

Investment Hangover and the Great Recession[†]

By MATTHEW ROGNLIE, ANDREI SHLEIFER, AND ALP SIMSEK*

We present a model of investment hangover motivated by the Great Recession. Overbuilding of durable capital such as housing requires a reallocation of productive resources to other sectors, which is facilitated by a reduction in the interest rate. When monetary policy is constrained, overbuilding induces a demand-driven recession with limited reallocation and low output. Investment in other capital initially declines due to low demand, but it later booms and induces an asymmetric recovery in which the overbuilt sector is left behind. Welfare can be improved by ex post policies that stimulate investment (including in overbuilt capital) and ex ante policies that restrict investment. (JEL E22, E23, E32, E43, E52, R21, R31)

After 2008, the US economy went through the worst macroeconomic slump since the Great Depression. Real GDP per capita declined from more than \$49,000 in 2007 (in 2009 dollars) to less than \$47,000 in 2009, and surpassed its prerecession level only in 2013. The civilian employment ratio, which stood at about 63 percent in January 2008, fell below 59 percent by the end of 2009, and remained below 59.5 percent by the end of 2015.

Recent macroeconomic research emphasizes the boom-bust cycle in house prices—and its effects on financial institutions, firms, and households—as the main culprit for these developments. The collapse of home prices arguably affected the economy through at least two principal channels. First, financial institutions that suffered losses related to the housing market cut back their lending to firms and households (Brunnermeier 2009, Ivashina and Scharfstein 2010). Second, homeowners who had borrowed against rising collateral values during the boom faced tighter borrowing constraints and had to reduce their outstanding leverage (Eggertsson and Krugman 2012, Mian and Sufi 2014b, Guerrieri and Lorenzoni 2017). Both

*Rognlie: Department of Economics, Northwestern University, 2211 Campus Drive, Evanston, IL 60208 (email: matthew.rognlie@northwestern.edu); Shleifer: Department of Economics, Harvard University, Littauer Building, Cambridge, MA 02138, and NBER (email: shleifer@fas.harvard.edu); Simsek: Department of Economics, MIT, Building E52, Cambridge, MA 02142, and NBER (email: asimsek@mit.edu). We thank Jennifer La’O, John Leahy, Guido Lorenzoni, Monika Piazzesi, Giacomo Ponzetto, Ricardo Reis, John Shea, Nancy Stokey, Michael Woodford, and Kamil Yilmaz for helpful comments. We also thank the seminar participants at the BIS, Columbia University, Cornell University, Georgetown University, the Institute for International Economic Studies, London Business School, MIT, Northwestern University, Norwegian Business School, Princeton University, the Sveriges Riksbank, Stanford University, the University of Chicago; and the conference participants at the Bank of Portugal Conference on Monetary Economics, the CSEF-CIM-UCL Conference, Koc Winter Workshop, the SED Annual Meeting, and the NBER Summer Institute for their comments. Masao Fukui provided outstanding research assistance. Simsek acknowledges support from the NSF under Grant Number SES-1455319. The authors declare that they have no relevant or material financial interests that relate to the research described in this paper.

[†]Go to <https://doi.org/10.1257/mac.20160211> to visit the article page for additional materials and author disclosure statement(s) or to comment in the online discussion forum.

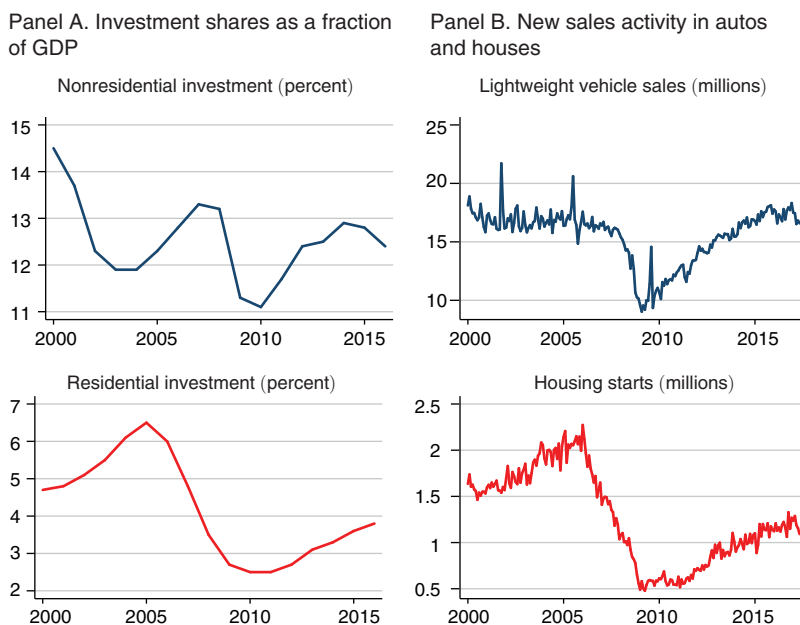


FIGURE 1

Notes: Panel A plots the two components of investment in the United States as a share of GDP. Panel B plots new sales of autos and light trucks (top) and housing starts (bottom).

Source: US Bureau of Economic Analysis and US Bureau of the Census, retrieved from St. Louis Fed

channels reduced aggregate demand, plunging the economy into a Keynesian recession. The recession was exacerbated by the zero lower bound (ZLB) on the nominal interest rate, also known as the liquidity trap, which restricted the ability of monetary policy to counter demand shocks (Hall 2011; Christiano, Eichenbaum, and Trabandt 2015).

A growing body of evidence shows that these views are at least partially correct: the financial and the household crises both appear to have played a part in the Great Recession.¹ But these views also face a challenge in explaining the nature of the recovery after the Great Recession. The recovery has been quite asymmetric across components of aggregate private spending. As panel A of Figure 1 illustrates, nonresidential investment—measured as a fraction of output—almost reached its prerecession level by 2015, while residential investment remained depressed. One explanation for this pattern is that households were unable to buy homes due to ongoing deleveraging. But panel B of Figure 1 casts doubt on this explanation: sales of durables not directly related to housing such as cars—which should also be affected by household deleveraging—rebounded strongly while sales of new homes lagged behind. Another potential explanation is that US residential investment generally

¹Several recent papers, such as Campello, Graham, and Harvey (2010) and Chodorow-Reich (2014), provide evidence that financial crisis affected firms' investment before 2010. Mian, Rao, Sufi (2013) and Mian and Sufi (2014a, b) provide evidence that household deleveraging reduced household consumption and employment between 2007 and 2009.

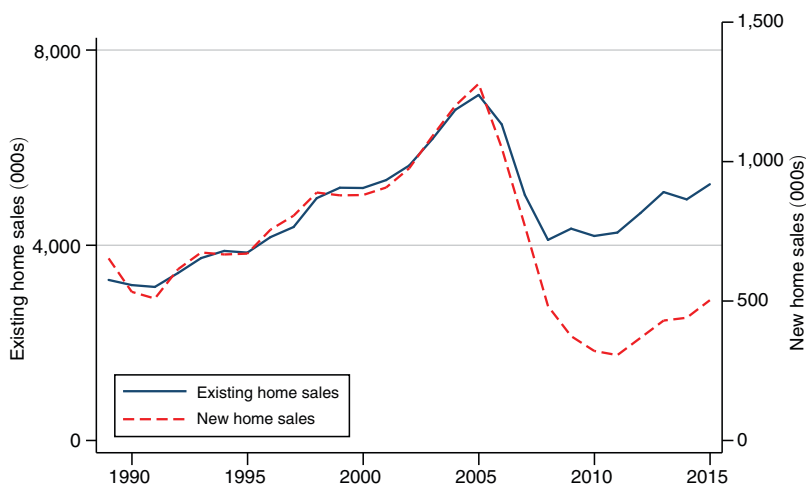


FIGURE 2

Notes: The dashed curve plots the new one family homes sold in the United States (seasonally adjusted annual rate). The solid curve plots the existing home sales in the United States (seasonally adjusted annual rate).

Source: FRED (2000–2016) and National Association of Realtors (2017)

lags behind in recoveries. This explanation is also incorrect: Leamer (2007) analyzes the post-war recessions in the United States and shows that residential investment typically recovers before nonresidential investment and other consumer durables.

In this paper, we supplement these two accounts of the Great Recession with a third channel, which we refer to as the *investment hangover*. Our key hypothesis is that there was also an *investment boom* in the housing market in addition to the price boom, which led to an overbuilding of housing capital by 2005. This hypothesis is supported by economic theory as well as empirical evidence. Standard investment theories (e.g., the Q theory) suggest that an asset price boom driven by optimism about asset valuations should also be associated with an investment boom. Moreover, once the valuations are revised downwards, past investment would appear excessive in retrospect—which is what we refer to as overbuilding. Consistent with theory, Figure 1 illustrates a sharp increase in residential investment, and housing starts before 2005. Since housing capital is highly durable, it was arguably overbuilt by the Great Recession (see Section IVB for further empirical support for this hypothesis).

Motivated by our hypothesis, we develop a stylized macroeconomic model to analyze how the economy behaves after overbuilding a durable type of capital—such as housing, structures, or infrastructure (e.g., roads or railroads). Our model's first prediction is that investment in overbuilt capital declines. Intuitively, an excess of initial stock substitutes for new investment. Figure 2 provides evidence from the Great Recession consistent with this prediction. The sales of newly constructed homes, which have historically changed in proportion to the sales of existing homes, fell disproportionately starting around 2005.

Of course, the challenge for a macroeconomic model is to understand why not only housing, but other investment as well as consumption also fell in the Great Recession. In principle, the flow of resources out of housing investment would reduce interest rates and lead to a boom in other investment and consumption. In our view, monetary policy plays a central role in this aggregate reallocation mechanism. If inflation cannot increase in the short run—an assumption that we maintain—then the real interest rate can fall and counter the demand shock only if monetary policy lowers the nominal interest rate. In practice, many constraints on monetary policy might prevent this from happening. In the aftermath of the Great Recession, monetary policy in developed economies was constrained by the zero lower bound on the nominal interest rate. In economies with fixed exchange rates (e.g., the eurozone), or exogenously determined money supply (e.g., the gold standard), monetary policy is often constrained even if the nominal interest rate is above zero. We show how these types of constraints undermine the aggregate reallocation mechanism. If the initial overbuilding is sufficiently large, then the interest rate does not decline sufficiently and overbuilding induces a demand-driven recession.

Our model shows how a slowdown in the overbuilt sector naturally spills over to other sectors. The recession reduces the return to other types of capital—such as equipment and machines—which were not necessarily overbuilt but are used in the production of overbuilt capital. Thus, other types of investment can also decline, in line with the acceleration principle of investment (Samuelson 1939), despite the low cost of capital implied by the low interest rate. As the economy decumulates the overbuilt capital, other investment recovers in anticipation of a recovery in output. Through the lens of our model, then, the recession can be roughly divided into two phases. In the first phase, all types of investment decline, generating a severe and widespread slump. In the second phase, investment in overbuilt capital remains low but other investment increases, generating a partial recovery. In the context of the Great Recession, this implies that housing investment is left behind in the recovery, as in Figure 1.

We attempt a quantitative evaluation of the model during the Great Recession. To begin, we provide an accounting exercise that decomposes the decline in output into various components of demand, including residential investment, nonresidential investment, and consumption. We then calibrate the model, and find that using a housing starts shock from Haughwout et al. (2013) and fairly standard parameter estimates, our model can match the path of housing prices and investment, but does not generate an overall recession. We then augment the model with two other plausible shocks—one to the risk premium and one to household leverage—and show that a calibrated version of the augmented model generates an overall recession. Moreover, the calibrated model matches the demand-side accounting results for the Great Recession reasonably well. The overbuilding shock generates a sizable cumulative decline in output, in addition to explaining the asymmetric recovery of housing and nonhousing investment.

We investigate the implications of our analysis for policies directed towards regulating investment. A naïve intuition would suggest that the planner should not stimulate investment in overbuilt capital, such as housing during the Great Recession, since the problems originate in this sector. We find that this intuition is incorrect: if

the recession is sufficiently severe, then the planner optimally stimulates investment and slows down the decumulation of overbuilt capital. This result is driven by two factors. First, the planner recognizes that raising investment in a demand-driven recession stimulates aggregate demand and employment. In view of these *aggregate demand externalities*, the planner perceives a lower cost of building than does the private sector. The lower cost, by itself, is not a sufficient reason for intervention—the planner also considers the benefits. The second factor is that the return from investment in overbuilt capital need not be low—especially for long-lived capital such as housing or infrastructure. New investment will generate low flow utility in the short run but will be useful in the future. Stimulating investment in overbuilt capital is beneficial because it helps to economize on future investment.

We find that, before the economy enters the liquidation episode, it is optimal for the planner to reduce the accumulation of capital, so as to stimulate investment and aggregate demand during the recession. This result is also driven by aggregate demand externalities, and it holds as long as the agents in our model assign a positive probability to the recession (that is, the planner does not need to fully anticipate the recession to intervene). Our model suggests that the intervention is more desirable for investment in more durable types of capital, because durability is the link by which past investment affects future economic activity. Taken together, our welfare analysis supports policies that intertemporally substitute investment towards periods that feature deficient demand, especially for long-lived capital.

The rest of the paper is organized as follows. The next subsection discusses the related literature. Section I describes the equilibrium in the baseline model in which the economy decumulates the overbuilt capital in a single period. Section II characterizes this equilibrium and presents our main result that excessive overbuilding induces a recession. Section III considers a variant of the baseline model (with adjustment costs) in which the decumulation is spread over multiple periods, so as to investigate the behavior of investment within the recession. Section IV presents a quantitative evaluation of our model. Section IVA performs a demand-side accounting of the output decline in the Great Recession, and Section IVB analyzes the extent to which a calibrated version of our model can replicate the accounting results. Section V analyzes the ex post and ex ante policy implications of our analysis using variants of the baseline model. Section VI concludes. The online Appendices A, B, and C contain respectively the details of our calibration exercise, extensions of the baseline model, and the omitted proofs.

Related Literature.—Our paper makes contributions to several strands of the literature. First, we identify the ex ante overbuilding of housing as an important source of deficient aggregate demand during the Great Recession. A large literature emphasizes other types of demand shocks such as those driven by financial frictions or household deleveraging.² Other papers emphasize long-run factors that might have lowered demand more persistently (Summers 2013; Eggertsson, Mehrota, and

²See also Gertler and Karadi (2011), Midrigan and Philippon (2016), Jermann and Quadrini (2012), and He and Krishnamurthy (2014) for quantitative dynamic macroeconomic models that emphasize either banks', firms', or households' financial frictions during the Great Recession.

Robbins 2017; Caballero and Farhi forthcoming). Our paper complements this literature and provides an explanation for why residential investment has lagged behind in the recovery.

Another strand of the literature investigates the role of housing during the Great Recession, but often focuses on channels other than overbuilding. Many papers, e.g., Iacoviello and Pavan (2013), emphasize the collateral channel by which house price shocks tighten household borrowing constraints. Boldrin et al. (2016) also emphasize overbuilding, but they do not analyze the resulting deficient demand problem. Instead, they focus on the supply-side input-output linkages by which the slowdown in construction spills over to other sectors.³

Second, and more broadly, we illustrate how overbuilding durable capital can trigger a recession. As DeLong (1990) discusses, Hayekian (or liquidationist) views along these lines were quite popular before and during the Great Depression, but were relegated to the sidelines with the Keynesian revolution in macroeconomics. Our paper illustrates how Hayekian and Keynesian mechanisms can come together to generate a recession. The Hayekian mechanism finds another modern formulation in the recent literature on news-driven business cycles. A strand of this literature argues that positive news about future productivity can generate investment booms, occasionally followed by liquidations if the news is not realized (see Beaudry and Portier 2014 for a review). This literature typically generates business cycles without nominal rigidities (see, for instance, Beaudry and Portier 2004 and Jaimovich and Rebelo 2009), whereas we emphasize nominal rigidities and a demand-side channel.

In recent and complementary work, Beaudry, Galizia, Portier (BGP, forthcoming) also investigate whether overbuilding can induce a recession driven by deficient demand. In BGP, aggregate demand affects employment due to a matching friction in the labor market, whereas we obtain demand effects through nominal rigidities. In addition, BGP show how overbuilding increases the (uninsurable) unemployment risk, which exacerbates the recession due to households' precautionary savings motive. We describe how overbuilding exacerbates the recession due to the endogenous response of other types of investment.⁴

Third, our analysis illustrates how a constrained monetary policy, e.g., due to the liquidity trap or exogenous money supply, restricts the efficient reallocation of resources between sectors. A large literature investigates the role of reallocation shocks compared to aggregate activity shocks in generating unemployment (see, for

³A large literature develops quantitative business-cycle models with housing, but without focusing on the Great Recession or overbuilding, e.g., Greenwood and Hercowitz (1991); Gervais (2002); Iacoviello (2005); Campbell and Hercowitz (2005); Davis and Heathcote (2005); Fisher (2007); Piazzesi, Schneider, and Tuzel (2007); and Kiyotaki, Michaelides, and Nikolov (2011).

⁴The literature on lumpy investment has also considered the possibility of a hangover (or conversely, pent-up demand), driven by past aggregate shocks that can shift the latent distribution of firms' investment imbalances (see Caballero, Engel, Haltiwanger 1995). Thomas (2002) argued that the lumpiness, and the associated latent investment distribution, does not affect aggregate investment much once the cost of capital is endogenized. House (2014) clarified that this result is driven by the feature of standard neoclassical models—with or without lumpy investment—that the timing of investment is highly elastic with respect to the changes in cost of capital. However, most empirical evidence suggests that investment timing is not so elastic, especially over short and medium horizons (see Caballero 1999). As House (2014) also notes, "the key property of the model which generates the irrelevance results—the infinite elasticity of investment demand—is a feature of the models and may not be a feature of reality."

instance, Lilien 1982, Abraham and Katz 1986, Blanchard and Diamond 1989, and Davis and Haltiwanger 1990). Our paper shows that the constrained monetary policy blurs the line between reallocation and aggregate activity shocks. In our setting, reallocation away from investment in overbuilt capital triggers a Keynesian recession. Moreover, other types of investment also decline earlier in the recession, generating sectoral comovement that resembles an aggregate activity shock. Caballero and Hammour (1996) describe a supply-side channel by which reallocation is restricted because the expanding sectors are constrained due to a hold-up problem.

Fourth, we obtain several positive and normative results for investment when the economy experiences a demand-driven recession. These results apply regardless of whether the episode is driven by overbuilding or some other (temporary) demand shock.⁵ On the positive side, we show that investment can decline earlier in the recession, even if the real interest rate remains low and there are no financial frictions, because low aggregate demand lowers the return to investment. This mechanism is reminiscent of the acceleration principle of investment that was emphasized in an older literature (see Clark 1917 or Samuelson 1939).⁶ On the normative side, we show that the private investment decisions during or before the recession are typically inefficient and characterize the constrained optimal interventions. These results complement a recent literature that analyzes the inefficiencies driven by aggregate demand externalities. Korinek and Simsek (2016) and Farhi and Werning (2016) focus on ex ante financial market allocations, such as leverage and insurance, whereas we establish inefficiencies associated with physical investment.⁷

I. Baseline Model

The economy is set in infinite discrete time $t \in \{0, 1, \dots\}$ with a single consumption good and three factors of production: a special type of durable capital, h_t , other capital, k_t , and labor, l_t . Our prime example for the special capital is housing, and thus, we refer to it also as housing capital. Other examples are structures or infrastructure. For brevity, we also refer to nonhousing capital as “capital.” Each unit of housing capital produces one unit of housing services. Capital and labor are combined to produce the consumption good according to a neoclassical technology that we describe later in this paper.

Absent shocks, the economy converges to a level of housing capital denoted by h^* , which we refer to as the target level (see equation (3)). We analyze situations in which the economy starts with an initial housing capital that exceeds the target, $h_0 > h^*$, which we refer to as *overbuilding*. We interpret the assumption, $h_0 > h^*$, as capturing an unmodeled overbuilding episode that took place before the start of

⁵A growing theoretical literature investigates various aspects of the liquidity trap, but often abstracts away from investment for simplicity (see, for instance, Krugman 1998, Eggertsson and Woodford 2003, Auerbach and Obstfeld 2005, Adam and Billi 2006, Jeanne and Svensson 2007, and Werning 2012).

⁶The mechanism is also present in many other New Keynesian models with capital and constrained monetary policy, but it is not always emphasized. Schmitt-Grohe and Uribe (2017) also show that the liquidity trap can generate an investment slump driven by low return.

⁷A separate literature emphasizes the inefficiencies in physical investment driven by pecuniary externalities (see, for instance, Shleifer and Vishny 1988, Lorenzoni 2008, Stein 2012, Hart and Zingales 2015, He and Kondor 2016, and Dávila and Korinek forthcoming).

our model. In particular, suppose the (expected) housing demand increased in the recent past relative to its historical level. The economy has built housing capital to accommodate this high level of demand, captured by h_0 . At date 0, the economy receives news that the high-demand conditions are not sustainable. The stock of housing capital needs to adjust to its historical average, captured by h^* . Section V introduces an ex ante period and formalizes this interpretation. We would like to understand how the economy reacts to an excess stock of housing capital.

In our baseline model, we assume that one unit of the consumption good can be converted into one unit of housing or nonhousing capital, or vice versa, without adjustment costs. Thus, the two types of capital evolve according to

$$(1) \quad h_{t+1} = h_t(1 - \delta^h) + i_t^h \quad \text{and} \quad k_{t+1} = k_t(1 - \delta^k) + i_t^k.$$

Here, i_t^h (resp. i_t^k) denotes housing (resp. nonhousing) investment, and δ^h (resp. δ^k) denotes the depreciation rate for housing (resp. nonhousing) capital. These assumptions also imply that the relative price of housing capital is constant and normalized to one. Hence, overbuilding in this setting will reduce housing investment without changing house prices. In Sections III and IV, we introduce adjustment costs to housing capital, in which case overbuilding also reduces the price of housing capital.

Households.—The economy features a representative household whose problem can be written as

$$(2) \quad \max_{\{l_t, \hat{c}_t, a_{t+1}, i_t^h\}_t} \sum_{t=0}^{\infty} \beta^t (u(\hat{c}_t - v(l_t)) + u^h \mathbf{1}[h_t \geq h^*])$$

subject to

$$\hat{c}_t + a_{t+1} + i_t^h = w_t l_t + \Pi_t + a_t(1 + r_t),$$

$$h_{t+1} = h_t(1 - \delta^h) + i_t^h.$$

The household earns wage income per unit of labor (w_t) and receives profits from firms that will be described later in this paper (Π_t). She chooses labor (l_t), consumption (\hat{c}_t), financial asset holdings (a_{t+1}), and housing investment to maximize discounted utility. The functions in her per-period utility, $u(\cdot)$, $v(\cdot)$, satisfy the standard regularity conditions. She also receives utility from housing services as captured by the separable term, $u^h \mathbf{1}[h_t \geq h^*]$. This is equal to u^h if $h_t \geq h^*$ and zero otherwise, where we take u^h to be a large constant.

Our specification of household preferences in (2) relies on two simplifying assumptions. Households receive a large utility from investing up to h^* but zero marginal utility from additional units. This implies that when u^h is sufficiently large (and the interest rate is not too negative, $r_{t+1} > -\delta^h$) the household's optimal housing investment is

$$(3) \quad h_{t+1} = h^*, \quad \text{which implies} \quad i_t^h = h^* - h_t(1 - \delta^h).$$

Intuitively, households invest or disinvest so as to reach the target level of housing capital in a single period.⁸ In particular, starting with some $h_0 > h^*$, the economy decumulates the excess residential capital in one period. Hence, a period in this setting should be thought of as long as necessary (several years) to adjust the housing capital to its steady-state level. In our extensions with adjustment costs (Sections III and IV), decumulation is spread over multiple periods.

The second simplification in household preferences is the functional form $u(\hat{c}_t - v(l_t))$, which implies that the household's labor supply decision does not depend on its consumption (see Greenwood, Hercowitz, and Huffman (GHH) 1988). Specifically, the optimal labor solves the static problem,

$$(4) \quad e_t = \max_{l_t} w_t l_t - v(l_t).$$

Here, e_t denotes households' labor income net of the disutility of labor. We also define $c_t = \hat{c}_t - v(l_t)$ as *net consumption*. In terms of the net variables, the household solves a standard consumption and savings problem,

$$(5) \quad \max_{\{c_t, a_{t+1}\}_t} \sum_{t=0}^{\infty} \beta^t u(c_t)$$

subject to

$$c_t + a_{t+1} + i_t^h = e_t + \Pi_t + a_t(1 + r_t).$$

The optimal household behavior is summarized by equation (3) and problems (4) and (5).

REMARK 1 (Role of the Simplifying Preference Assumptions): *GHH preferences provide tractability. In Section V, we show that our main results continue to obtain in a version of the model with separable preferences at date 0, $u(c_0) - v_0(l_0)$. The kinked demand for housing services plays a more important role. First, this assumption considerably simplifies the housing investment part of our model, as illustrated by equation (3), and allows us to focus on the effect of overbuilding on the remaining equilibrium allocations. Second, the assumption also implies that housing investment in the short run does not react to the changes in the interest rate. With more elastic housing demand, housing investment would qualitatively follow a similar dynamic path as in our model (described in Section II), but its initial decline would be dampened as monetary policy responds by lowering the interest rate. These additional effects are not a major concern for our analysis, because we focus on scenarios in which monetary policy is constrained.*

⁸Housing capital not only provides housing services, but it also represents an investment technology. Hence, equation (3) also requires the gross interest rate, $1 + r_{t+1}$, to be greater than the gross return (on unutilized houses), $1 - \delta^h$. This is ensured by the required condition, $r_{t+1} > -\delta^h$, which will be the case in equilibrium.

Investment Firms, Production Firms, and the Constrained Interest Rate.—The capital stock of the economy is managed by a competitive investment sector. This sector invests up to the point at which the cost of capital is equated to the net return to physical capital,

$$(6) \quad r_{t+1} = R_{t+1} - \delta^k.$$

Here, R_{t+1} denotes the rental rate. The cost of capital is the same as the safe interest rate since there is no uncertainty and no risk premium. In the calibration exercise in Section IVB, we introduce a wedge between the cost of capital and the safe interest rate, which can be thought of as capturing a risk premium in reduced form. The capital market clearing condition is given by $a_t = k_t$.

Our key ingredient is that monetary policy is constrained so that the nominal interest rate does not react to demand shocks as much as in a real business-cycle model. In practice, there are several reasons why the monetary authority might be unable or unwilling to lower the interest rate sufficiently to counter demand shocks. In our baseline analysis, we consider the zero lower bound constraint on the nominal interest rate, $r_{t+1}^n \geq 0$, which appeared to be relevant during the Great Recession (see online Appendix B.2 for an alternative setting with exogenous money supply). The zero lower bound constraint emerges because cash in circulation yields zero interest in addition to providing households with transaction services.⁹ If the nominal interest rate fell below zero, then individuals would switch to hoarding cash instead of holding financial assets. Therefore, monetary policy cannot lower the nominal interest rate (much) below zero. The situation in which the nominal interest rate is at its lower bound is known as the liquidity trap.

Constraints on the nominal interest rate might not affect the real allocations by themselves. However, we also assume that nominal prices are sticky so that a constraint on the nominal rate translates into a constraint on the real rate. For analytical tractability, we assume prices are completely sticky (see Remark 2 for an interpretation and a discussion of how the results would generalize). This ensures that the real interest rate is also bounded from below,

$$(7) \quad r_{t+1}^n = r_{t+1} \geq 0 \quad \text{for each } t.$$

As we will show, the lower bound on the interest rate plays a central role by creating an upper bound on investment as well as consumption.

We formally introduce nominal price rigidities with the standard New Keynesian model. Specifically, there are also two types of production firms. A competitive final good sector uses intermediate varieties $\nu \in [0, 1]$ to produce the final output according to the Dixit-Stiglitz technology, $\hat{y}_t = \left(\int_0^1 \hat{y}_t(\nu)^{\frac{\varepsilon-1}{\varepsilon}} d\nu \right)^{\varepsilon/(\varepsilon-1)}$, where $\varepsilon > 1$. In turn, a unit mass of monopolistic firms labeled by $\nu \in [0, 1]$ each produces the

⁹To simplify the notation and the exposition, however, we do not explicitly model money or its transaction services in the main text. Online Appendix B.2 analyzes a version of the model with these features.

variety according to $\hat{y}_t(\nu) = F(k_t(\nu), l_t(\nu))$, where $F(\cdot)$ is a neoclassical production function with standard regularity conditions.

Each monopolist has a preset and constant nominal price, $P_t(\nu) = P$ for each ν . This assumption implies that the aggregate price level is also constant, thereby formalizing the bound in (7).¹⁰ The assumption also implies that monopolists are symmetric: they face the same real price (equal to one), and they choose the same level of inputs and outputs subject to an aggregate demand constraint. In particular, the representative monopolist's problem can be written as

$$(8) \quad \Pi_t = \max_{k_t, l_t} F(k_t, l_t) - w_t l_t - R_t k_t$$

subject to

$$F(k_t, l_t) \leq \hat{y}_t.$$

REMARK 2 (Role of the Price Stickiness Assumption): *The extreme price stickiness captures in reduced form a situation in which inflation is sticky in the upward direction during the decumulation episode. In practice, this type of stickiness could be driven by nominal rigidities at the micro level (in the goods market or the labor market), or by constraints on monetary policy against creating inflation. It is also worth emphasizing that making the prices more flexible at the micro level does not necessarily circumvent the bound in (7). In fact, if monetary policy cannot credibly commit to creating inflation (e.g., due to an inflation targeting policy regime), then limited price flexibility exacerbates the bound in (7). This is because the negative output gap during the zero lower bound episode exerts a downward pressure on inflation. As the inflation (and expected inflation) falls, the real interest rate increases, and the demand shortage becomes more severe (see remarks 1–3 in Korinek and Simsek 2016 for further discussion).*

Efficient Benchmark and Monetary Policy.—In the equilibria we analyze, the monopolists who solve problem (8) will find it optimal to meet all of their demand. Thus, the output satisfies $\hat{y}_t = F(k_t, l_t)$. With GHH preferences, we also find it convenient to work with *the net output*, that is, output net of labor costs, $y_t = \hat{y}_t - v(l_t)$. The net output is determined by the net aggregate demand, $y_t = c_t + i_t^k + i_t^h$, which in turn is determined by monetary policy as well as other factors.

To describe monetary policy, we first define the efficient benchmark at some date t as the continuation allocation that maximizes households' welfare subject to the feasibility constraints (and given the state variables, $k_t, h_t \geq h^*$). Online Appendix C.1 shows that the efficient benchmark solves a standard neoclassical planning problem.

¹⁰ Alternatively, we could also assume that firms set their prices at every period mechanically according to a predetermined inflation target, that is, $P_t(\nu) = P(1 + \pi)^t$ for some $\pi \geq 0$. This formulation yields a very similar bound as in (7) and results in the same economic trade-offs. We normalize the inflation target to zero so as to economize on notation.

With GHH preferences, the efficient employment maximizes the net output in every period. We define

$$(9) \quad L(k_t) \in \arg \max_{\tilde{l}} F(k_t, \tilde{l}) - v(\tilde{l}) \quad \text{and} \quad S(k_t) = F(k_t, L(k_t)) - v(L(k_t))$$

as, respectively, the efficient (or the supply-determined) level of the labor supply and net output.

Since the price level is fixed, we assume that monetary policy focuses on stabilizing employment and output (analogous to a Taylor rule). In our setting, this corresponds to replicating the (statically) efficient allocations in (9) subject to the constraint in (7).¹¹ Specifically, monetary policy follows the interest rate rule,

$$(10) \quad r_{t+1}^n = r_{t+1} = \max(0, r_{t+1}^*) \quad \text{for each } t \geq 0.$$

Here, r_{t+1}^* is recursively defined as the natural interest rate that obtains when the employment and the net output at date t are given by (9), and monetary policy follows the rule in (10) at all future dates. This policy is constrained efficient in our environment as long as monetary policy cannot use forward guidance: that is, it cannot commit to setting future interest rates beyond the current period.

DEFINITION 1: *The equilibrium is a path of allocations, $\{h_t, k_t, l_t, \hat{c}_t, c_t, i_t^h, i_t^k, \hat{y}_t, y_t\}_t$, and real prices and profits, $\{w_t, R_t, r_{t+1}, \Pi_t\}_t$, such that the households and firms choose allocations optimally as described previously, the interest rate is set according to (10), and all markets clear.*

II. Investment Overhang

We next characterize the equilibrium and establish our main result that excessive overbuilding triggers a demand-driven recession. We start by establishing the properties of equilibrium within a period.

LEMMA 1:

- (i) *If $r_{t+1} > 0$, then $y_t = S(k_t)$, $l_t = L(k_t)$, and $R_t = S'(k_t)$.*
- (ii) *If $r_{t+1} = 0$, then the net output is below the efficient level, $y_t \leq S(k_t)$, and is determined by net aggregate demand, $y_t = c_t + i_t^k + i_t^h$. The labor supply is below its efficient level, $l_t \leq L(k_t)$, and is determined as the unique solution to*

$$(11) \quad y_t = F(k_t, l_t) - v(l_t) \quad \text{over the range } l_t \in [0, L(k_t)].$$

¹¹ In our setting, the equilibrium without nominal rigidities would also feature monopoly distortions that should ideally be corrected by targeted policies such as monopoly subsidies. To simplify the notation, we ignore this distinction and assume the monetary policy attempts to correct for monopoly distortions as well as the distortions due to nominal rigidities.

The rental rate of capital is given by $R_t = R(k_t, l_t) \equiv \frac{v'(l_t)}{F_l(k_t, l_t)} F_k(k_t, l_t)$, where the function $R(k_t, l_t)$ is strictly decreasing in k_t and strictly increasing in l_t over the range $l_t \in [0, L(k_t)]$ with $R(k_t, L(k_t)) = S'(k_t)$.

Part (i) describes the case in which the interest rate is positive, and monetary policy replicates the efficient outcomes. Part (ii) describes the case in which monetary policy is constrained by the zero lower bound. In this case, the economy experiences a recession with low net output and employment.

For either case, the result also characterizes the rental rate of capital, which determines the return to investment. To understand these results, consider monopolists' factor demands, captured by the optimality conditions for problem (8),

$$(12) \quad (1 - \lambda_t) F_k(k_t, l_t) = R_t \quad \text{and} \quad (1 - \lambda_t) F_l(k_t, l_t) = w_t.$$

Here, $\lambda_t \geq 0$ denotes the Lagrange multiplier on the demand constraint in (8). Combining the second equation with the household optimality condition implies that the Lagrange multiplier is equal to the labor wedge,

$$(13) \quad \lambda_t = \tau_t \equiv 1 - v'(l_t)/F_l(k_t, l_t).$$

If the interest rate is positive, then employment is at its efficient level, and the labor wedge is zero. In this case, equation (12) implies that capital earns its marginal contribution to supply. If instead the interest rate is zero, then employment is below its efficient level, and the labor wedge is positive. In this case, capital earns a lower return characterized by combining equations (12) and (13). Intuitively, low aggregate demand also lowers the return to capital, which will play a central role in our analysis of the investment response in Section III.

Lemma 1 implies further that the capital stock is bounded from above,

$$(14) \quad k_{t+1} \leq \bar{k} \quad \text{for each } t, \text{ where } S'(\bar{k}) - \delta^k = 0.$$

Here, the upper bound \bar{k} is the level of capital that delivers a net return of zero absent a demand shortage. Investing beyond this level would never be profitable given the lower bound to the cost of capital implied by (7), as well as the possibility of a demand shortage. Intuitively, only so many projects can be undertaken without violating the lower bound on the interest rate.

Dynamic Equilibrium with Investment Overhang.—We next characterize the dynamic equilibrium under the assumption that the economy starts with too much housing capital,

$$(15) \quad h_0 = (1 + b_0) h^*, \quad \text{where } b_0 > 0.$$

Here, b_0 parameterizes the degree of past overbuilding. Equation (3) then implies

$$(16) \quad i_0^h = h^* - (1 - \delta^h)h_0 = (\delta^h - b_0(1 - \delta^h))h^*.$$

Note that housing investment at date 0 is below the level required to maintain the target, $i_0^h < \delta^h h^*$. Thus, overbuilding represents a negative shock to housing investment. The equilibrium depends on how the remaining components of aggregate demand, i_0^k and c_0 , respond to this shock.

To characterize this response, we solve the equilibrium backwards. Suppose the economy reaches date 1 with $h_1 = h^*$ and some capital level $k_1 \leq \bar{k}$. Since the housing capital has already adjusted, the zero lower bound does not bind in the continuation equilibrium, that is, $r_{t+1} > 0$ for each $t \geq 1$. Consequently, monetary policy replicates the efficient benchmark starting at date 1 given $h_1 = \bar{h}$ and $k_1 \leq \bar{k}$. Online Appendix C.1 shows that the solution converges to a steady state (k^*, l^*, y^*, c^*) , characterized by

$$(17) \quad S'(k^*) - \delta^k = 1/\beta - 1,$$

and

$$l^* = L(k^*), \quad y^* = S(k^*), \quad c^* = S(k^*) - \delta^k k^* - \delta^h h^*.$$

The initial consumption is given by $c_1 = C(k_1)$, for an increasing function $C(\cdot)$.

Next, consider the equilibrium at date 0. The key observation is that aggregate demand is bounded from above due to the constraint on the interest rate. We have already seen in equation (14) that capital is bounded from above, which implies that nonhousing investment is bounded,

$$i_1^k \leq \bar{k} - (1 - \delta^k)k_0.$$

Likewise, consumption is bounded by the Euler equation at the zero interest rate,

$$(18) \quad c_0 \leq \bar{c}_0, \quad \text{where} \quad u'(\bar{c}_0) = \beta u'(C(\bar{k})).$$

Combining the bounds in (14) and (18) with the demand shock in (16), the aggregate demand (and output) at date 0 is also bounded,

$$(19) \quad y_0 \leq \bar{y}_0 \equiv \bar{k} - (1 - \delta^k)k_0 + \bar{c}_0 + (\delta^h - b_0(1 - \delta^h))h^*.$$

The equilibrium depends on the comparison between the maximum demand and the efficient level, i.e., whether $\bar{y}_0 < S(k_0)$. This in turn depends on whether the amount of overbuilding b_0 exceeds a threshold level,

$$(20) \quad \bar{b}_0 \equiv \frac{\bar{k} - (1 - \delta^k)k_0 + \bar{c}_0 + \delta^h h^* - S(k_0)}{(1 - \delta^h)h^*}.$$

PROPOSITION 1 (Overbuilding and the Demand-Driven Recession): *Suppose $b_0 > 0$:*

(i) *If $b_0 \leq \bar{b}_0$, then the date 0 equilibrium features*

$$r_1 \geq 0, \quad y_0 = S(k_0), \quad \text{and} \quad l_0 = L(k_0).$$

(ii) *If $b_0 > \bar{b}_0$, then the date 0 equilibrium features a demand-driven recession with*

$$r_1 = 0, \quad k_1 = \bar{k}, \quad y_0 = \bar{y}_0 < S(k_0), \quad \text{and} \quad l_0 < L(k_0).$$

Moreover, the net output y_0 and the labor supply l_0 , as well as the actual output, $\hat{y}_0 = y_0 + v(l_0)$, are decreasing in b_0 .

In either case, the continuation allocations starting at date 1 feature positive interest rates and solve a neoclassical planning problem. The economy converges to a steady state (k^, l^*, y^*, c^*) given by (17).*

Part (i) describes the equilibrium for the case in which the initial overbuilding is not too large. In this case, the economy does not experience a demand-driven recession. Low investment in housing capital is offset by a reduction in the interest rate and an increase in nonhousing investment and consumption, leaving the output and employment determined by productivity. The left part of the panels in Figure 3 (the range corresponding to $b_0 \leq \bar{b}_0$) illustrate this outcome for a particular parameterization (and starting with $k_0 = k^*$).

Part (ii), our main result, characterizes the case in which the initial overbuilding is sufficiently large. In this case, the reduction in aggregate demand due to low housing investment is large enough to plunge the economy into a demand-driven recession. The lower bound on the interest rate prevents the nonhousing investment and consumption from expanding sufficiently to pick up the slack, which leads to low output and employment. Figure 3 illustrates this result. Greater overbuilding triggers a deeper recession.

Comparative Statics of the Recession.—When is a given amount of overbuilding, b_0 , more likely to trigger a demand-driven recession? As illustrated by equation (20), factors that reduce aggregate demand at date 0, such as a higher discount factor β (that lowers \bar{c}_0), increase the incidence of the demand-driven recession in our setting. More generally, frictions that reduce aggregate demand during the decumulation phase, such as household deleveraging or financial crisis, are complementary to our mechanism. Intuitively, this is because the zero lower bound represents a nonlinear constraint on monetary policy. A demand shock that lowers the interest rate leaves less slack for monetary policy, increasing the potency of other demand shocks such as overbuilding.

Equation (20) illustrates further that overbuilding of the two types of capital is complementary in terms of triggering a demand-driven recession: greater initial level of nonhousing capital stock k_0 increases the incidence of a demand-driven

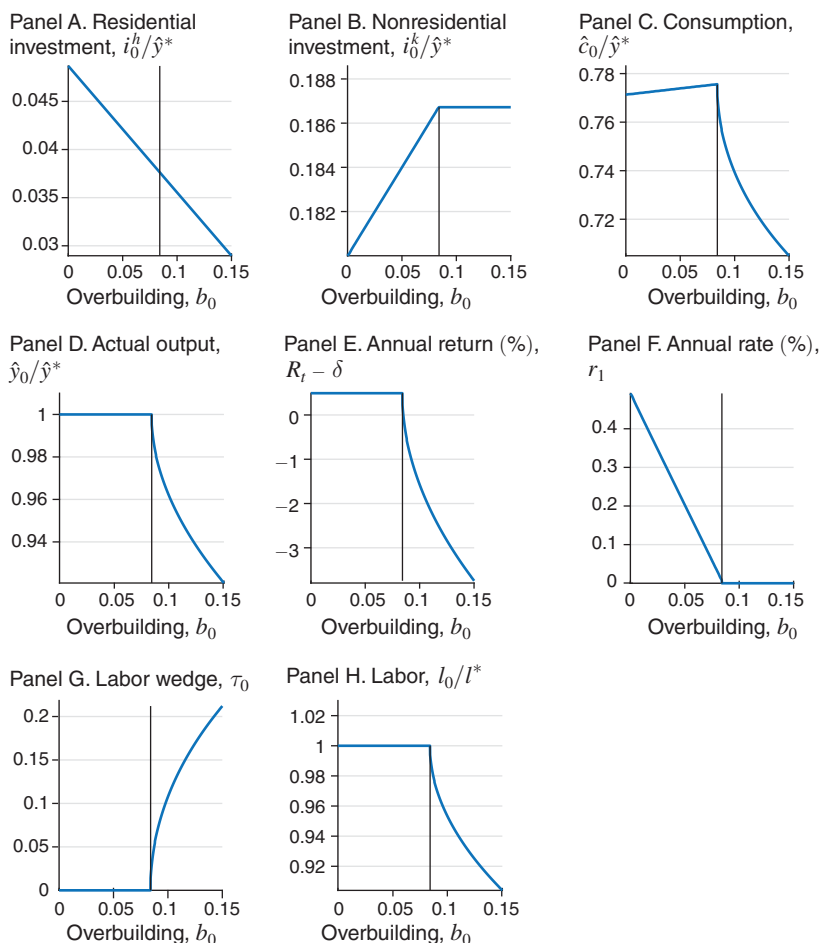


FIGURE 3

Note: Date 0 equilibrium variables as a function of the initial overbuilding b_0 (measured as a fraction of the steady-state residential capital stock, h^*).

recession. A high level of k_0 affects the equilibrium at date 0 through two channels. First, it reduces nonhousing investment at date 0 and lowers aggregate demand—similar to a high level of h_0 . Second, it increases the efficient output, $S(k_0)$, and makes a demand shortage more likely.

A distinguishing feature of housing capital is its high durability relative to many other types of capital. In online Appendix B.1, we consider a slight variant of the model to investigate whether high durability is conducive to triggering a demand-driven recession. The extension features two types of housing capital, one more durable (i.e., depreciates more slowly) than the other. The analysis reveals that, controlling for the total amount of overbuilding in both types of capital, overbuilding durable capital is more likely to trigger a demand-driven recession. Intuitively, depreciation helps to “erase” the overbuilt capital, reducing the impact of past overbuilding on future aggregate demand. Since durable capital depreciates more slowly, once overbuilt it tends to stay around for longer and reduce aggregate demand by a

larger amount. This suggests that overbuilding is a greater concern when it hits durable capital such as housing, structures, or infrastructure, as opposed to less durable capital such as equipment or machinery.¹²

Other Constraints on Monetary Policy.—For concreteness, we focus on the zero lower bound constraint on monetary policy. While the ZLB is relevant for the Great Recession, monetary policy can be constrained for many other reasons. In economies with fixed exchange rates (such as the eurozone), monetary policy is often constrained because it is linked with the policies of other countries. In economies under the gold or silver standard, which have been historically common, monetary policy is constrained since the money supply is linked to the quantity of precious metals. As should be clear from our analysis, our main result (as well as our results in subsequent sections) continues to apply when monetary policy is constrained for reasons other than the zero lower bound.

Online Appendix B.2 illustrates this point by deriving a version of Proposition 1 in an environment in which the money supply follows an exogenous path. In this setting, the interest rate is determined by the money supply and household liquidity preferences. Since these forces are largely exogenous, the interest rate does not decline sufficiently to meet the decline in aggregate demand. Consequently, excessive overbuilding triggers a demand-driven recession, as in our baseline analysis. In fact, the recession is often more severe because, while the interest rate during the recession declines to zero in the baseline model, it can remain above zero when the money supply is exogenous. Our investment hangover mechanism can thus shed light on some historical business cycles other than the Great Recession.¹³

Dynamics of the Slump.—So far, we have been agnostic about the equilibrium before the start of our model (date -1). Our results apply generally as long as the ex ante equilibrium leads to h_0 that sufficiently exceeds h^* . To describe how the macroeconomic aggregates change over time, we now suppose that the economy is initially at a steady state in which household preferences are associated with a higher target level of housing, $h^{*,old} = h_0$. The equilibrium allocations at date -1

¹² A previous literature has empirically investigated whether the overbuilding of information technology (IT) equipment during the boom years of the late 1990s and 2000 might have contributed to the 2001 recession in the United States (see Desai and Goolsbee 2004 and the references therein).

¹³ A prime example is the American business cycle of 1879–1885, which is often linked with an investment cycle in railroads—a highly durable type of capital that constituted a sizable fraction of aggregate investment at the time. Fels (1952) provides a narrative of the episode and describes many of the effects predicted by our model, including the accelerator effects on other capital as well as an asymmetric recovery in which the overbuilt railroad sector is left behind (see Section III). He writes:

Construction of railroads was the principal factor in the upswing. The number of railroad miles built rose spectacularly from 2,665 in 1878 to 11,569 in 1882... The downswing gathered momentum slowly in 1883. The decline in railroad construction not only eliminated the jobs of many workers directly employed in railroad building but also spread depression to other industries. As one would expect from the theory of the acceleration principle, the iron and steel industry was particularly affected... Nevertheless, contraction gradually came to an end and gave way to weak revival in the course of 1885... But railroad-building by itself, which was to experience a great boom in 1886 and especially 1887, was at its lowest ebb at the time of the cyclical upturn. Thus, the upturn occurred not because of the behavior of railroad construction but in spite of it (Fels 1952).

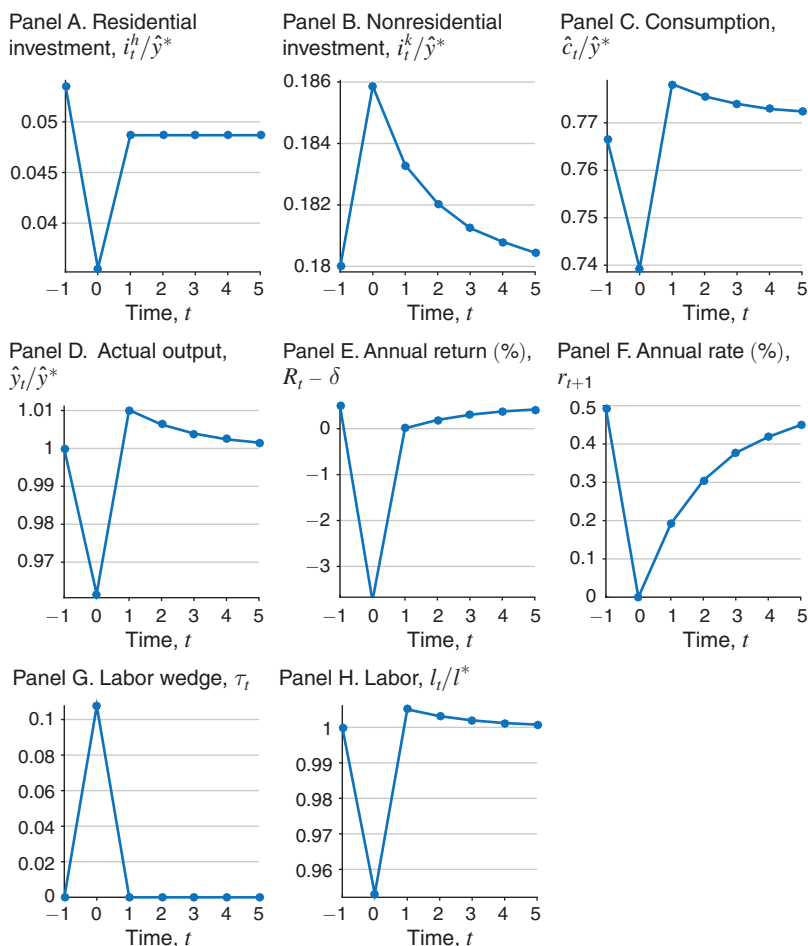


FIGURE 4. THE EVOLUTION OF EQUILIBRIUM VARIABLES OVER TIME, STARTING WITH $b_0 > \bar{b}_0$

are determined according to this steady state. At the beginning of date 0, there is an unexpected and permanent shock to household preferences that lowers the target level of housing to $h^* < h_0 = h^{*,old}$. The equilibrium allocations from date 0 onwards are then characterized by Proposition 1.

Figure 4 plots the resulting dynamic equilibrium. Housing investment, employment, and output decline during the slump, but nonhousing investment increases. The recession is confined to the overbuilt sector. This is a counterfactual prediction that we revisit in the next section. Note that the aftermath of the slump (date 1 onwards) features a neoclassical adjustment to the steady state.

REMARK 3 (Consumption Response and the Multiplier): *The effect of overbuilding on consumption during the slump is nuanced. While it always increases net consumption, c_t , in view of the Euler equation (18), it might actually reduce actual consumption, $\hat{c}_t = c_t + v(l_t)$, in view of the decline in employment, l_t (see Figure 4). The latter channel is driven by the GHH utility function, $u(\hat{c} - v(l))$, which generates a Keynesian multiplier effect even though we work with a representative household. We*

view this feature of the model as capturing in reduced form the multiplier effect that would emerge in more realistic variants of our model with heterogenous households and borrowing constraints.¹⁴ In online Appendix A, we follow Auclert and Rognlie (2017) and show that the first-order approximation to the multiplier in a period is given by the inverse of the labor wedge in that period, $1/\tau_t$ (cf. equation (13)). Hence, the multiplier is especially powerful in the neighborhood of the supply-determined region that features a zero labor wedge. In our calibration exercise in Section IVB, we introduce appropriately calibrated labor taxes to ensure that the multiplier is smaller and in line with the empirical estimates from the recent macroeconomic research.

III. Investment Response and Asymmetric Recovery

In our model so far, overbuilding (that is large enough to trigger a recession) reduces housing investment, employment, and output. However, as Figure 4 illustrates, it increases nonresidential investment, which is not consistent with what happens in major recessions. This feature of the model is driven by the stylized features of our baseline analysis. In this section, we develop a version of the model with housing adjustment costs, which can naturally generate a recession in which investment in both types of capital decline.

The analysis is motivated by Figure 4, which shows that overbuilding reduces the net return to nonhousing capital during the recession (see also Lemma 1). One could expect these low returns to translate into low nonresidential investment. This does not happen in the baseline model, however, because the current capital, k_0 , is already predetermined and the next period's capital, k_1 , is associated with full recovery. Introducing housing adjustment costs enables us to spread the recession over multiple periods, and thus to investigate the investment response during the recession.

We now assume investing i_t^h reduces the household utility by $\frac{1}{2}\psi(i_t^h - i^{h,*})^2$. Thus, the adjustment costs take a quadratic form centered around the steady-state level of investment, $i^{h,*} = \delta^h h^*$. The parameter ψ captures the level of the adjustment costs. The household then solves the following analog of problem (2):¹⁵

$$(21) \quad \max_{\{l_t, \hat{c}_t, a_{t+1}, i_t^h\}_t} \sum_{t=0}^{\infty} \beta^t \left(u(\hat{c}_t - v(l_t)) + u^h \mathbf{1}[h_t \geq h^*] - \frac{1}{2}\psi(i_t^h - i^{h,*})^2 \right)$$

subject to

$$\hat{c}_t + a_{t+1} + i_t^h = w_t l_t + \Pi_t + a_t(1 + r_t),$$

$$h_{t+1} = h_t(1 - \delta^h) + i_t^h.$$

¹⁴In our NBER working paper, we extend the model by introducing additional households that have high marginal propensities to consume (MPC) out of income. We show that, if there are sufficiently many high-MPC households, then overbuilding generates a decline in net consumption during the recession (as well as actual consumption). Intuitively, the low output in the recession lowers all households' incomes, which in turn reduces aggregate consumption due to the high-MPC households.

¹⁵The results are generally similar when we specify adjustment costs in terms of final goods instead of utility. We choose the latter formulation so that the adjustment costs do not directly affect aggregate demand, which facilitates the calibration exercise in the next section.

To analyze the equilibrium, let Q_t denote the Lagrange multiplier on the last equation (that describes the evolution of housing capital) divided by the Lagrange multiplier on the budget constraint. Note that Q_t measures the shadow price of housing capital at the end of period t (in terms of the consumption good). Taking the first-order conditions for i_t^h and \hat{c}_t , we obtain a relatively standard q -theory equation,

$$(22) \quad i_t^h - i^{h,*} = \frac{u'(c_t)}{\psi} (Q_t - 1), \quad \text{where} \quad i_t^h = h_{t+1} - h_t(1 - \delta^h).$$

The first-order condition for h_{t+1} , together with the Euler equation, implies the asset pricing equation, $Q_t = \delta_{t+1} + \frac{1 - \delta^h}{1 + r_{t+1}} Q_{t+1}$, where δ_{t+1} denotes a subgradient of the kinked function, $u^h \mathbf{1}[h_t \geq h^*]$. Under our assumption that u^h is sufficiently large, this can be rewritten as a complementary slackness condition,

$$(23) \quad Q_t \geq \frac{1 - \delta^h}{1 + r_{t+1}} Q_{t+1}, \quad h_{t+1} \geq h^*,$$

and one of the inequalities holds as equality. When $h_{t+1} > h^*$, the marginal utility from housing capital is zero, and thus, the price is equal to the value of the part of housing capital that will remain non-depreciated in the next period.

The remaining equilibrium conditions are the same as in the previous section and can be written as

$$(24) \quad \begin{aligned} u'(c_t) &= \beta(1 + r_{t+1})u'(c_{t+1}), \\ R(k_{t+1}, l_{t+1}) - \delta^k &= r_{t+1}, \\ y_t = F(k_t, l_t) - v(l_t) &= c_t + k_{t+1} - (1 - \delta^k)k_t + i_t^h, \\ y_t &\leq S(k_t), \quad r_{t+1} \geq 0, \end{aligned}$$

and one of the inequalities holds as equality, where $S(k)$ is defined by equation (9), and $R(k, l) = \frac{v'(l)}{F_l(k, l)} F_k(k, l)$ (see Lemma 1). Here, the first equation is the Euler equation, the second equation is the optimality condition for investment firms, and the third equation is the aggregate resource constraint. The last equation captures the monetary policy rule in (10), which we have rewritten in complementary slackness form.

The equilibrium corresponds to the path that solves equations (22)–(24) for each t . While all variables are jointly determined, it is useful to think of equations (22) and (23) as determining the optimal path of housing prices and investment, $\{Q_t, i_t^h\}_{t=0}^\infty$, that brings the economy from h_0 to h^* . In view of adjustment costs, residential investment can (and typically does) remain below its steady-state level for multiple periods. The equations in (24) then determine the periods over which the economy is in a liquidity trap (if any), as well as the equilibrium allocations during and after the liquidity trap.

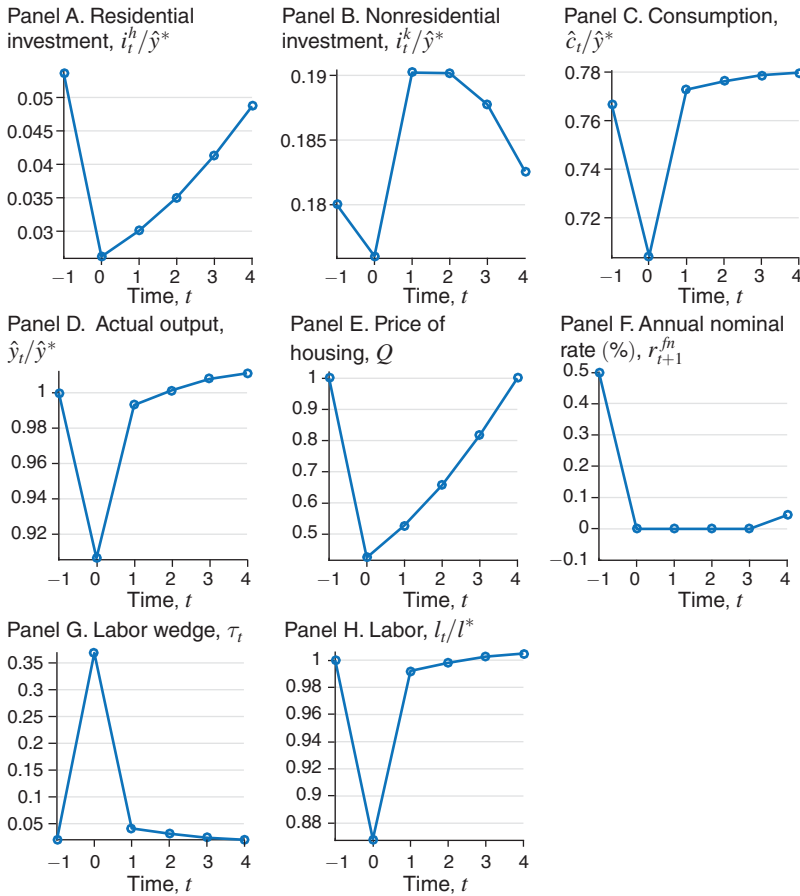


FIGURE 5. THE EVOLUTION OF EQUILIBRIUM VARIABLES OVER TIME WITH ADJUSTMENT COSTS

Figure 5 illustrates the dynamic equilibrium for a particular parameterization. As before, date -1 corresponds to the initial steady state in which the target level of housing capital is $h^{*,old} = h_0$. A sufficiently large amount of overbuilding generates a liquidity trap throughout the decumulation phase. The difference with the previous section is that the decumulation is now spread over multiple periods. In this example, the decumulation is completed in four periods, that is, $h_t > h^*$ for $t \in \{0, 1, 2, 3\}$ and $h_4 = h^*$.¹⁶ More strikingly, nonresidential investment follows a non-monotonic path during the recession: it declines in the second period but increases afterwards.

To understand this non-monotonic investment response, first note that when $r_{t+1} = 0$ the investment optimality condition in (24) can be rewritten as

$$R(k_{t+1}, l_{t+1}) - \delta^k = 0.$$

¹⁶A period in this version of the model should be thought of as lasting shorter than in the baseline model. In fact, we calibrate the example so that the outcomes over dates $t \in \{0, 1, 2, 3\}$ in Figure 5 can be directly compared to date $t = 0$ in Figure 4.

Recall that the return function $R(\cdot)$ is decreasing in the capital stock k_{t+1} and increasing in employment l_{t+1} . Note also that, in the liquidity trap, employment is determined by aggregate demand and output: formally, l_{t+1} is the solution to $y_{t+1} = F(k_{t+1}, l_{t+1}) - v(l_{t+1})$. The optimality condition then implies that, when the aggregate output at date $t + 1$ is expected to be greater, firms invest more at date t , and obtain a greater capital stock at date $t + 1$. Our model thus implies a version of the acceleration principle of investment, which posits that investment is proportional to expected changes in output.¹⁷

Next, recall that overbuilding triggers a demand-driven recession and reduces output. When the reduction in output is sufficiently large, investment in the earlier phase of the recession declines due to (our version of) the acceleration principle. Intuitively, the recession lowers the return to capital, as depicted in Figure 3, and firms optimally respond to this low return to capital. In later periods, aggregate demand and output gradually increase in anticipation of the eventual recovery. As this happens, the low cost of capital becomes the dominant factor for nonhousing investment. Consequently, the economy starts re-accumulating capital and, in fact, exits the slump with the maximum level of capital \bar{k} as in the previous section.

It follows that the recession in our model can be divided into two phases. In the first phase, captured by period 0 in the model, both types of investment fall. This induces a particularly severe recession with low output and employment. In the second phase, housing investment remains low whereas nonhousing investment recovers. The investment response also raises aggregate demand. The second phase of the recession in our model represents a partial and asymmetric recovery in which the housing sector is left behind, similar to the aftermath of the Great Recession (see Figure 1).

IV. A Quantitative Evaluation

We next turn to a quantitative evaluation of the investment overhang mechanism in the context of the Great Recession. We first provide an accounting exercise that decomposes the decline in output into various components of demand. We find that residential investment accounts for a sizable fraction of the output shortfall during the Great Recession and that its effects are more persistent than those of nonresidential investment and consumption. We then ask whether a calibrated version of our model can reproduce these effects when we feed it with direct measures of housing overbuilding (obtained from external sources). As we show, the overbuilding shock helps to explain the variables related to the housing market. It is not sufficiently strong to trigger the recession by itself, but it also helps to explain output and employment when combined with two other shocks that arguably lowered demand in recent years.

¹⁷ See Eckaus (1953) for a review of the early literature on the acceleration principle and our NBER working paper version for a discussion of how our mechanism differs from this literature.

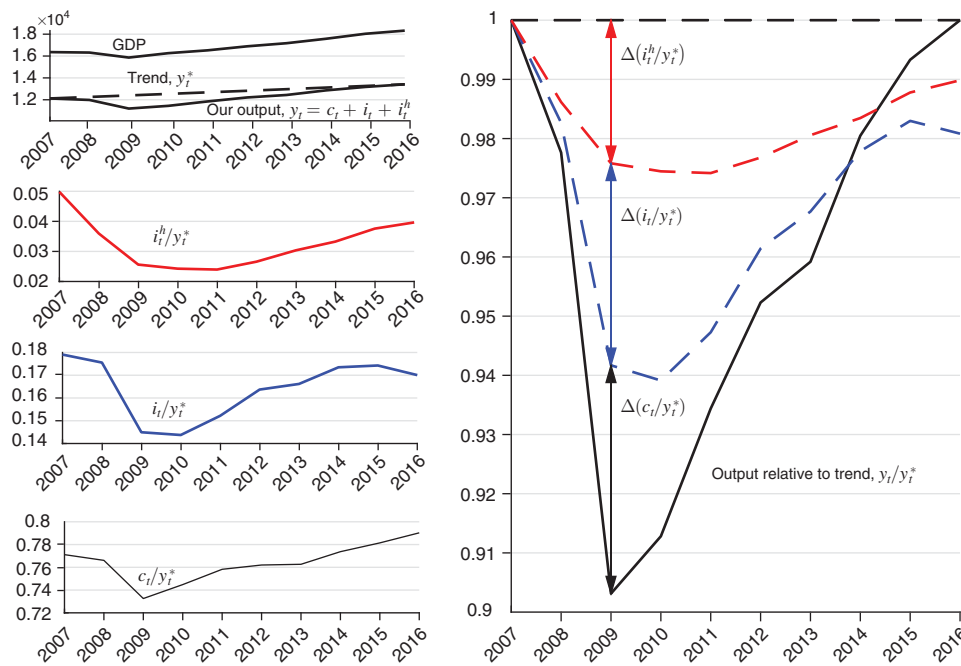


FIGURE 6

Notes: The top left panel plots our concept of output as well as actual GDP (for the United States) in 2009 prices. The bottom left panels plot the components of output as a fraction of trend output. The right panel shows output as a fraction of trend output and decomposes the shortfall in output into contributions coming from its components.

A. Accounting for the Decline in Output during the Great Recession

We first construct a slightly modified measure of output that is consistent with our model. Specifically, we exclude from GDP net exports as well as government consumption and investment—as these variables do not have counterparts in our model. We also exclude housing services (i.e., rents), which our model accounts for as part of household utility as opposed to output. Hence, our measure of output is given by $y_t = c_t + i_t + i_t^h$, where c_t denotes private consumption (excluding housing services), i_t denotes private nonresidential investment, and i_t^h denotes private residential investment (excluding commissions). The top left panel in Figure 6 illustrates the evolution of y_t (in real prices) together with the actual GDP.

We evaluate the changes in output and its components relative to a trend level, denoted by y_t^* , that can be thought of as approximating the level of output that would obtain absent demand shocks. The typical approach is to apply a smoothing (and detrending) procedure to historical output series. We believe this approach is not appropriate for the Great Recession since the postwar data does not have any other episodes in which the interest rate hits the zero lower bound. Guided by theory, we instead construct y_t^* by interpolating the actual output between 2007 and 2016. Our approach implicitly assumes the economy featured zero output gaps in 2007 and 2016, and negative output gaps in between, since nominal interest rates declined

to zero in 2008 and remained at zero until December 2015. While this assumption is strong, it leads to a relatively transparent accounting exercise. The right panel of Figure 6 plots the output relative to trend, y_t/y_t^* . The lower left panels of Figure 6 plot each component of output as a fraction of trend output, respectively, i_t^h/y_t^* , i_t/y_t^* , and c_t/y_t^* . Note that there is a sharp fall and gradual recovery in output as well as each of its components.

We next decompose the shortfall in output according to the following equation:

$$\Delta \frac{y_t}{y_t^*} = \Delta \frac{i_t^h}{y_t^*} + \Delta \frac{i_t}{y_t^*} + \Delta \frac{c_t}{y_t^*}, \quad \text{where} \quad \Delta x_t = x_t - x_{2007}.$$

The right panel of Figure 6 visualizes this decomposition. From top to bottom, the difference between curves illustrates respectively the contribution of residential investment, $\Delta \frac{i_t^h}{y_t^*}$, investment, $\Delta \frac{i_t}{y_t^*}$, and consumption, $\Delta \frac{c_t}{y_t^*}$. Residential investment accounts for about 25 percent of the output decline in 2009. Nonresidential investment and consumption account for, respectively, 35 and 40 percent of the decline. Since residential investment has a delayed recovery, its relative contribution grows over time and exceeds 50 percent by 2012. In contrast, since consumption recovers rapidly, its contribution declines over time and in fact becomes negative by 2014. The relative contribution from nonresidential investment remains roughly stable during the slump.

B. Calibrated Model Predictions for the Great Recession

We next calibrate the model and ask to what extent housing overbuilding can explain the accounting results. For a reasonable calibration, we first generalize the baseline model (with housing adjustment costs) in two ways. These generalizations do not strengthen our overbuilding mechanism. Their only role is to ensure that the underlying neoclassical model is roughly in line with certain aspects of the data.

The first generalization is to make a distinction between the nominal risk-free interest rate and the return to capital, which are identical in our baseline model (for simplicity). In the data, the risk-free interest rate is much lower than the return to capital. To accommodate this fact, we introduce a constant risk-premium wedge, $\phi \geq 0$ (later, we will make this time varying). In particular, the return to capital is now given by $r_{t+1} = r_{t+1}^f + \phi$, where r_{t+1}^f denotes the real risk-free interest rate. We also introduce a constant inflation rate denoted by $\pi \geq 0$ (see footnote 10 in Section I for a micro-foundation), so that $r_{t+1}^f = r_{t+1}^{fn} - \pi$, where r_{t+1}^{fn} denotes the nominal risk-free interest rate. With these assumptions, the return to capital is related to the nominal interest rate according to $r_{t+1} = r_{t+1}^{fn} + \phi - \pi$. As before, monetary policy controls the nominal interest rate, r_{t+1}^{fn} , which in turn affects the required return to capital. The zero lower bound constraint, $r_{t+1}^{fn} \geq 0$, continues to imply a (possibly nonzero) lower bound on the return to capital. More specifically, the constrained monetary policy rule in (10) is now replaced with

$$(25) \quad r_{t+1} = \max(\phi - \pi, r_{t+1}^*) \quad \text{for each } t \geq 0.$$

Note that the parameters ϕ and π do not affect the analysis except for changing the threshold return of capital at which the economy enters the liquidity trap region. We calibrate the inflation rate (π) as 2 percent per year based on the recent inflation data from the United States. We also calibrate the risk premium (ϕ) as 7.5 percent per year so that, when the real risk-free rate is equal to 1 percent (its historical average), the return to capital is equal to 8.5 percent, which is in line with the estimates in Poterba (1998).

The second generalization concerns the Keynesian multiplier in the baseline model. As we describe in Remark 3, the GHH preferences generate a multiplier effect, which is (to a first-order approximation) proportional to the inverse of the labor wedge, $1/\tau_t$. This multiplier is particularly strong in the neighborhood of the frictionless neoclassical equilibrium with zero labor wedge. We introduce labor taxes into the model so as to weaken and parameterize this multiplier effect. Specifically, the monopolist's problem (8) is now replaced with

$$(26) \quad \Pi_t = \max_{k_t, l_t} F(k_t, l_t) - \frac{1}{1 - \tau^l} w_t l_t - R_t k_t$$

subject to

$$F(k_t, l_t) \leq \hat{y}_t.$$

Here, w_t denotes the after-tax wage as before, and $\frac{1}{1 - \tau^l} w_t$ denotes the pre-tax wage. The tax revenues are rebated lump sum to the representative household. The analysis of the equilibrium with labor taxes closely parallels the baseline analysis and is completed in online Appendix A. In the supply-determined region, the labor wedge is equal to the tax parameter, that is, $\tau_t = \tau^l$. We calibrate $\tau^l = 2/3$ so that the implied multiplier in the neighborhood of the supply-determined region is approximately $1/\tau^l = 3/2$, which is in line with the empirical estimates from the recent literature (see, for instance, Nakamura and Steinsson 2014).

Benchmark with Pure Overbuilding Shocks.—We next present a benchmark calibration with overbuilding but no other shocks. The economy starts in January 2008. The period length is two years. These choices are guided by the observation that nonresidential investment fell in 2008 and 2009, and started to recover in 2011 (see Figure 6). In our model, nonresidential investment (with sufficiently strong demand shocks) falls in the first period of the recession and recovers in subsequent periods (see Figure 5). Making the period length two years enables us to match the timing of the recovery in the data and in the model without introducing additional ingredients.¹⁸ We describe the parameters that depend on the period length (such as β , δ , r_{t+1}^f)

¹⁸We could also match the timing of the recovery by introducing adjustment costs to nonresidential investment and calibrating the adjustment cost parameter appropriately. We decided against this approach to keep the model as parsimonious as possible.

in terms of their yearly values for ease of interpretation. In our numerical calculations, we transform the parameters appropriately so that each period is two years.

We work with constant elasticity functional forms for output and the disutility of labor,

$$F(k, l) = \left(\alpha k^{(\varepsilon-1)/\varepsilon} + (1 - \alpha) l^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)} \quad \text{and} \quad v(l) = \frac{1}{1 + \nu} l^{1+\nu}.$$

We set the elasticity of substitution between capital and labor, $\varepsilon = 0.5$, based on the meta-analysis of Chirinko (2008). We set the Frisch elasticity of the labor supply, $1/\nu = 0.4$, based on the meta-analysis of Reichling and Whalen (2012).

We set β so that the steady-state level of return to capital (r^*) is equal to 8.5 percent, in line with the estimates in Poterba (1998). With the risk premium (ϕ) set at 7.5 percent, this also implies that the steady-state real interest rate is equal to 1 percent, in line with its historical average. We then set α and δ to ensure the ratio of capital to yearly output is 165 percent, and the ratio of nonresidential investment to output is 18 percent, consistent with the NIPA data in 2007 using our concept of output. These choices imply that the output share of capital in the model is around 32 percent.

We work with constant elasticity preferences, $u(c) = (c^{1-\theta} - 1)/(1 - \theta)$. We set the elasticity of intertemporal substitution at $1/\theta = 0.1$, based on the average of the macro and the micro estimates obtained in the meta-analysis by Havránek (2015). Our final calibration results in Section IVB are robust to allow for higher levels of $1/\theta$.

We calibrate the amount of overbuilding based on the analysis in Haughwout et al. (2013). They estimate that, after adjusting for demographics, the trend rate of growth of the number of households since the mid-1990s should have been around 1.17 million per year. They also estimate the depreciation from the current stock of housing units should have been around 230 thousand units per year. This suggests that the economy needed about 1.4 million new houses per year since the mid-1990s. Their figure 2.8 provides a measure of oversupply by plotting the cumulative housing production since 1995 relative to the predicted trend of 1.4 million per year. This analysis illustrates that the economy produced many more houses relative to what was needed (based on historical patterns), with the difference peaking at around 3.4 million in mid-2007. They further show that this measure of overbuilding is quite consistent with an alternative measure that they obtain from the census data on housing vacancies (see online Appendix A for details).

Based on this analysis, we set

$$(27) \quad h_0 = h^{*, old} = 129\kappa \quad \text{and} \quad h^* = 125.6\kappa,$$

where κ can be thought of as the average value of a million housing units. We set κ to ensure that the ratio of aggregate housing capital to (yearly) output in the old steady state is 148 percent. This ratio is consistent with NIPA data in 2007, and it implies that the average value of a housing unit in 2007 is around \$140 thousand (in 2009 prices). To see the magnitude of the overbuilding shock, note that 3.4 million

TABLE 1—CALIBRATION PARAMETERS

Parameters	Description	Calibration	Target	Source
β	Discount factor	0.92	Avg. K return = 0.085	Poterba (1998)
ϕ	Risk premium	0.075	Avg. ff-pce, 03–07	FRED (2003–2007)
π	Inflation	0.02	Avg. pce infl., 03–07	NIPA
ϵ	$K - L$ elasticity	0.5		Chirinko (2008)
α	Share parameter	0.26	Match $k/y = 1.65$ in 07	NIPA
δ	Depreciation rate	0.11	Match $i/y = 0.18$ in 07	NIPA
τ^l	Labor tax	2/3	Implied multiplier = 1.5	Nakamura and Steinsson (2014)
$1/\theta$	EIS	0.1	Avg. micro and macro meta	Havránek (2015)
$1/\nu$	Frisch labor supply	0.4	Median of meta-analysis	Reichling and Whalen (2012)
δ^h	Res. depreciation rate	0.034	Match $i^h/y = 0.05$ in 07	NIPA
h_0	2007 housing stock (mil.)	129κ		Haughwout et al. (2013)
h^*	2007 housing need (mil.)	125.6κ		Haughwout et al. (2013)
κ/y_{-1}	\$ per mil. h, over GDP	0.011	Match $h_0/y = 1.48$ in 07	NIPA
ψ	Res. adj. cost	$150u(c^*)$	Decum. in 6 yrs.	Haughwout et al. (2013)
$\phi^{new} - \phi$	Risk-premium shock	0.03	Takes economy to ZLB	—
$\{\gamma_t\}$	Discount-rate shock	(series)	Δc from $MPC \times h$ shock	Mian, Rao, and Sufi (2013)

excess housing units corresponds to about \$480 billion (in 2009 prices), which amounts to about 4 percent of our measure of output in 2007. Note also that our calibration is rather conservative, since it focuses only on the overbuilding of housing units (excluding, for instance, overbuilding in consumer durables related to housing, as well as overbuilding in the size or the quality of the average home).

We set the housing depreciation rate, δ^h , so that the residential investment to output ratio in the old steady state is equal to 5 percent. We also set the housing adjustment cost parameter, ψ , so that decumulation is completed in three periods (or six years), that is, $h_t > h^*$ for $t \in \{0, 1, 2\}$ and $h_3 = h^*$. This is consistent with Figure 2.8 in Haughwout et al. (2013), which suggests the overbuilt capital would be worked off in about five years. Table 1 summarizes the parameters used in our analysis.

Figure 7 illustrates the results from our benchmark calibration exercise with pure overbuilding shocks. The residential investment to output ratio falls to 4 percent and gradually reverts to a level that is slightly below 5 percent. This is qualitatively consistent with the behavior of the residential investment series in Figure 6. Quantitatively, residential investment in the data falls by a greater magnitude and does not really recover to 5 percent. We offer two explanations for this discrepancy. First, as we describe previously, our calibration is rather conservative and does not consider all potential sources of overbuilding. Second, and more importantly, the collapse of house prices might also have reduced the demand for housing going forward (e.g., due to pessimism about the housing market or credit constraints in the mortgage market). Consistent with this explanation, Haughwout et al. (2013) find that the household formation rate in recent years has been much lower than the rate that they predict based on historical trends and demographics (see online Appendix A). Hence, some of the ongoing weakness in the housing market is likely to be driven by unusually low demand. We leave this additional demand shock out of our calibration exercise since it is difficult to quantify.

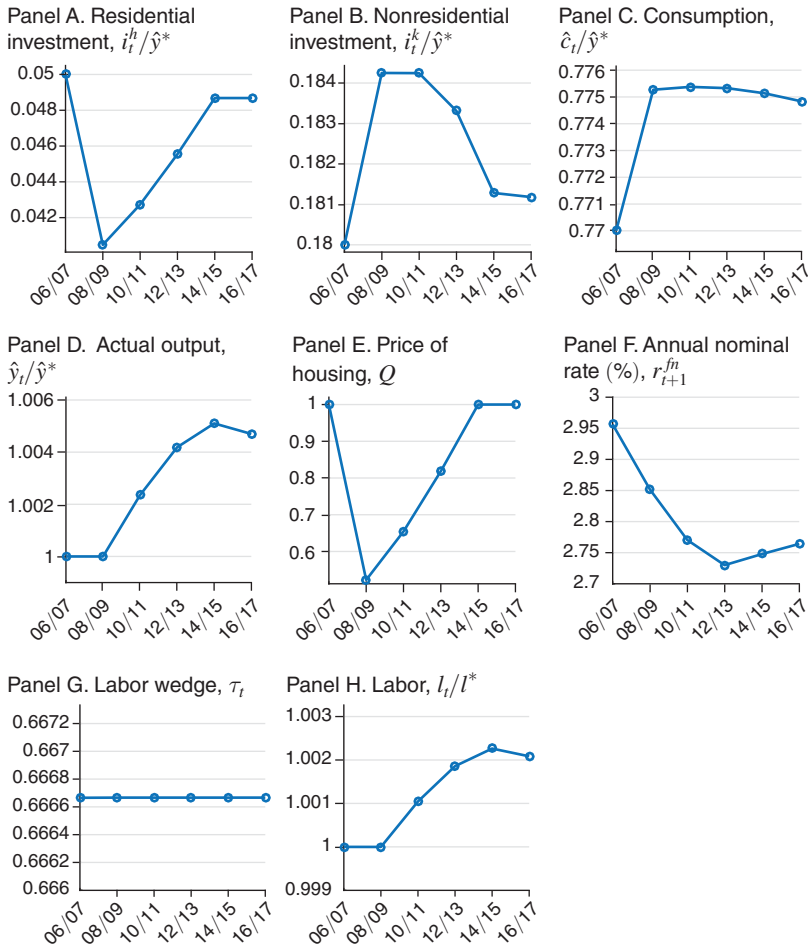


FIGURE 7. BENCHMARK CALIBRATION WITH OVERBUILDING BUT NO OTHER DEMAND SHOCKS

The model also generates about a 50 percent decline in the price of housing capital followed by a recovery. This is qualitatively consistent with the dynamics of house prices in practice, but the price declined less in the data than in the model. This discrepancy obtains in part because we assume the required return on housing capital is the same as for nonhousing capital.¹⁹ In practice, the discount rate for housing capital is likely to be lower, which would make the price of housing depend relatively more on its long-term value and lead to a smaller price decline during the decumulation episode (see equation (23)).

¹⁹Even after we introduce a risk premium, we continue to assume there is a single rate, r_t , that determines the return to housing capital as well as nonhousing capital (see equation (25)). A version of the model with multiple rates of return with heterogeneous risk premia would be more realistic but would take us too far from our baseline analysis.

Figure 7 also illustrates that, while the overbuilding shock helps to explain the variables related to the housing market, it is not sufficiently large to generate a recession by itself. The interest rate declines by 0.2 percentage points, which is not sufficient to trigger a recession. Note, however, that the decline in the interest rate is quite persistent. This suggests that, if the overbuilding shock is combined with other demand shocks, it could lead to a drag on aggregate output and employment. We verify this in the next subsection.

Overbuilding and Risk-Premium Shocks.—In our benchmark calibration, the decline in the interest rate triggers an investment boom and mitigates the recession (see Figure 7). In practice, however, the US economy did not experience an investment boom even though interest rates have been unusually low for many years (see Figure 6). To fix this aspect of the model, we introduce a shock to the risk-premium parameter, ϕ . Specifically, we replace the lower bound in (25) with

$$r_{t+1} = \max(\phi_{t+1} - \pi, r_{t+1}^*) \quad \text{for each } t \geq 0,$$

where ϕ_{t+1} denotes the risk premium between dates t and $t + 1$. We suppose $\phi_{t+1} = \phi^{new} \geq \phi$ during the periods $t \in \{0, 1, 2, 3\}$, that correspond to zero interest rates in the data. We calibrate the size of the shock ($\phi^{new} - \phi$) as 3 percent per year so that it puts the economy to the zero lower bound, but it does not reduce output by itself (similar to Midrigan and Philippon 2016). We also suppose that ϕ_{t+1} gradually declines back to ϕ over periods $t \geq 4$.²⁰

Figure 8 illustrates the results from this exercise. The dashed line illustrates the case with risk-premium shocks but without overbuilding. The ϕ shock lowers the risk-free rate to zero, but it does not affect the equilibrium allocations by itself. The solid line illustrates the joint effect of overbuilding and the risk-premium shocks. Starting from near-zero interest rates, the overbuilding shock leads to roughly a 2 percentage point reduction in output in the first two years (2008/2009), as well as a cumulative reduction of about 5.3 percentage points of yearly output. To understand where this decline comes from, recall that our overbuilding shock is about 4 percent of yearly output. After accounting for depreciation that naturally erases some overbuilt capital (see online Appendix B.1), the cumulative shortfall in residential investment (relative to its new steady-state level) is about 3.5 percent of yearly output. With a Keynesian multiplier of 1.5, a back-of-the-envelope calculation would suggest a cumulative decline of 5.2 percentage points, which is close to the decline in our calibration.²¹

²⁰The exact path by which ϕ_{t+1} reverts back to its old level affects the path of interest rates but does not matter for the equilibrium allocations. This is because, by period 4, the decumulation is already completed and the outcomes are supply determined even if $\phi_{t+1} = \phi^{new}$. In this region, the monetary policy increases the nominal interest rate to counter the declines in ϕ_{t+1} .

²¹This calculation is not exact since there are also the investment accelerator effects that lower investment (and the capital stock) in the initial period and raise it in subsequent periods. The cumulative demand effect of the accelerator is close to zero, and thus, the back-of-the-envelope calculation is roughly accurate.

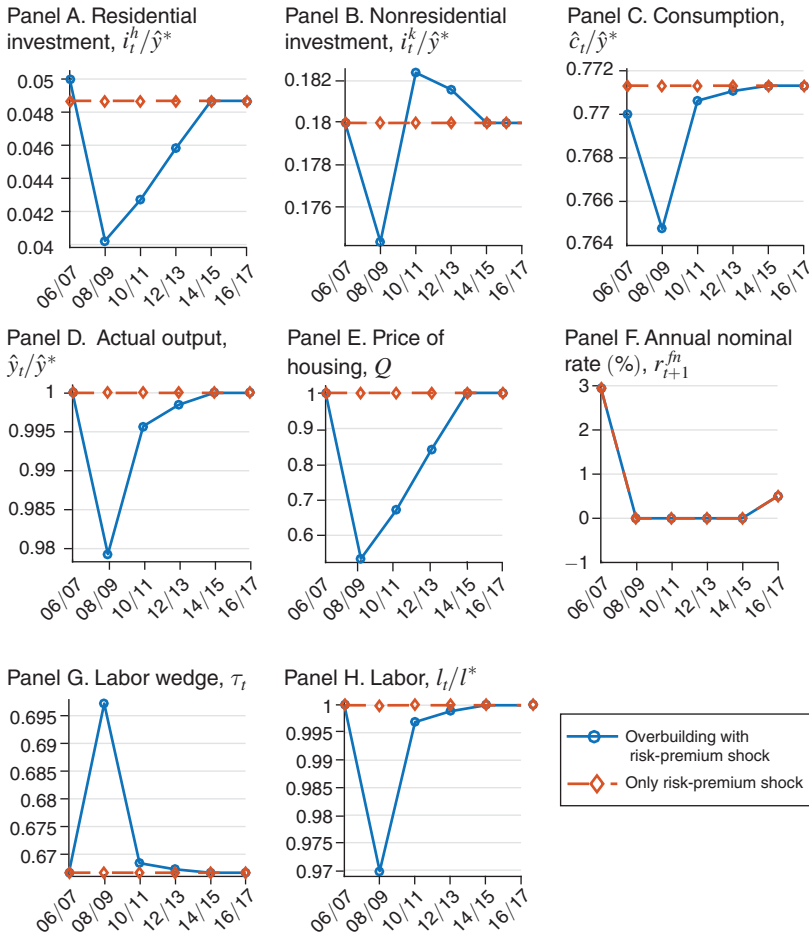


FIGURE 8. CALIBRATION WITH OVERBUILDING AND RISK-PREMIUM SHOCKS

Overbuilding with Risk-Premium and Deleveraging Shocks.—The risk-premium shock ensures that overbuilding affects output and employment. The model also generates a decline in consumption and investment in the first period, but at much smaller levels than those observed in the data (see Figure 6). To fix these aspects, we introduce an additional shock that we interpret as capturing household deleveraging in reduced form. Specifically, we replace the Euler equation with

$$u'(c_t) = (1 + \gamma_t)\beta(1 + r_{t+1})u'(c_{t+1}) \quad \text{for each } t,$$

for an exogenous sequence $\{\gamma_{tj}\}_{t=0}^{\infty}$. A positive γ_t reduces aggregate (net) consumption at time t , which can be thought of as capturing household deleveraging. We calibrate $\{\gamma_{tj}\}_{t=0}^{\infty}$ based on the analysis in Mian, Rao, and Sufi (2013). Specifically, we combine their estimate for the MPC out of housing net worth with the decline

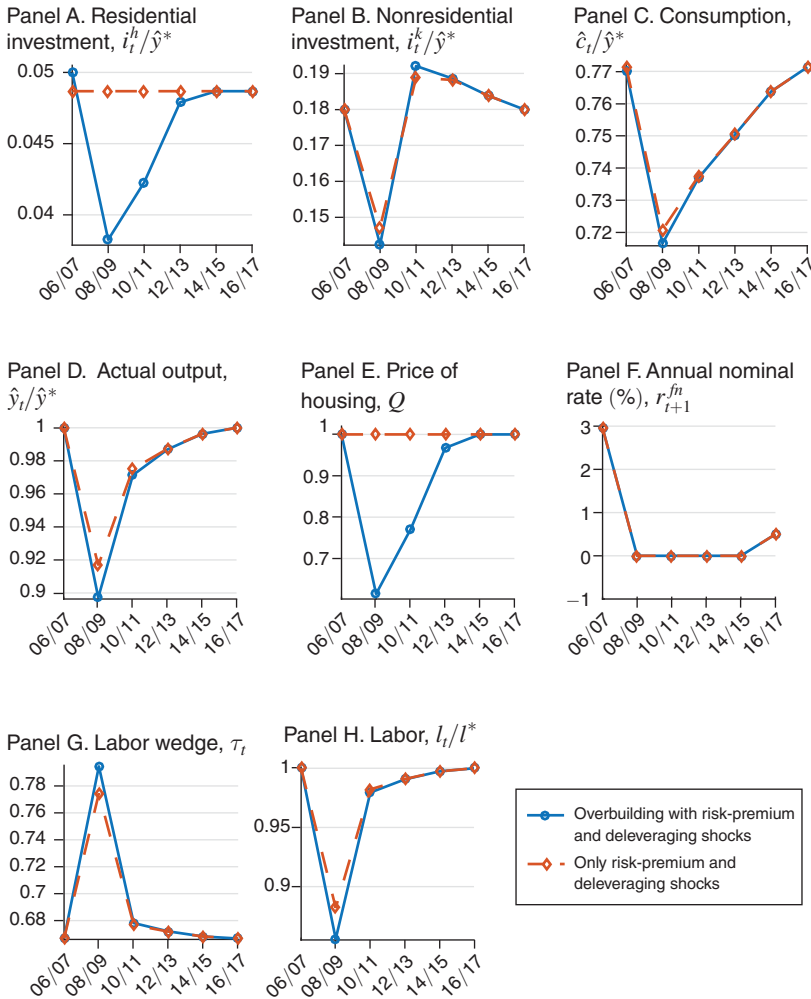


FIGURE 9. CALIBRATION WITH OVERBUILDING, RISK-PREMIUM, AND DELEVERAGING SHOCKS

in housing net worth since 2006 to calculate an implied decline in consumption for each year between 2008 and 2015. We then set the sequence $\{\gamma_t\}$ to generate the same consumption declines in periods $t \in \{0, 1, 2, 3\}$ of the model starting with the steady-state consumption in all periods.

Figure 9 plots the results of this exercise. The solid line is our final calibration that incorporates all three shocks. The dashed line is a comparison benchmark that features the deleveraging and the risk-premium shocks without overbuilding. Similar to the previous exercise, the overbuilding shock generates an additional 2 percentage points reduction in output in the first two years (2008/2009) as well as a cumulative reduction of about 4.7 percentage points of yearly output. The three shocks together match the decline in aggregate output as well as its decomposition reasonably well.

Figure 10 illustrates this point by replicating the accounting exercise in Section IVA in the calibrated model environment. The model-implied decline in

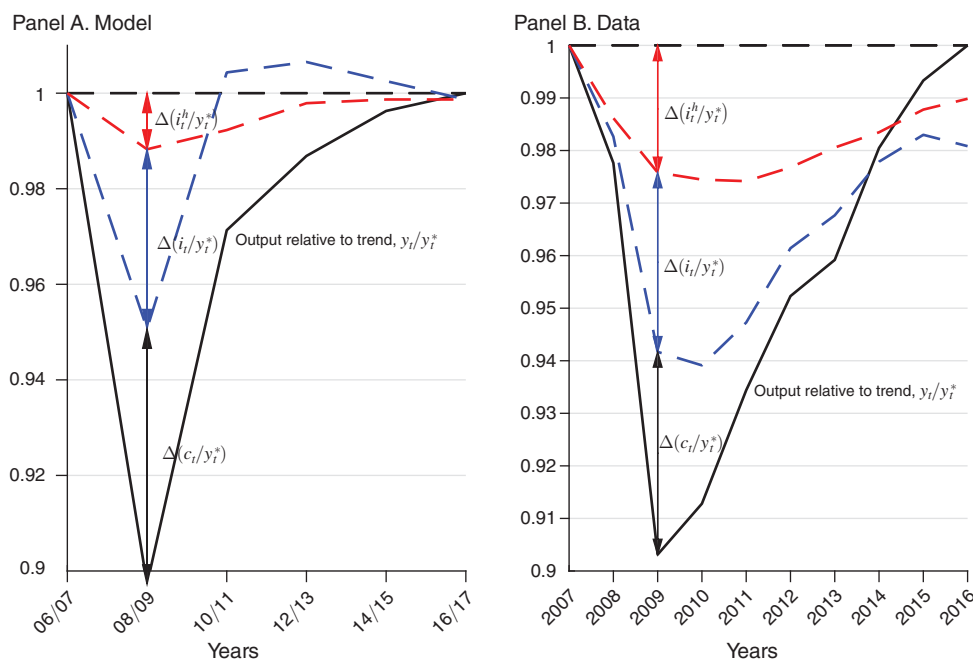


FIGURE 10

Notes: Panel A decomposes the shortfall in output in the calibrated model into contributions coming from its components. Panel B, which is from Figure 6, illustrates the same decomposition exercise in the data.

investment-output ratio is almost as large as in the data even though we did not introduce a shock (such as the financial crisis) that exclusively lowers investment in the first period. This suggests that the accelerator could be a contributing factor to low investment during the Great Recession. The model-implied decline in consumption is also close to the level observed in the data, which supports the deleveraging mechanism. The contribution of residential investment to the decline in output grows over time in the model as in the data. However, the model generates too fast a recovery in nonresidential investment compared to the data, which also induces too fast a recovery in output. Hence, the model cannot fully explain the weakness in nonresidential investment in recent years.

We take away four main conclusions from the quantitative evaluation. First, in a demand-side accounting exercise, residential investment accounts for a relatively sizable and persistent fraction of the decline in output. Second, the overbuilding shock (which we measure directly from external data sources) helps to understand the decline in residential investment, as well as the decline in house prices. Third, when combined with a risk-premium shock that lowers the interest rate to zero, the overbuilding shock generates a cumulative decline in output roughly equal to 5 percentage points of yearly output. Fourth, overbuilding, risk-premium, and deleveraging shocks can together match the demand-side accounting results for the earlier phase of the slump reasonably well.

V. Policy Implications

We next investigate the welfare implications of our analysis. Since our model features a liquidity trap, several policies that have been discussed in the literature are also relevant here.²² We skip a detailed analysis of these policies for brevity. Instead, we focus on constrained policy interventions directed towards controlling investment (housing and nonhousing), which plays the central role in our analysis. We first discuss ex post policies by which the government can improve welfare once the overbuilding is realized. We then discuss ex ante policies that the government can implement (prior to date 0) as a precaution.

The policy implications are driven by *aggregate demand externalities*, which are best illustrated by Figure 3 in the baseline setting. In the region $b_0 \geq \bar{b}_0$, increasing the initial stock of housing, b_0 , does not change the initial net consumption, c_0 , which is a sufficient statistic for welfare (because it also takes into account labor costs). That is, starting the economy with more housing capital (or conversely, destroying some housing capital) neither raises nor lowers welfare. Intuitively, giving one unit of housing capital to a household raises her welfare (see equation (28)), but it also lowers housing investment. This in turn reduces aggregate demand and employment and reduces other households' welfare. In the baseline setting, these demand externalities are so strong that they completely undo the direct value of housing capital.

The externalities are very powerful in part because of the multiplier embedded in GHH preferences (see Remark 3). To provide a more transparent cost-benefit analysis for policy interventions, in this section, we work with a slight modification of the baseline model in Section I (all of the results also hold in the baseline setting). Suppose at date 0, and only at this date, households' preferences over consumption and labor are given by the separable form, $u(c_0) - v_0(l_0)$, as opposed to the GHH form, $u(\hat{c}_0 - v(l_0))$. With a slight abuse of terminology, we use c_0 to denote consumption at date 0 as opposed to net consumption, and $y_0 = F(k_0, l_0)$ to denote output at date 0 as opposed to net output. We also abstract away from adjustment costs so that the competitive equilibrium decumulates the excess capital in a single period. Lemma 2 in online Appendix B.3 establishes that a sufficiently high level of overbuilding triggers a demand-driven recession also in this setting.

A. Ex Post Policies: Slowing Down Disinvestment

A natural question in this environment concerns the optimal government policy regarding housing investment. On the one hand, since overbuilding is associated with housing, it might sound intuitive that the planner should not interfere with the decumulation of this type of capital. On the other hand, policies that support the housing market have been widely used during and after the Great Recession (see

²²In particular, welfare can be improved with unconventional monetary policies as in Eggertsson and Woodford (2003), or unconventional tax policies as in Correia et al. (2013). Once we modify the model appropriately to include government spending, welfare can also be improved by increasing government spending during the recession as in Werning (2012) and Christiano, Eichenbaum, and Rebelo (2011).

Berger, Turner, and Zwick 2016 for an evaluation of some of these policies). We next formally analyze the desirability of these types of policies.

We start by revisiting the representative household's equilibrium trade-off for housing investment, which provides a useful benchmark for the planner's trade-off. Imagine a household who already invested up to the target level, $h_1 = h^*$, and who is considering investing an additional unit. Online Appendix B.3 defines the value function, $W_0(h_1)$, for this household and shows that

$$(28) \quad \frac{d_+ W_0(h_1)}{dh_1} \Big|_{h_1=h^*} = u'(\bar{c}_0) \left(\frac{1 - \delta^h}{1 + r_1} - 1 \right) < 0.$$

Here, $\frac{d_+ W_0(h_1)}{dh_1}$ denotes the right derivative, and the inequality follows since $r_1 = 0$. The household assigns a positive value, $1 - \delta^h$, to the excess unit of housing capital: even though she does not receive any flow utility in the short run, she will benefit from the non-depreciated housing in the future. Nonetheless, she chooses $h_1 = h^*$ in equilibrium because the benefit is lower than the private cost of capital.²³

Next, consider a constrained planner who can fully determine housing investment at date 0, but cannot interfere with the remaining market allocations either at date 0 or in the future. Online Appendix B.3 defines the value function, $W_{0,pl}(h_1)$, for this constrained planner and shows that

$$(29) \quad \frac{d_+ W_{0,pl}(h_1)}{dh_1} \Big|_{h_1=h^*} = u'(\bar{c}_0) \left((1 - \delta^h) - (1 - \tau_0) + \frac{dc_0}{dh_1} \tau_0 \right).$$

Here, $\tau_0 > 0$ is the labor wedge, which captures the severity of the demand shortage (as in the baseline model). Comparing equations (28) and (29) illustrates that the (direct) social benefit of building is the same as the private benefit, $1 - \delta^h > 0$. However, the social cost is lower, $1 - \tau_0 < 1$, which leads to the following result.

PROPOSITION 2 (Slowing Down Disinvestment): *Consider the equilibrium characterized in Lemma 2. There exists \tilde{b}_0 such that if $b_0 > \tilde{b}_0$, then the planner chooses a higher level of housing investment than the target level, $h_{1,pl} > h^*$.*

The planner recognizes that housing investment increases aggregate demand and employment. This is socially beneficial, and the benefits are captured by the labor wedge, τ_0 , because employment is below its efficient level. Thus, the demand externalities lower the social cost of building. The reduced cost, by itself, does not create sufficient rationale for intervention—the planner also compares the cost with the benefit. Proposition 2 shows that the planner intervenes as long as the initial overbuilding is sufficiently large (since greater overbuilding increases the labor wedge). Equations (28) and (29) suggest further that this is more likely if the overbuilt capital is more durable, so that $1 - \delta^h$ is higher. Intuitively, durable capital—such as

²³The right derivative, $\frac{d_+ W_0(h_1)}{dh_1}$, is strictly less than zero at the optimal housing level, $h_1 = h^*$, since the household preferences in (2) feature a kink at this level.

housing—has a relatively high value, even if it is overbuilt in the short run, because it helps to economize on future investment.²⁴

Our model thus provides a rationale for policies that support housing investment during an investment hangover. In practice, the planner can do this by increasing housing demand, e.g., with mortgage subsidies or modifications, or by increasing housing supply, e.g., with construction subsidies. Both types of policies can internalize the inefficiency in our model. Note, however, that the demand-side policies tend to increase house prices, whereas the supply-side policies tend to decrease them. The demand-side interventions might be more appropriate if one considers additional ingredients, such as financial frictions, that are left out of our analysis.

To isolate the trade-offs, we focused on a planner who can only influence housing investment. In practice, the policymakers can use various other tools to fight a demand-driven slump. Equation (29) would also apply in variants of the model in which the planner optimally utilizes multiple policies. In those variants, the equation would imply that the planner should stimulate housing investment as long as she cannot substantially mitigate the demand shortage (i.e., lower the labor wedge, τ_0) by using only the other feasible policies. This prediction is arguably applicable to various developed economies in recent years, e.g., the United States and Europe, that have featured zero nominal interest rates with low employment and output despite utilizing various stimulus policies.

B. *Ex Ante Policies: Restricting Investment*

We next analyze whether the planner can improve welfare via ex ante interventions. To this end, consider the baseline model with an ex ante period, date -1 . Suppose also that the economy can be in one of two states at date 0, denoted by $s \in \{H, L\}$. State L is a low-demand state in which the target level of housing capital is h^* as before (and the planner has no tools for ex post intervention). State H is a high-demand state in which the utility function in (2) is modified so that the target level of housing capital is $(1 + \lambda^H)h^*$ for some $\lambda^H > 0$. Let $\pi^H \in (0, 1)$ denote the ex ante probability of the high-demand state at date 0. The economy starts with $h_{-1} = (1 + \lambda^H)h^*$ and $k_{-1} = k^*$.

The model can be thought of as capturing a situation in which housing demand has recently increased relative to its historical level, and the economy has already adjusted to this new level. However, there is a possibility that the current state is not sustainable and the housing demand will revert back to its historical level. We also envision that π^H is large, so that the representative household believes the high-demand state is likely to persist, but also that $\pi^H < 1$ so that there is room for precautionary policies.

²⁴Equation (29) illustrates an additional benefit of investing in durable capital, captured by the nonnegative term, $\frac{dc_0}{dh_1}\tau_0$ (see online Appendix B.3). Intuitively, bringing the non-depreciated part of the capital to date 1 creates a future wealth effect that raises consumption not only at date 1, but also at date 0, which further increases employment. This channel is reminiscent of the forward guidance policies that create a similar wealth effect by committing to low interest rates in the future. In fact, increasing h_1 also lowers the future interest rate, r_2 , in our setting. Note, however, that future output remains efficient in our model, $y_1 = S(k_1)$, whereas it exceeds the efficient level in environments with forward guidance (Werning 2012).

We first characterize the choice of h_0 and k_0 in the competitive equilibrium, which we then compare with the constrained efficient allocations. The preferences in (2) imply that the opportunity cost of consuming housing services below target is very large. Consequently, households invest in housing capital according to their demand in state H , that is, $h_0 = (1 + \lambda^H)h^*$. The degree of overbuilding in state L is now endogenized, $b_0 = \lambda^H$.²⁵ Nonhousing investment, k_0 , is in turn determined by a standard optimality condition,

$$(30) \quad u'(c_{-1}) = \beta(\pi^H(R_0^H + 1 - \delta^k)u'(c_0^H) + (1 - \pi^H)(R_0^L + 1 - \delta^k)u'(c_0^L)).$$

Online Appendix B.3 completes the characterization and establishes that there is a demand-driven recession in state L of date 0 if λ^H and π^H are sufficiently high.

Next, consider a constrained planner who can determine households' date -1 allocations, including h_0, k_0 , but cannot interfere with equilibrium allocations starting date 0. Like households, the planner also optimally chooses $h_{0,pl} = (1 + \lambda^H)h^*$. However, the planner's choice of nonhousing capital, $k_{0,pl}$, is potentially different. Online Appendix B.3 describes the constrained planning problem and characterizes the planner's optimality condition as

$$(31) \quad u'(c_{-1}) = \beta(\pi^H(R_0^H + 1 - \delta^k)u'(c_0^H) + (1 - \pi^H)(R_0^L + (1 - \tau_0)(1 - \delta^k))u'(c_0^L)).$$

Conditions (30) and (31) are similar except that the planner penalizes the non-depreciated part of the capital in state L , since $1 - \tau_0 < 1$, which leads to the following.

PROPOSITION 3 (Restricting Ex Ante Investment): *Consider the setup with an ex ante period, characterized in Lemma 3 in online Appendix B.3. The constrained planner chooses a lower level of investment compared to the competitive equilibrium, $k_{0,pl} < k_0$.*

Intuitively, some of the capital invested at date -1 remains non-depreciated at date 0, which in turn lowers aggregate demand and exacerbates the recession in state L . Private agents do not internalize these negative externalities and overinvest in capital from a social point of view. In our stylized model, the inefficiency does not show up in housing capital, because the extreme preferences in (2) imply a corner solution for both the private sector and the planner. In alternative formulations with somewhat elastic housing demand, the planner would optimally restrict ex ante investment in both types of capital. In fact, equation (31) suggests that the externality is particularly strong for more durable types of capital such as housing, because the inefficiency is driven by the non-depreciated part.

Proposition 3 is reminiscent of the results in a recent literature, e.g., Korinek and Simsek (2016) and Farhi and Werning (2016), which investigate the implications

²⁵The feature that overbuilding is determined exactly by the demand in state H is extreme. However, a similar outcome would also obtain in less extreme versions as long as π^H is sufficiently large.

of aggregate demand externalities for ex ante macro-prudential policies in financial markets. For instance, Korinek and Simsek (2016) show that, in the run-up to liquidity traps, private agents take on too much debt, because they do not internalize that leverage reduces aggregate demand. We complement this analysis by showing that aggregate demand externalities also create inefficiencies for ex ante *physical* investment. Our model highlights a distinct mechanism and generates policy implications that are not the same as the macro-prudential policies typically emphasized in this literature. We provide a rationale for restricting ex ante investment regardless of whether investment is financed by debt or other means.

The planner could restrict investment by using a variety of direct policies, e.g., taxes, quantity restrictions, or financing restrictions. A natural question is whether the planner should also use monetary policy. The US Federal Reserve has been criticized for keeping the interest rate low in the run-up to the Great Recession. Our next result investigates whether a contractionary policy that raises the interest rate at date -1 above its natural level might be desirable.

PROPOSITION 4 (Jointly Optimal Monetary and Investment Policy): *Consider the setup in Proposition 3. Suppose the planner chooses the interest rate, r_0 , at date -1 , in addition to controlling the household's ex ante allocations. It is optimal for this planner to set $r_0 = r_0^*$ and implement $y_{-1} = S(k_{-1})$.*

Once the investment (restricting) policies are in place, it is optimal for monetary policy to pursue its myopic output stabilization goal described in (10). The constrained efficient outcome (characterized by condition (31)) is to reduce the investment at date -1 while increasing consumption, so that there is some reallocation but not a recession at date -1 . The investment policies implement this outcome by allowing the interest rate to be determined in equilibrium so as to clear the goods market (the zero lower bound constraint does not bind at date -1 under our assumptions). In contrast, setting a high level of the interest rate, $r_0 > r_0^*$, reduces investment while also creating an inefficient recession at date -1 .²⁶

Let us summarize the insights from the welfare analysis. Ex post, once the economy is in the demand-driven slump, welfare can be improved by policies that stimulate investment, including investment in the overbuilt capital. Ex ante, before the economy enters the slump, welfare can be improved by policies that restrict investment. The optimal ex post and ex ante policies share the broad principle that they intertemporally substitute investment from periods that feature efficient outcomes to periods (or states) that feature deficient demand. Intertemporal substitution is less costly for more durable types of capital that deliver a utility flow over a long horizon. Our analysis thus suggests that the policy interventions are particularly desirable for more durable types of capital.

²⁶That said, if the planner does not have access to the investment policies described previously, or faces additional costs in implementing these policies, then she might want to resort to constrained monetary policy as a second-best measure.

VI. Conclusion

We have presented a model of investment hangover motivated by the Great Recession that combines Hayekian and Keynesian features. On the Hayekian side, the recession is precipitated by overbuilding of durable capital such as housing, which necessitates a reallocation of resources to other sectors. On the Keynesian side, a constrained monetary policy prevents the interest rate from declining sufficiently, which slows down reallocation and creates an aggregate demand shortage. The demand shortage can also reduce investment in other types of capital (that are not overbuilt) via an accelerator effect, leading to a severe recession. Eventually, other types of investment recover, but the slump in the overbuilt sector continues for a long time.

The model yields predictions consistent with the broad trends of GDP, housing investment, and nonhousing investment in the Great Recession. In particular, the model explains why both types of investment declined initially, but housing investment recovered much less robustly than nonhousing investment. In a calibration exercise, the overbuilding shock (that we measure from external sources) can match the path of housing prices and investment, but it is not sufficiently strong to trigger the recession by itself. When combined with two other plausible shocks—one to the risk premium and one to household leverage—the overbuilding shock also explains a cumulative 5 percentage point reduction in output. A model with these three shocks can reasonably account for the decline in output and its demand-side components during the Great Recession.

The model also features aggregate demand externalities, with several policy implications for investment. Welfare can be improved by ex post policies that slow down the decumulation of housing capital, as well as ex ante policies that restrict the accumulation of capital. These policies intertemporally substitute investment towards periods that feature deficient demand.

Although we have focused on the Great Recession, the model is more widely applicable in environments in which the key assumptions hold: durable capital is overbuilt and monetary policy is constrained. During the times of Hayek and Keynes, speculative overbuilding was seen as a critical impetus to recessions, but the focus was more on railroads and industrial plant than on housing. In the recent European context, overbuilding of houses (or structures) might have contributed to the macroeconomic slump in many countries, and monetary policy was constrained by the currency union as well as the liquidity trap. We leave an elaboration of these applications of our model for future work.

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