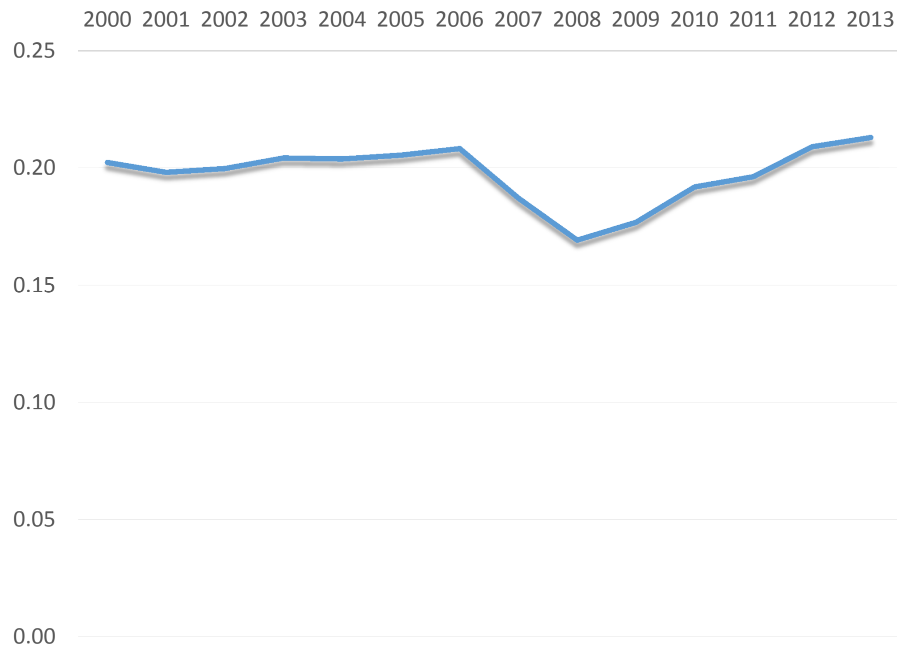


Figure 10: Business Earnings as a Ratio to the Value of Capital

A basic question is why investment fell so much despite the continuing profitability of business activities. Macroeconomics has gravitated toward an analysis of wedges as ways of describing what seem to be failures of incentives. The capital wedge is the difference between the measured return to investment and the financial cost of investment. I take the latter to be the risk-free real interest rate. The risk premium is one component of the wedge between the return to business capital and the risk-free interest rate. Other components are taxes, financial frictions, and liquidity premiums. To measure the total wedge, I calculate the annual return to capital and subtract the one-year safe interest rate from it.

The calculation of the return to capital uses the following thought experiment: A firm purchases one extra unit of investment. It incurs a marginal adjustment cost to install the investment as capital. During the year, the firm earns incremental gross profit from the extra unit. At the end of the year, the firm owns the depreciated remainder of the one extra unit of installed capital. Installed capital has a shadow value measured by Tobin's q.

Installation incurs a marginal cost at the beginning of the period of $\kappa(k_t/k_{t-1} - 1)$. Thus the shadow value of a unit of installed capital at the beginning of the year is

$$q_t = \kappa \left(\frac{k_t}{k_{t-1}} - 1 \right) + 1 \tag{4}$$

units of capital. From its investment of a unit of capital at the beginning of year t together with the marginal installation cost—with a total cost of $q_t p_{k,t}$—the firm's nominal return ratio is the gross profit per unit of capital π_t/k_t plus the depreciated value of the capital in year $t+1$, all divided by its original investment:

$$1 + r_{k,t} = \frac{1}{q_t p_{k,t}} \left[\frac{\pi_t}{k_t} + (1-\delta_t) q_{t+1} p_{k,t+1} \right]. \quad (5)$$

Gross profit includes pre-tax accounting profit, interest payments, and accounting depreciation. In principle, some of proprietors' income is also a return to capital— non-corporate business owns significant amounts of capital—but attempts to impute capital income to the sector result in an obvious shortfall in labor compensation measured as a residual. The reported revenue of the non-corporate business sector is insufficient to justify its observed use of human and other capital. Note that business capital as measured in the NIPAs now includes a wide variety of intangible components in addition to plant and equipment.

The implied wedge between the return to capital and the risk-free real interest rate $r_{f,t}$ is the difference between the nominal rate of return to capital and the one-year safe nominal interest rate:

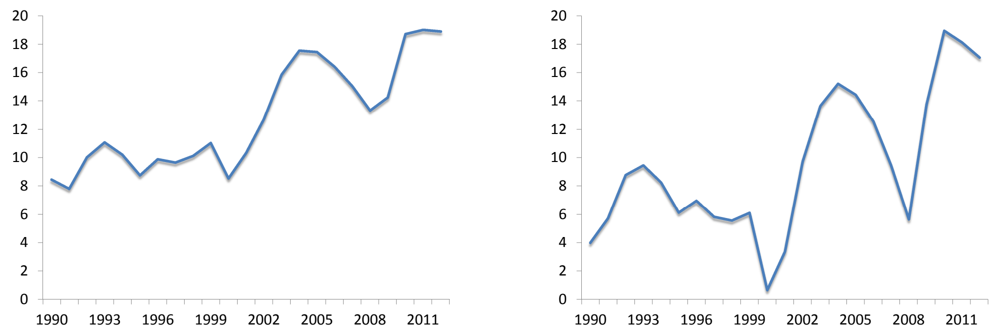
$$g_t = r_{k,t} - r_{f,t}. \quad (6)$$

This calculation is on the same conceptual footing as the investment wedge in Chari, Kehoe and McGrattan (2007), stated as an interest spread. Note that g_t is in real units—the rate of inflation drops out in the subtraction.

Figure 11 shows the values of the business capital wedge for two values of the adjustment cost parameter κ, calculated from equation (6), combining plant, equipment, and intellectual property. On the left, κ is taken as zero and on the right, as 2. The former value accords with the evidence in Hall (2004) and the latter with the consensus of other research on capital adjustment costs. The value $\kappa = 2$ corresponds to a quarterly parameter of 8.

The two versions agree about the qualitative movements of the wedge since 1990, but differ substantially in volatility. The wedge was roughly steady or falling somewhat during the slow recovery from the recession of 1990, rose to a high level in the recession of 2001, declined in the recovery, and then rose to its highest level after the crisis. The two calculations agree that the wedge remained at a high level of about 18 percent per year through 2013.

Hall (2011a) discusses the surprising power of the financial wedge over general economic activity. The adverse effect of the wedge on capital formation cuts market activity in much the same way as taxes on consumption or work effort.



(a) $\kappa = 0$

(b) $\kappa = 2$

Figure 11: The Capital Wedge for Two Values of the Adjustment Cost κ

3.3.1 Agency frictions

One branch of the recent literature on the propagation of financial collapse into a corresponding collapse of output and employment emphasizes agency frictions in businesses and financial intermediaries. The simplest model in the case of an intermediary—completely dominant in this literature though not obviously descriptive of the actual U.S. economy—grants the intermediary the opportunity to abscond with the investors' assets. Absconding takes place if the intermediary's continuation value falls short of the value of absconding, taken to be some fraction of the amount stolen from the investors. If the intermediary's equity falls on account of a crisis—for example, if mortgage-backed securities suffer a large capital loss—the investors need to restore the intermediary's incentive to perform by granting a larger spread between the lending rate the intermediary earns and the funding rate it pays to the investors. Hence spreads rise after a financial crisis. This view is consistent with the actual behavior of the spread between the return to capital and the risk-free rate.

The same type of agency friction can occur between a non-financial business and its outside investors. Depletion of the equity in the business will threaten the investors' capital. They need to raise the rents earned by the business to increase the continuation values of the insiders, and again spreads will rise.

Gertler and Kiyotaki (2010a) covers this topic thoroughly in a recent volume of the *Handbook of Monetary Economics*. Brunnermeier, Eisenbach and Sannikov (2012) is another recent survey. Key contributions to the literature include Bernanke, Gertler and Gilchrist

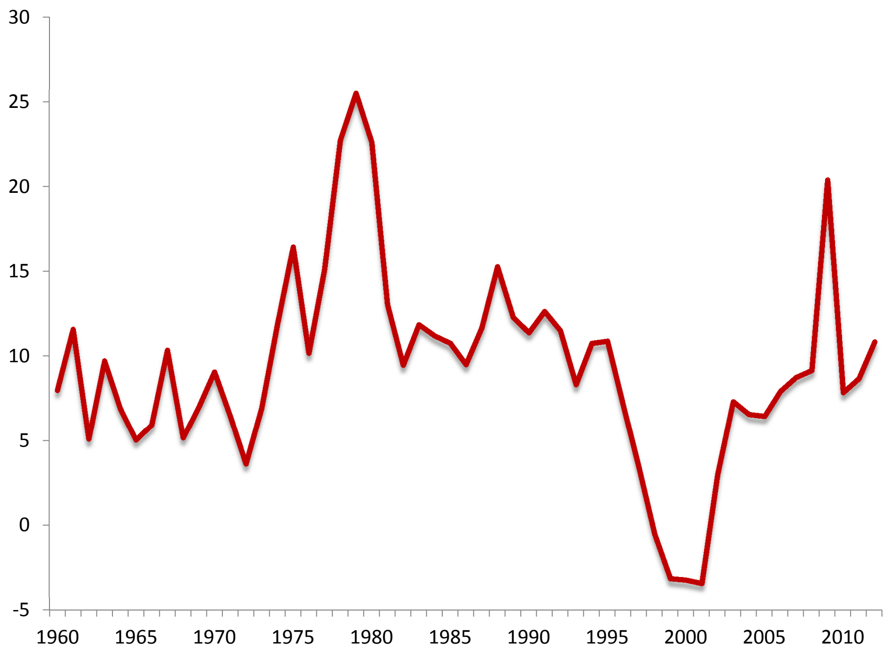


Figure 12: The S&P Risk Premium, 1960 through 2012

(1999), Kiyotaki and Moore (2008), Gertler and Karadi (2009), Brunnermeier and Sannikov (2014), and Gertler and Kiyotaki (2010b). See also Krishnamurthy and Vissing-Jorgensen (2012), Zhiguo and Krishnamurthy (2015) Adrian, Colla and Shin (2012) , and Korinek and Simsek (2014).

3.4 Discounts and confidence

A second branch of the literature linking financial collapse to rising spreads considers widening risk premiums in crises and ensuing slumps. Cochrane (2011) discusses the high volatility of the risk premium in the stock market, measured as the discount rate less the risk-free rate. Lustig and Verdelhan (2012) document the tendency for discounts to rise in slumps.

A basic property of the stock market is that, when the level of the stock market is low, relative to a benchmark such as dividends, discounts are higher—see Campbell and Shiller (1988). Normalized consumption is another reliable predictor of returns. Figure 12 shows the equity premium for the S&P stock-price index from a regression of annual returns on those two variables (see Hall (2014a) for further discussion and details of its construction). The risk premium spiked in 2009. Notice that it is not nearly as persistent as the slump itself—the premium was back to normal well before unemployment fell back to normal and long before investment recovered.

Figure 13: Growth Rate of Real Consumption of Nondurable Goods per Person

Macroeconomics and finance are currently debating the explanation for the high volatility of discounts. In principle, high discounts arise when the marginal utility of future consumption is high. Generating this outcome in a model is a challenge. Marginal utility would need to be highly sensitive to consumption to generate observed large movements in discounts from the modest expected declines in consumption that occur even in severe contractions. Contractions in consumption appear to be almost completely surprises. If a model implied that occasional drops in consumption occurred as surprises, and consumption then grew faster than normal to regain its previous growth path, the discount rate would *fall* after a crisis, because marginal utility would be lower in the future.

Figure 13 shows the history of the growth of real consumption of nondurable goods per person from 2001 through 2014. The largest decline was in 2009, at 2.5 percent, about 3.5 percent below its normal growth. With a coefficient of marginal utility with respect to consumption of 2 (elasticity of intertemporal substitution of 0.5), the effect on marginal utility would be a substantial 7 percent. But this applies to a fully foreseen decline. The process for consumption change is close to white noise, so the hypothesis of a large negative expected change seems untenable.

Bianchi, Ilut and Schneider (2012) propose a mechanism to overcome the problem that expected increases in marginal utility are inconsistent with the observed behavior of consumption. They disconnect discounts from rational expectations of changes in marginal utility by invoking ambiguity aversion. Investors form discounts based on their perceptions of a bad-case realization of marginal utility. During periods when investors have unusually pessimistic views, discounts are high.

Angeletos, Collard and Dellas (2014) overcomes the problem in a related way. Investors form expectations about the future state of the economy based on biased beliefs about beliefs of other decision makers. When these second-order beliefs are unusually pessimistic, investors believe that their own future consumption will be lower and their future marginal utility higher, and thus apply higher discounts. The authors use the term *confidence* to refer to optimism in second-order beliefs.

In general, if a financial crisis or other salient event causes investors to shift their beliefs toward higher future marginal utility, discounts will rise. To the extent that the mean of future marginal utility rises, the safe real rate will increase along with the discounts applied to risky returns. To harness the mechanism to explain the decline in the safe rate in the Great Slump along with the rise in the risky discount, the change in the distribution of future marginal utility needs to lower the mean but raise the expected product of marginal utility and the payoffs that govern the levels of employment and output.

The spreads between yields on risky and safe bonds of the same maturity are informative about variations in discounts. **?** argues that the bond spread may be more informative. Because the difference in the values of a risky bond and a safe bond is sensitive only to shocks that alter payoffs conditional on default, and default is relatively rare for bonds, the bond spread encodes information about the rare, serious events that could account for high discounts on business income and low discounts on safe payoffs. Figure 14 shows the option-adjusted spread between BBB-rated bonds and Treasurys of the same maturity.

The spread widened dramatically in 2009, supporting the hypothesis that the perceived probability of a collapse of business cash flow had increased substantially. But the widening was transitory. The spread returned to historically normal levels in 2010 and remained there subsequently. It would take a powerful propagation mechanism for the change in perceptions to account for the persistent slump after 2010.

Gilchrist, Sim and Zakrajek (2014a), Figures 2 and 3, shows IRFs for a spread shock, derived from a vector autoregression. These show relatively little persistence in the shock, but substantial persistence in investment and GDP responses.

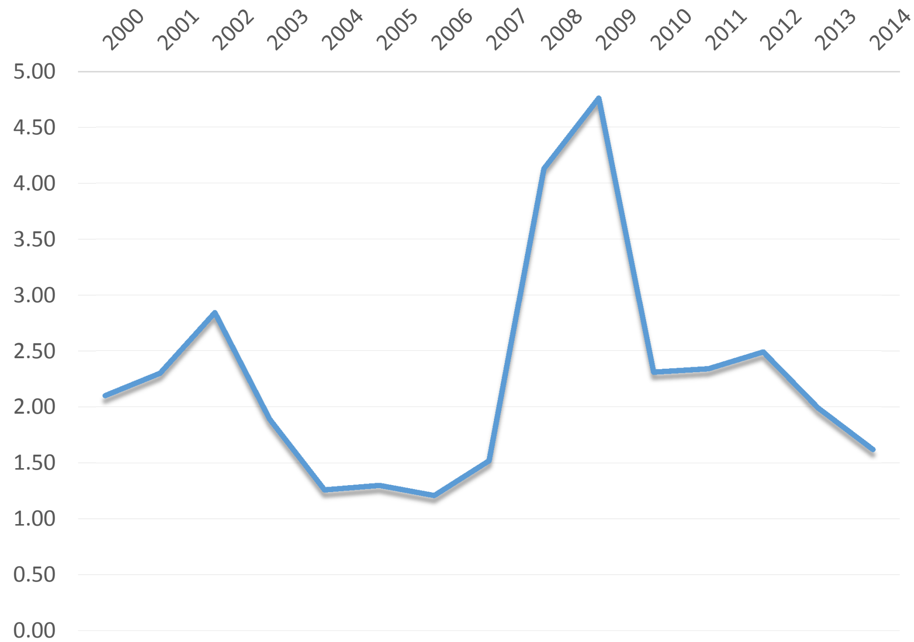


Figure 14: BBB-Treasury Bond Spread

Other contributions relating to discounts and confidence include Farmer (2012), He and Krishnamurthy (2013), Gourio (2012), Bianchi et al. (2012), Van Nieuwerburgh, Lustig and Verdelhan (2010), and Eckstein, Setty and Weiss (2015).

3.5 Productivity

A decline in TFP growth was an important factor in the shortfall of output during the post-crisis U.S. slump. Fernald (2014) makes the case that the productivity slowdown was unrelated to the crisis. Rather, he argues, it was a slowdown only relative to rapid TFP growth in the late 1990s and early 2000s, associated with adoption of modern information technology. The episode illustrates the importance of TFP growth as a driving force of medium-term fluctuations, even though TFP is not a consistent driver of sharp contractions.

3.6 Product-market wedge

Market power in product markets creates a wedge that has been discussed extensively as a driving force of fluctuations, mainly in the context of the New Keynesian model. Rotemberg and Woodford (1999) discuss how sticky product prices result in cyclical fluctuations in markups—in a slump, prices fall less than costs, so market power rises. In almost any modern macro model, the market-power wedge has a negative effect on employment and output. Nekarda and Ramey (2013) question the evidence supporting this view, with respect to shocks apart from productivity. Bils, Klenow and Malin (2014) defend the view, using new evidence.

Gilchrist, Schoenle, Sim and Zakrašek (2014b) shows that firms facing higher financial stress after the crisis raised prices (and thus the wedge) relative to other firms, a finding that supports the idea that the product-market wedge rose in general when overall financial stress worsened. The likely mechanism is different from the one in Rotemberg and Woodford (1999)—it is an idea launched in Phelps and Winter (1970). Financially constrained firms borrow, in effect, by raising prices relative to cost and shedding some of their customer bases.

Chari et al. (2007) provide a comprehensive discussion of wedges in general. See also Gourio and Rudanko (2014)

4 Propagation mechanisms

4.1 Capital

The capital stock is an important source of propagation in slumps, a point that has escaped analysis in the cycle-around-trend view of fluctuations. Investment falls sharply in slumps, leaving a depleted capital stock in a slump that lasts several years. Capital depletion also helps account for the divergent behavior of output and labor-market tightness. See Gilchrist et al. (2014a) and Gomme, Ravikumar and Rupert (2011)

4.2 Unemployment dynamics

In the standard search-and-matching model, calibrated in in Shimer (2005), the unemployment rate is a fast-moving state variable. With job-finding rates around 50 percent per month even during slumps, unemployment converges to the stationary level dictated by tightness and the job-finding rate within a few months. Unemployment dynamics have essentially nothing to do with the persistence of slumps.

Some facts about the U.S. labor market call this view into question. Hall (1995) observed that research on the experiences of workers who lost jobs after gaining substantial tenure gave a quite different view of unemployment. Davis and von Wachter (2011) summarize more recent results with the same conclusion and emphasize the discord between the quick recovery from job loss implicit in the basic search-and-matching model and the actual experience of workers with three or more years of tenure following job loss. That experience involves an extended period of low employment—much greater loss than a 50-percent per month re-employment rate—and years of loss of hourly earnings. Jarosch (2014) confirms this view. The aggregate implications are that a wave of layoffs from a major shock, such as the financial crisis, results in an extended period of unemployment and a much longer period of lower productivity of the higher-tenure workers who lose jobs from the shock.

Some progress has been made in reconciling high monthly job-finding rates with the low recovery from high unemployment following a shock. Hall (2014a) shows, from the tenure data in the Current Population Survey, that the overwhelming majority of separations occur in the first month of new jobs. The distribution of job durations is utterly unlike the exponential distribution with a constant separation hazard usually assumed in search-and-matching models. This finding explains the high job-finding rates found in the CPS—there is a huge amount of churn in the U.S. labor market. Hall and Schulhofer-Wohl (2015) show that job-finding rates over year-long periods are well below what would be expected from monthly job-finding rates. The obvious explanation of this finding is that job-seekers often take interim jobs during much longer spells of mixed unemployment and brief employment.

Shimer (2008) discusses the labor-market wedge as a convenient summary of the effects of labor-market frictions.

Other contributions relating to propagation through unemployment dynamics include Valletta and Kuang (2010b), Cole and Rogerson (1999), Chodorow-Reich and Karabarbounis (2014), Hall and Schulhofer-Wohl (2015), Davis and von Wachter (2011), Davis, Faberman and Haltiwanger (2012), Petrosky-Nadeau and Wasmer (2013), Fujita and Moscarini (2013), Jarosch (2014), Rothstein (2011), Petrosky-Nadeau and Zhang (2013), Daly, Hobijn, Şahin and Valletta (2012), Mortensen (2011), Valletta and Kuang (2010a), Şahin, Song, Topa and Violante (2012), Krueger and Mueller (2011a), Daly, Hobijn and Valletta (2011b), Kuehn, Petrosky-Nadeau and Zhang (2013), Mulligan (2012a), Barnichon and Figura (2012), Estevão and Tsounta (2011), Krueger, Cramer and Cho (2014), Herz and van Rens (2011), Şahin, Song, Topa and Violante (2011), Farber and Valletta (2013), Kaplan and Menzio (2013), Elsby, Hobijn, Şahin and Valletta (2011), Krueger and Mueller (2011b), Davis and Haltiwanger (2014), Hall (2012a), Fujita (2011), Hagedorn, Karahan, Manovskii and Mitman (2013), Daly, Hobijn, Şahin and Valletta (2011a), Mulligan (2012b), Ravn and Sterk (2012)

4.3 The zero lower bound

The policy of every modern central bank is to issue two types of debt: reserves and currency. The bank pays interest or collects negative interest on reserves. No direct force constrains the rate on reserves. It is impractical to pay or collect interest on currency. Central banks keep currency and reserves at par with each other by standing ready to exchange currency for reserves or reserves for currency in unlimited amounts. If the bank sets a reserve rate below the negative of the storage cost of currency, owners of reserves will convert them to higher-yielding currency. No central bank has set a reserve rate low enough to induce any significant hoarding of currency, though the Bank of Denmark, with a rate at this writing of -0.60 percent, has announced an intention to continue lowering the rate until hoarding begins. So the zero lower bound is actually somewhere below -0.60 percent. I will continue to refer to a zero lower bound, but the actual bound is probably around minus one percent.

The lower bound on the real interest rate is the bound on the nominal rate less the expected rate of inflation. Figure 15 shows three time series relevant for measuring expected inflation. The top line is the median expected rate of inflation over the coming year for the Michigan Survey of Consumers. The line starting in 2007 is the median forecast of the average annual rate of change of the PCE price index over the coming 5 years, in the Survey of Professional Forecasters of the Philadelphia Federal Reserve Bank. The bottom line is the breakeven inflation rate in the 5-year TIPSs and nominal 5-year note—the rate of inflation that equates the nominal yields of the two instruments. See also Fleckenstein, Longstaff and Lustig (2013) on extracting expected inflation from inflation swaps.

The three measures agree that essentially nothing happened to expected inflation over the period of the post-crisis slump. All recorded a drop around the time of the crisis, but then returned to close to pre-crisis levels despite high unemployment. This finding pretty much eliminates an idea that permeated macroeconomics over the past 50 years, that slack more or less automatically results in lower inflation. Some combination of factors in 2008 prevented the collapse of the price level that occurred, for example, in the much deeper slump following the contraction of 1929 to 1933.

Had expected inflation declined by the amounts that occurred in the earlier slumps of the past 50 years, the influence of the zero lower bound on the real interest rate would have been more severe. And if deflation at the rate experienced in 1929 to 1933 had occurred, a catastrophe similar to the Great Depression would probably have occurred. Good fortune

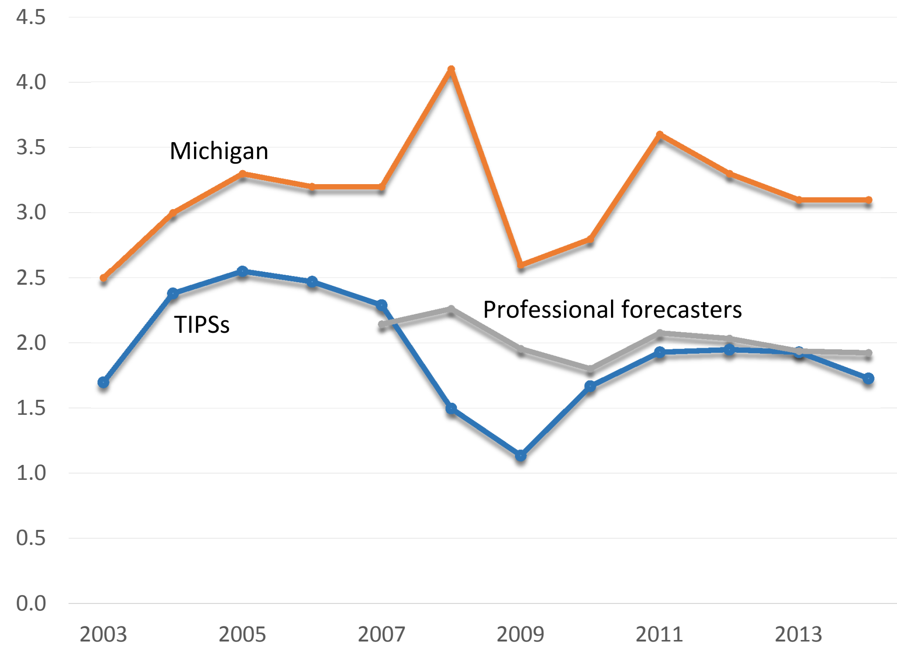


Figure 15: Inflation Expectations and Forecasts

kept expected inflation at normal levels and avoided high real interest rates and their likely adverse effects on output and employment.

In view of the importance of the inflation rate in determining the real interest rate corresponding to a zero nominal rate, the complete absence of a model of inflation is a considerable shortcoming of current macroeconomic thinking. About the best that macro modeling can do is to take expected inflation as an exogenous constant, currently around two percent. It is common for macroeconomists to say that "inflation is firmly anchored at the Fed's target of two percent" as if that amounted to a model. But it's not—at best it is an observation that expected inflation has remained at about that level despite large changes in output, employment, and other macro variables.

With exogenous, constant inflation, the bound on the nominal interest rate places a bound on the safe real rate at the nominal bound minus the rate of inflation—minus two percent in the recent slump if the nominal bound is zero; minus three percent if the nominal bound is minus one percent.

Stock and Watson (2010) studies the joint behavior of inflation and unemployment with conclusions similar to those stated here. Ball and Mazumder (2011) argue in favlor of the conventional view that inflation has a stable relation to slack.

4.3.1 Incorporating the zero lower bound in macro models

Hall (2011c) discusses the issues in modeling an economy with a safe real rate fixed above the value that would clear the output market under normal conditions. In brief, the high real rate creates the illusion of an opportunity to defer consumption spending when deferral is actually infeasible. Because of the mispricing of the benefit of saving, consumers create congestion as they try to save and defer spending. Congestion arises from the same force that slows traffic on a highway that is underpriced, so more drivers try to use it than its capacity. As a practical matter, the congestion appears to take the form of low job-finding rates and abnormally high unemployment.

Modeling of the congestion resulting from the mispricing of saving is still at a formative stage. To frame the issue, consider a simple frictionless general-equilibrium macro model with a unique equilibrium. The model will describe an equilibrium value of the short-term safe real interest rate. Now implant a central bank in the model with a policy of setting that rate at a value above the equilibrium value. In particular, suppose that the bank's interest rate is elevated by the zero lower bound. What happens in the model? It cannot have an equilibrium—its only equilibrium is ruled out by assumption. One solution in macro theory to disable one equation. Then the model has one less endogenous variable, the interest rate (made exogenous by the zero lower bound), and one less equation. One example is to drop a clearing condition for the labor market and to interpret the gap between labor supply and labor demand as unemployment. When the central bank sets a rate above equilibrium, labor demand will fall short of labor supply and unemployment will be above its normal level. This approach has some practical appeal and often gives reasonable answers.

A closely related approach is to place the demand gap in the product market. Krugman (1998) and Korinek and Simsek (2014) are examples of that approach. Farhi and Werning (2013) present a general analysis of demand gaps, where any set of prices and wages can be jointly restricted and gaps can occur in any market.

The New Keynesian tradition takes a different and more subtle approach to this issue by adding the price level as another endogenous variable without any corresponding equation. The model has demand gaps in the product market associated with temporarily sticky prices that adjust over time to close the gaps. Eggertsson and Krugman (2012) and Christiano, Eichenbaum and Rebelo (2011) apply the NK model to the zero lower bound issue. One branch of the NK literature—notably Walsh (2003), Gertler et al. (2008), and, most recently, Christiano et al. (2013)—uses the Diamond-Mortensen-Pissarides framework to describe the labor market, so the only role of demand gaps in in the product market.

Hall (2014c) tackles the congestion issue directly, in the DMP setup. Both the output and labor markets suffer from congestion when the central bank elevates the real rate above the market-clearing level. The central bank's acceptance of deposits at the elevated real rate creates an outside option in the product-price bargain that creates slack according to standard DMP principles.

In general, a model that combines the DMP view of unemployment with a real interest rate held above its market-clearing level will incorporate an additional variable, analogous to congestion in the highway case, that changes the DMP unemployment rate and the demand-gap rate until they are equal. To be concrete about that variable, suppose it is matching efficiency. A decline in efficiency increases hiring cost, raises the cost of labor, lowers the demand for labor, and raises demand-gap unemployment. The decline in efficiency lowers the job-finding rate and raises the DMP unemployment rate. The second effect is robust in the DMP model and presumably exceeds the effect on demand-gap unemployment. In equilibrium, unemployment is less than demand-gap unemployment would be at normal matching efficiency but higher than DMP unemployment would be at normal efficiency. The model would need to tie matching efficiency to the spread between the bank's interest rate and the rate that cleared the output and labor markets. Though this mechanism is attractive because matching efficiency did fall after the 2008 crisis, I do not have a model embodying variations in matching efficiency. The model in Hall (2014c) is rather more complicated and invokes DMP principles in both product and labor markets.

If the effect of congestion in the labor market on labor demand is small enough to be neglected, the gap between labor supply and labor demand controls unemployment. In this case, the traditional view that ignores DMP-type considerations applies. In that case, the general-equilibrium model simply omits the DMP-based equations. In the background, labor-market congestion fluctuates to bring unemployment into line with the level dictated by product demand. In the model laster in this chapter, I take this approach as an interim solution pending development of fully articulated models of congestion induced by above-equilibrium real interest rates.

Michaillat and Saez (2014) build a model of labor- market congestion that differs from the DMP model in one crucial respect—it lacks a resource decision to control the tightness of the market. In the DMP model, recruiting effort determines the tightness of the labor market. Employers expand recruiting effort until the payoff to creating an incremental vacancy equals the expected recruiting cost. In a simple real business-style macro model with a DMP labor market, equilibrium is determinate. By contrast, in the model of Michaillat and Saez, the corresponding basic model is indeterminate. It has a continuum of equilibria indexed by the real interest rate, with tightness depending on that rate. A monetary intervention that sets the real interest rate picks out one of those equilibria. Adding that monetary intervention to the DMP-based model would make it over-determined.

This discussion presupposes that the central bank can set any path it chooses for the real interest rate. Friedman (1968) reached the opposite conclusion. In his view, a bank that tried to keep the real rate below the market-clearing level would cause exploding inflation (the case that concerned him in 1967), and a policy aiming to keep the real rate above the market-clearing level presumably would cause exploding deflation. Recent experience does not bear his prediction out—the lower bound froze the safe real rate at around minus two percent because expected inflation remained unchanged at around two percent per year. Our lack of understanding of inflation stands in the way of fully satisfactory modeling of central bank policies that control the real interest rate.

See also Attanasio and Weber (1995), Correia, Farhi, Nicolini and Teles (2010), Eggertsson and Krugman (2011), Cochrane (2014), Hall (2014c), and Eggertsson and Mehrotra (2014)

4.3.2 The zero lower bound and product demand

The zero lower bound, together with low expected inflation, has prevented central banks from lowering interest rates as much as would seem to be appropriate. Lower rates should stimulate output and employment. The Federal Reserve and the Bank of Japan have kept rates slightly positive since the crisis, while the European Central Bank did the same until recently, when it pushed the rate just slightly negative. All three economies had combinations of high unemployment and substandard inflation that unambiguously called for lower rates, according to standard principles of modern monetary economics. Under normal conditions, fluctuations in product demand are not a source of important fluctuations in output and employment, because interest rates change as needed to clear those markets. Under almost any view of purposeful monetary policy, the central bank adjusts its policy rate to accommodate those demand fluctuations. But the zero lower bound is an exception to that principle. Economies with low inflation rates and low equilibrium real interest rates run the danger of episodic slumps when the lower bound is binding.

In the slump that began in 2008, three driving forces for product demand appeared to be important: Rising discounts, tightening lending standards to businesses, and tightening lending standards to households. All three of these declines may also reflect the rising importance of another driving financial frictions. Other sources could be declining government purchases and transfers and declining export demand. In the recent slump, government purchases fell slightly relative to trend, transfers rose dramatically, and exports fell.

4.3.3 Discounts

As documented elsewhere in this section, discounts applied to future risky cash flows appeared to rise dramatically during and immediately after the financial crisis. Basic principles of investment theory hold that purchases of new capital goods decline when discounts rise. In fact, all three major categories of investment fell sharply: (1) business purchases of new plant, equipment, and intellectual property, (2) residential construction, and (3) autos and other consumer durables. Eggertsson and Krugman (2012) describe how a rise in discounts pushes the economy into a regime where the zero lower bound binds.

4.3.4 Lending standards to businesses

Survey data show unambiguously that bank officials believe that they tightened lending standards after the crisis. It remains controversial whether the tightening is an independent driving force or just a symptom of other adverse forces. Chodorow-Reich (2014), using data on individual bank-borrower relationships, argues for a separate role for tightening standards. Tighter standards may also be a driving force for the sharp decline in residential construction, given the dependence of major house-builders on bank lending.

4.3.5 Lending standards to households

Survey data also show a belief that lending standards to households tightened, for mortgages, loans against home equity, and unsecured borrowing (mostly credit cards). Mian and Sufi (2010) use detailed geographic data to argue that household credit restrictions caused declines in consumption. Mian and Sufi (2012), Mian, Rao and Sufi (2013), and Dynan (2012) document the relation between economic activity and household debt. See also Blundell, Pistaferri and Preston (2008), Petev, Pistaferri and Eksten (2011), and Nardi, French and Benson (2011)

5 Fiscal driving force and multiplier

The multiplier is the derivative of total GDP or a component, such as consumption, with respect to an exogenous shift in product demand. The obvious source of such a shift is government purchases, but the same multiplier describes the propagation of other shifts in product demand, notably those induced by changes in household access to credit.

Ramey (2011a) is a recent survey of the literature on the multiplier. See also Coenen, Erceg, Freedman, Furceri, Kumhof, Lalonde, Laxton, Lind, Mourougane, Muir, Mursula, de Resende, Roberts, Roeger, Snudden, Trabandt and in't Veld (2012), Shapiro and Slemrod (2009), Spilimbergo, Symansky and Schindler (2009), Hall (2009), Barro and Redlick (2011), Johnson, Parker and Souleles (2009), Kaplan and Violante (2011), Ramey (2011b), and Parker, Souleles, Johnson and McClelland (2011)

6 Other issues

6.1 Decline in the labor share

Economists have pursued multiple explanations of the decline, but no consensus has formed. Rognlie (2015) provides a comprehensive discussion of this topic. See also Karabarbounis and Neiman (2014).

6.2 Time Use

Some indication about the changing balance between work and other uses of time comes from the American Time Use Survey, which began in 2003. Table 2 shows the change in weekly hours between 2003 and 2013 in a variety of activities. For men, the biggest change by far is the decline of 2.5 hours per week at work, a big drop relative to a normal 40-hour work week. A small part of the decline is attributable to higher unemployment—the unemployment rate was 6.0 percent in 2003 and 7.4 percent in 2013. The decline for women is much smaller, at 0.8 hours per week. For both sexes, the big increases were in personal care (including sleep) and leisure (mainly video-related activities). Essentially no change occurred in time spent in

	Personal care	*Household work*	*Market work*	*Education*	*Leisure*	*Other*
Men	1.3	0.1	-2.5	0.2	1.3	-0.4
Women	1.6	-0.7	-0.8	-0.1	0.8	-0.8

Table 2: Changes in weekly hours of time use, 2003 to 2013, people 15 and older

education. Women cut time spent on housework. See also Aguiar, Hurst and Karabarbounis (2013).

7 A Model

Most macro-fluctuations models omit slower-moving driving forces and are correspondingly estimated or calibrated to data filtered to remove slower movements. Growth models generally omit cyclical and medium-frequency driving forces. A small literature—notably including Comin and Gertler (2006)—deals explicitly with medium-frequency driving forces and corresponding movements of key macro variables. That paper focuses on technology and productivity. The model developed here considers other medium-frequency driving forces, such as labor-force participation and discounts. Hall (2005) discusses evidence of the importance of medium-frequency movements and argues against the suitability of superimposing a high-frequency business-cycle model on an underlying growth model. Instead, a unified model appears to be a better approach.

The model is inherently non-stationary–its labor force grows randomly and so does productivity. Solution methods widely used for stochastic macro models, either near-exact solutions using projection methods or approximate solutions based on log-linearization, require that models be restated in stationary form. I take a different approach. The model has random driving forces that are functions of a Markov discrete state. Over a finite horizon the model has an event space with a large but finite set of nodes. Models with this structure are widely used in finance and banking. I find essentially exact solutions for the contingent values of continuous state variables and other key macro variables at each node. Finance models, such as the binary option-pricing model, have backward-recursive solutions, but macro models require solving the entire model as a system of simultaneous equations.

Recursive models are highly sparse, and solution methods that fully exploit the sparseness are fast.

7.1 Specification

The equations of the model are the familiar first-order conditions for optimization by the decision makers in the model and laws of motion of the state variables, together with initial and terminal conditions. The framework does not require that the model be recursive, though the model here is actually recursive—it can be expressed in equations that consider only three dates: *Now*, for example, k, *Soon*, for example, k', and *Later*, for example, k''. Each value *Now* branches stochastically into N values in the *Soon* period and N^2 values in the *Later* period. Here N is the number of states in the discrete Markov process. The economy operates for T periods. Given initial and terminal conditions, an equilibrium is a set of $\sum_{t=1}^{T} N^t$ values of each of the endogenous variables, satisfying the equations of the model. For T=8 and $N = 4$, the model has 11,000 contingent unknown values of capital and labor input and takes about 6 minutes to solve on a recent-vintage PC.

The driving forces of the model are:
a: increment to total factor productivity
l: increment to the labor force
d: discount or confidence
z: product-market wedge arising from market power
g: government purchases of goods and services
f: financial agency friction

The continuous state variables are:
k: physical capital stock (endogenous)
A: total factor productivity (exogenous)
L: labor force (exogenous)

Endogenous variables that are functions of the state variables are:
y: output
n: employment
c: consumption

q: Tobin's q, the value of installed capital

r: the realized return to holding installed capital

r_f: the safe real interest rate

$\tilde{m}$: marginal utility of consumption, as biased by discount or confidence

m: actual marginal utility

x: the marginal revenue product of labor

b: a variable taking the value 1 when the safe real rate is held at a level different from the market-clearing rate.

The laws of motion of the state variables are:

$$\text{Prob}[s'|s] = \pi_{s,s'}. \tag{7}$$

$$k' = y' + (1 - \delta)k - c' - g'. \tag{8}$$

$$A' = \exp(a)A. \tag{9}$$

$$L' = \exp(l)L. \tag{10}$$

The other equations are:

$$y = An^{\alpha}k^{1-\alpha}. \tag{11}$$

$$q' = \kappa\left(\frac{k'}{k} - 1\right) + 1. \tag{12}$$

$$r' = \frac{(1-\alpha)\frac{y}{zk} + (1-\delta)q'}{q} - f - 1. \tag{13}$$

$$\tilde{m}' = (c' - d)^{-1/\sigma}. \tag{14}$$

$$m = c^{-1/\sigma}. \tag{15}$$

$$x = \alpha\frac{y}{zn}. \tag{16}$$

$$\mathbb{E}\ [tildem' - \beta(1+r'')m''] = 0. \tag{17}$$

$$\mathbb{E}\ [tildem' - \beta(1+r_f'')m''] = 0. \tag{18}$$

$$b \cdot (r_f - \bar{r}_f) = 0. \tag{19}$$

$$n = (1-u)L. \tag{20}$$

$$(1-b)\ \mathbb{E}\ \left[\tilde{m}' n_0 \left(\frac{1-u'}{u'}\right)^{\eta} x'^{\psi} - \beta m'' x''^{\omega}\right] = 0. \tag{21}$$

The model incorporates the assumption that investment and hiring decisions are made one period in advance. Time to build applies to both physical capital and an employer's workforce. In the Euler-capital-pricing equation (17), decisions made *Now* influence stochastic marginal utility *Soon* and *Later*; optimization calls for equating the two after accounting for impatience and the return to physical capital. The driving force d_s, interpreted as a discount, fear, or lack of confidence, biases marginal utility upward.

Equation (21) incorporates the idea that hiring is a form of investment, as in the Diamond-Mortensen-Pissarides model of the labor market. As with other forms of investment, the discount rate influences hiring, as discussed with citations in Hall (2014a). The equation also takes the marginal revenue product of labor as the measure of the benefit of a hire—subject to variation through changes in market power as in Rotemberg and Woodford (1999), stated in DMP terms in Walsh (2003).

The expectation operator $\mathbb{E}$ is the expectation as of *Now* over the *Soon* and *Later* states, with probabilities determined by the Markov process. For example, the Euler-capital-pricing equation (17) is

$$\sum_s \sum_{s'} \pi_{s,s'} \pi_{s',s''} [m' - \beta(1+r'')m''] = 0. \tag{22}$$

Although the indicator variable b for a constraint on the safe real rate—such as the zero lower bound—is in principle endogenous, I currently solve the model with the same value in every period. Thus I present one set of results for an economy with $b = 0$, where the safe short rate takes on a market-clearing value and another set where it is zero. The second set

State	*TFP growth*	*Discount*	*Labor-force growth*	*Wedge*	*Periods in state*
1	H	L	L	L	1952-53, 1954-55, 1958-59, 1962-63, 1988-89, 1990-91, 1996-97, 1998-99
2	H	L	H	L	1956-57, 1960-61, 1964-65, 1966-67, 1968-69, 1970-71, 1986-87, 2000-1
3	L	H	L	H	1982-83, 1992-93, 1994-95, 2004-5, 2006-7, 2008-9, 2010-11, 2012-13
4	L	H	H	H	1972-73, 1974-75, 1976-77, 1978-79, 1980-81, 1984-85, 2002-3

Table 3: The States of the Model

describes an economy at the zero lower bound of the safe short-term nominal rate with zero expected inflation.

7.2 Application to the U.S. economy

Given the interest in medium-term fluctuations, I define the time period of the model to be two years. Table 3 shows the discrete states of the model, in terms of the values of four of the driving forces. It also shows the classification of periods by state. I constructed the states by calculating the first two principal components of the data:

- TFP growth, from Fernald (2012), without utilization adjustment
- Discount, from Hall (2014a)
- Two-year log labor-force growth, from BLS series LNS11000000, civilian labor force
- Product-market wedge, following Bils et al. (2014), calculated as the residuals from a two-year ahead forecast of the log of the materials/revenue ratio

In a row in the table, H refers to values of a variable above its median in the state corresponding to that row and L to value below. For example, in state 1, TFP growth is high and the other three driving forces are low. The states are, roughly,

		To state				Ergodic probability
		1	2	3	4	
From state	1	0.38	0.50	0.13	0.00	0.21
	2	0.38	0.38	0.00	0.25	0.22
	3	0.14	0.00	0.71	0.14	0.33
	4	0.00	0.14	0.29	0.57	0.24

Table 4: Transition Matrix and Ergodic Distribution

1. Favorable value of TFP growth, the discount, and the wedge, but low labor-force growth
2. Favorable values of all driving forces
3. Unfavorable values of all driving forces
4. Unfavorable values of TFP growth, the discount, and the wedge, but high labor-force growth

Table 4 shows the two-year transition matrix among the four states together with the ergodic probabilities of the states. Figure 16 describes the persistence of the four states. The vertical position of each line is the difference between the probability of being in the given state in a given year and the ergodic probability of the state, starting with certainty in the given state in year 0. For example, if the process starts in state 3, with an ergodic probability of 0.33, the excess probability starts at 0.67. It drops to 0.24 two years later, and quickly falls to its baseline level of zero excess probability in the following periods. All four of these impulse response functions are similar, because they are all controlled by the largest eigenvalue of the transition matrix.

Figure 17 shows the impulse-response functions of the model's driving forces, defined as follows: For productivity, the discount, and the wedge, compare the expected values of the variables conditional on 50-percent probabilities of being in states 1 and 2 with the expected values conditional on being distributed across all four states according to the ergodic distribution. The result is the response to a shock taking the economy from an average state to a favorable state (1 or 2). For the labor force, do the same, but compare states 2 and 4 to the average state, to capture the response to a shock that raises the size of the labor force. The top left plot shows one of the exogenous state variables, total factor productivity

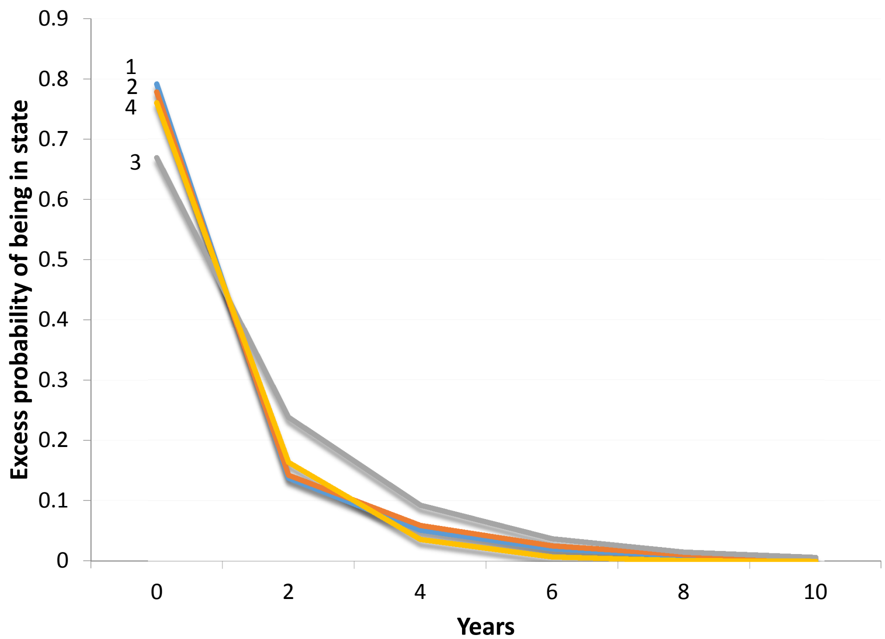
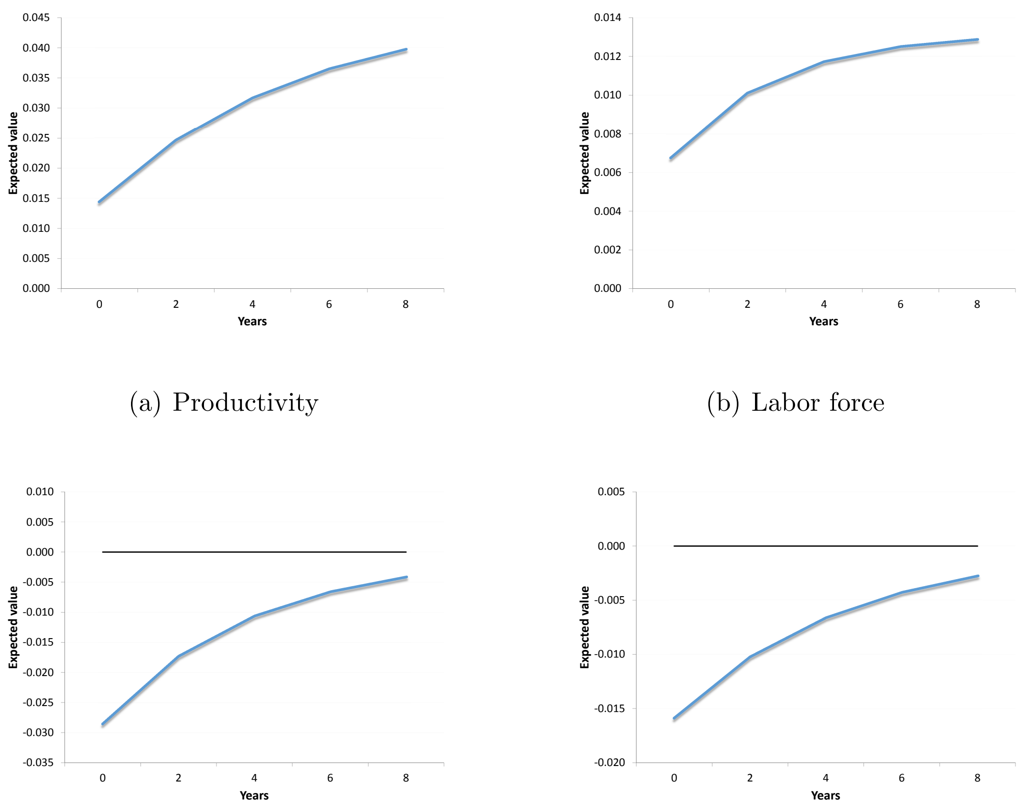


Figure 16: Persistence of the States

A. It cumulates to a long-run effect more than twice as large as the immediate effect. The top right plot shows the labor force L. Following a shock, it cumulates as well, to twice its initial effect. On the other hand, the discount and the wedge revert to zero in large measure by four years after the shock.

The next six figures, Figure 18 through Figure 23, describe the key properties of the model. Each figure shows the responses of key endogenous variables to one of the six driving forces. The graph on the left describes the model with a market-clearing short term safe real rate and the graph on the right describes the model with the rate fixed at zero. The three lines in each graph show the responses of consumption, the capital stock, and employment. The lines show the response as a ratio to the underlying movement of the driving force, as shown in Figure 17

Figure 18 shows the effects of a productivity shock. On the left, with a market-clearing safe rate, consumption and capital rise over all the years shown. In the later years, productivity itself flattens, as shown in Figure 17, but consumption and capital grow even faster than in the earlier years. Propagation occurs via the capital stock. Effects on employment are small. On the right, with the safe rate fixed at zero, employment rises upon the productivity shock and then subsides to normal. Propagation occurs through the capital stock, but



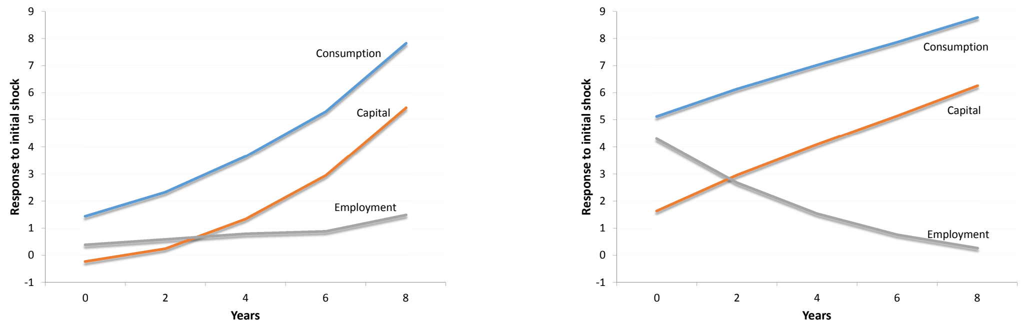
(a) Productivity

(b) Labor force

(c) Discount

(d) Wedge

Figure 17: Responses of Driving Forces to Their Own Shocks



(a) Market rate

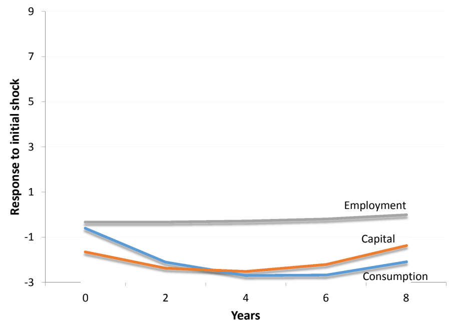
(b) Fixed rate

Figure 18: Responses of Endogenous Variables to a Productivity Shock

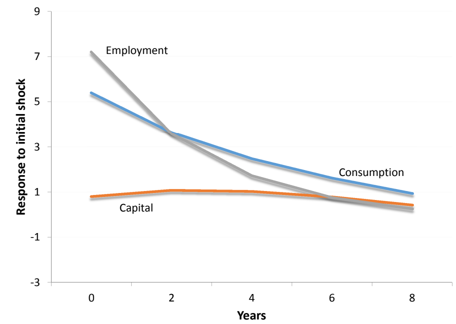
the upward slope of consumption is lower because output does not rise as steeply thanks to the decline in employment.

In the aftermath of the financial crisis of 2008, the process shown in Figure 18(b) operated in reverse. Low productivity growth resulted in a drop in employment, a slowdown in capital formation and a growing decline in consumption. Figure 7 earlier in the chapter showed the slowdown in capital formation, part of which was attributable to lower productivity growth. Whether the decline in productivity growth was the result of the crisis is a matter of debate.

Figure 19 shows the responses to a positive, unfavorable shock to the discount. Under normal conditions, equation (21) governs the determination of unemployment. The higher discount results in higher marginal utility in the *Soon* state. Thus unemployment rises and output falls. Households try to offset high d with higher c'. As they do so, they drive up r'', which also helps satisfy equation (17). Investment declines, so capital begins to fall. Output falls and drags down consumption. These effects are reversed starting around year 4. With a fixed safe rate, the responses are totally different. Equation (21) is longer in effect. Instead, equation (18) with $r'' = 0$ calls for an increase in consumption to lower $\tilde{m}'$. The increase in product demand in the *Soon* period results in lower unemployment, higher employment, higher output, and higher consumption, with little effect on capital. All of these effects subside as the shock subsides—there is little propagation because of the small effect on the capital stock. This response seems farfetched. I believe that it shows that the assumption of perfectly elastic supply of output with a fixed safe short-term real interest rate is incorrect.

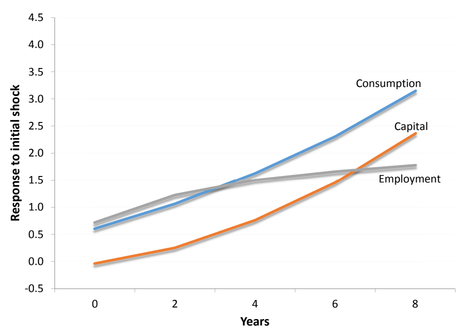


(a) Market rate

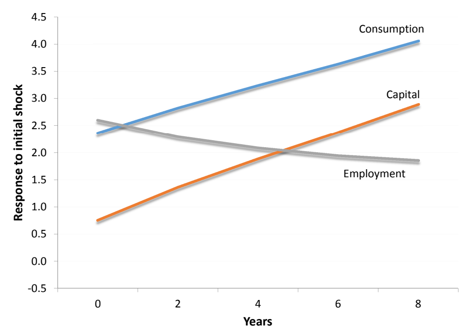


(b) Fixed rate

Figure 19: Responses of Endogenous Variables to a Discount Shock



(a) Market rate



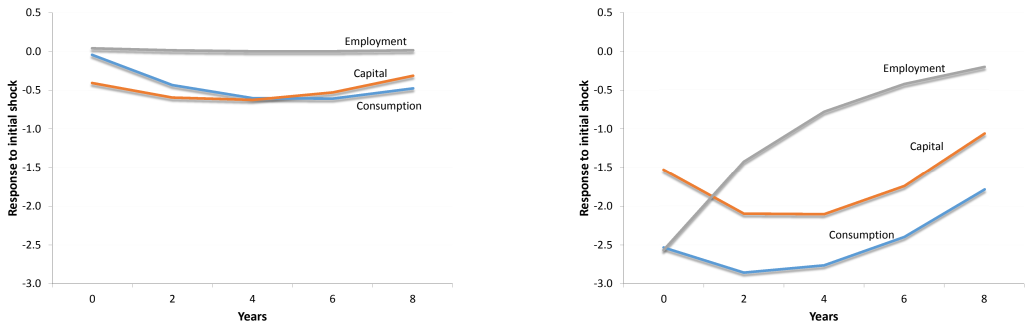
(b) Fixed rate

Figure 20: Responses of Endogenous Variables to a Labor-Force Shock

Figure 20 shows the model's responses to a labor-force shock. These responses are similar to those in Figure 18 for a productivity shock, not surprisingly, as both shocks add to the capacity to produce output. Naturally, the effect on employment is larger and permanent, as the shock results in a permanent rise in the labor force. With the interest rate fixed at zero, the immediate effect on employment is larger than the longer-run effect.

In the slump after the financial crisis, a pronounced and apparently permanent decline in the labor force occurred. According to the model, this decline was a contributor to the decline in employment after the crisis.

Figure 21 shows the model's response to an upward, unfavorable shock to the financial friction. I have not yet settled on an empirical measure of the friction, so these results are



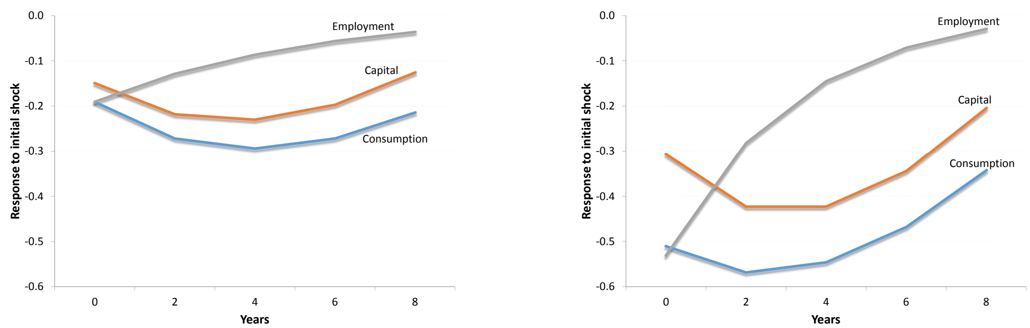
(a) Market rate (b) Fixed rate

Figure 21: Responses of Endogenous Variables to a Financial-Friction Shock

based on the assumption that the friction is $f = 0.05$ in states 1 and 2 and zero in states 3 and 4. This assumption implies that the own-shock IRF resembles the one for the discount. With a market-clearing safe interest rate, the friction shock causes a decline in investment, which cumulates into a persistent decline in capital, reaching a trough 4 years after the shock. Consumption rises a bit initially, but then declines as output declines. The shock has little effect on employment. These results are consistent with ones reported for a dynamic model without uncertainty in Hall (2011a).

Figure 21(b) shows quite different results for the financial-friction shock in an economy with a fixed real interest rate. The shock depresses investment. The decline in the investment component of product demand raises unemployment, which is free from determination by DMP principles. Employment returns close to normal as the friction disappears, but capital remains depleted even 8 years after the shock, so consumption also remains low.

Figure 23 shows the responses to an adverse upward shock to the product-market wedge—the driving force associated with the sticky-price New Keynesian model that dominates most recent discussions of macro fluctuations. With a market-clearing interest rate, on the left, employment falls when the shock hits, though not by much. Both investment and consumption fall. Employment returns to normal as the effects of the shock on the wedge subside, but capital returns only about halfway to normal and consumption recovers even less. Here again propagation effects operating through the capital stock are important. With a fixed interest rate, the qualitative effects are similar, but the magnitudes of the effects are about twice as large.



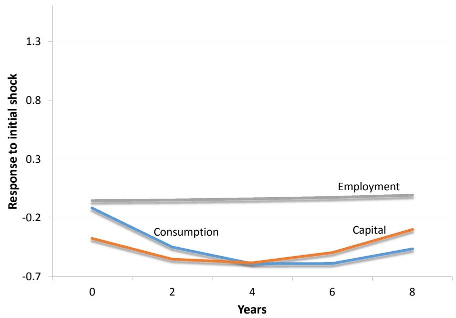
(a) Market rate

(b) Fixed rate

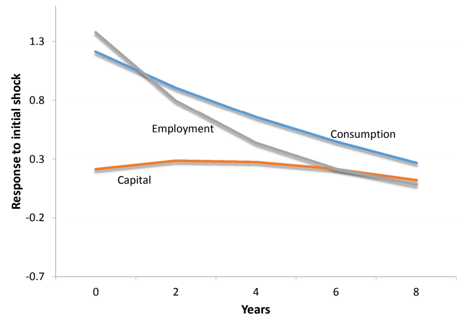
Figure 22: Responses of Endogenous Variables to a Product-Market Wedge Shock

Figure 23 shows the responses to an increase in product demand taking the form of an increase in government purchases. As in the case of the financial friction, I lack a firm basis for determining the persistence of this driving force, so I take it to be the same as for the discount driving force. The vertical axis in the graphs is interpreted as a conventional multiplier, the change in the level of a variable divided by the change in g. On the left, with the market-clearing interest rate, the consumption multiplier on impact is –0.1 and the investment multiplier is –0.4, so the output multiplier is $1 - 0.1 - 0.4 = 0.5$, in line with model-based values—see Hall (2009). As the shock fades, the negative effects on capital and consumption grow to a maximum at 4 years, after which the adverse effects begin to wear off. The shock has essentially no effect on employment.

In Figure 23(b), with a fixed interest rate, the effects are quite different. The shock to product demand raises employment substantially. On impact, the consumption multiplier is1.2 and the capital multiplier is 0.2, so the output multiplier is $1 + 1.2 + 0.2 = 2.4$, in line with values found in **?**, the leading analysis of this issue in a New Keynesian framework. I emphasize that this finding is conditional on the specification that assumes that the congestion effect from a safe real rate that is fixed above the market-clearing level has no effect on labor demand. This assumption leads to the treatment of unemployment as a residual separating labor supply from labor demand and removes any influence of the DMP model's determination of unemployment.



(a) Market rate



(b) Fixed rate

Figure 23: Responses of Endogenous Variables to a Product-Market Demand Shock

7.3 Propagation

I noted earlier that a model propagates the effect of a driving force if the effects of the driving force persist longer than does the driving force itself. The discussion in the previous subsection flagged a number of prominent instances of propagation. To measure propagation more systematically, I calculate a *propagation ratio*. This calculation forms a sequence by dividing (1) the impulse response function relating an endogenous variable to a shock in a driving force by (2) the impulse response function relating the driving force to its own shock. The ratio is defined as the ratio of the sum of the values of the sequence for 6 and 8 years to the sum of the value for 0 and 2 years. If the effects of the shock on the driving force die out faster than the effects of the shock on the endogenous variable, the ratio will be high and will indicate substantial propagation in the model for the effect of that driving force on that endogenous variable.

Table 5 shows the propagation ratios for the effects of the driving forces on consumption, capital, and employment. For all three variables, TFP, in the case of a market interest rate, has large amounts of propagation, especially for capital. In the first two periods, the shock to TFP has essentially no effect on capital. In the last two periods shown, 6 years and 8 years, the shock has large effects, so the ratio is close to infinite. This example is extreme. The ratio for consumption is 3.5 and for employment, 2.4. These propagation effects operate through the capital stock. With a fixed interest rate, propagation is not as strong, but still substantial for consumption and capital. Labor-force shocks also receive large amounts of

Driving force	*Interest rate*	*Endogenous variable*		
		Consumption	*Capital*	*Employment*
TFP	Market	3.5	449.2	2.4
	Fixed	1.5	2.5	0.1
Discount	Market	1.8	0.9	0.3
	Fixed	0.3	0.6	0.1
Labor force	Market	3.3	17.5	1.8
	Fixed	1.5	2.5	0.8
Financial friction	Market	2.3	0.8	0.3
	Fixed	0.8	0.8	0.2
Product market wedge	Market	1.1	0.9	0.3
	Fixed	0.8	0.8	0.1
Government purchases	Market	1.9	0.9	0.3
	Fixed	0.3	0.7	0.1

Table 5: Propagation Ratios by Driving Force, Interest Rate, and Endogenous Variable

propagation through capital effects. In general, propagation is stronger with market interest than with fixed interest.

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