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## *Financial Crash, Commodity Prices, and Global Imbalances*

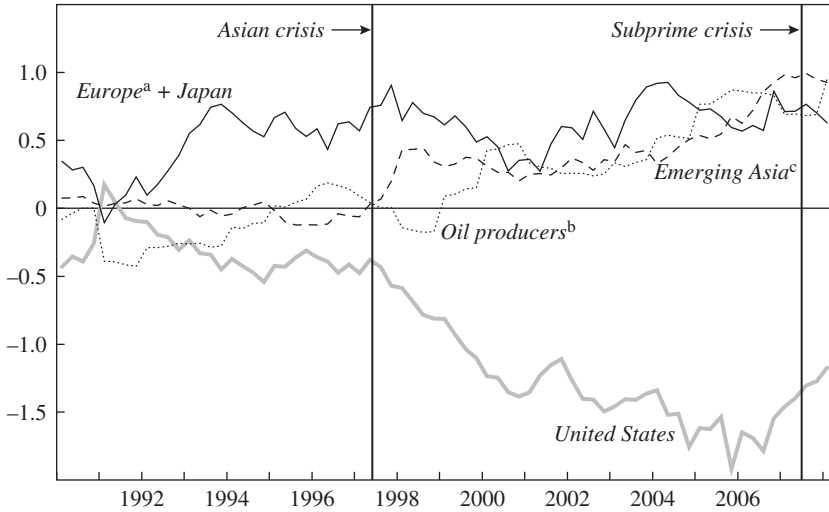
**ABSTRACT** The current financial crisis has its origins in global asset scarcity, which led to large capital flows toward the United States and to the creation of asset bubbles that eventually burst. In its first phase the crash exacerbated the shortage of assets in the world economy, which triggered a partial re-creation of the bubble in commodities markets, and oil markets in particular. This bubble in turn led to an increase in petrodollars seeking financial assets in the United States, which became a source of stability for the U.S. external balance. The second phase of the crisis is more conventional and began to emerge in the summer of 2008, when it became apparent that the financial crisis would permeate the real economy and sharply slow global growth. This slowdown worked to reverse the tight commodity market conditions required for a bubble to develop, ultimately destroying the commodity bubble.

In this paper we argue that the persistent global imbalances of recent decades, the subprime crisis, and the volatile oil and asset prices that followed it are tightly interconnected. All stem from a global environment where sound and liquid financial assets are in scarce supply.

Our story goes as follows: Global asset scarcity led to large capital flows toward the United States and to the creation of asset bubbles that eventually burst. The crash in the real estate market was particularly complex from the point of view of asset shortages, since it compromised the whole financial sector and, by so doing, closed many of the alternative saving vehicles. Thus, in its first phase, the crisis exacerbated the shortage of assets in the world economy, which triggered a partial re-creation of the

**Figure 1.** Current Account Balances, 1990–2008

Percent of world GDP



Sources: World Bank, *World Development Indicators*; International Monetary Fund, *World Economic Outlook* and *International Financial Statistics*; Organization for Economic Cooperation and Development; authors' calculations.

a. Austria, Belgium, Denmark, France, Germany, Iceland, Ireland, Italy, Netherlands, Spain, Sweden, and Switzerland.

b. Bahrain, Canada, Iran, Kuwait, Libya, Mexico, Norway, Oman, Russia, Saudi Arabia, and Venezuela.

c. China, Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, and Thailand.

bubble in commodities, and in oil markets in particular. Rising oil prices in turn led to an increase in petrodollars seeking financial assets in the United States. In contrast to the typical, destabilizing role played by capital outflows during financial crises, petrodollar flows became a stabilizing factor for the U.S. economy. The second phase of the crisis is more conventional and began to emerge during the summer of 2008. It became apparent then that the financial crisis would permeate the real economy and sharply slow global growth. This slowdown worked to reverse the tight commodity market conditions required for a bubble to develop, ultimately destroying the commodity bubble.

We now develop some of these steps, starting from the underlying structural force fueling U.S. asset appreciation. Figure 1 displays the main patterns of global imbalances since 1990 as revealed in the current accounts of the United States, Europe and Japan (combined), emerging Asia, and the oil-producing economies, all relative to world GDP. The facts are well known: Starting in 1991 the U.S. current account deficit worsened contin-

uously, reaching 6.4 percent of U.S. GDP in the fourth quarter of 2005, then falling back to 5 percent of GDP by early 2008. The current account surpluses that were the counterpart of the U.S. deficits initially emerged in Japan and Europe and were bolstered by surpluses in emerging Asia and the commodity-producing countries after 1997.

In a previous paper we showed how this buildup in global imbalances could be understood as the consequence of asymmetries in financial development and growth prospects across different regions of the world.<sup>1</sup> In particular, we argued that the emerging market crises at the end of the 1990s, the subsequent rapid growth of China and other East Asian economies, and the associated rise in commodity prices in recent years reoriented capital flows *from* emerging markets *toward* the United States. In effect, emerging markets and commodity producers in need of sound and liquid financial instruments to store their newfound wealth turned to the U.S. financial markets, which were perceived as uniquely positioned to provide these instruments.<sup>2</sup>

As we explained then, a by-product of this reallocation of capital flows was a necessary decline in U.S. and world real interest rates and a boom in U.S. asset markets. Ex ante real interest rates on 10-year U.S. government bonds fell below 2 percent a year in 2002 (figure 2), and the rate on a 30-year fixed-rate conventional mortgage reached 5.23 percent in June 2003 (figure 3), with annual inflation at 2.9 percent. As foretold by Ben Bernanke, then a governor of the Federal Reserve, in his influential “savings glut” speech,<sup>3</sup> it is now apparent that this boom was located in no small part in a rise in U.S. housing markets and the related markets for structured credit instruments (figures 4 and 5). In the context of low real interest rates, U.S. households were encouraged to take on more housing risk than they could bear, risks that then disappeared as if by magic from the mortgage-backed securities and other structured investment vehicles whose supply exploded over the same period (figure 5). The catastrophic and systemic failures of this originate-to-distribute model are now well documented.<sup>4</sup>

1. Caballero, Farhi, and Gourinchas (2008).

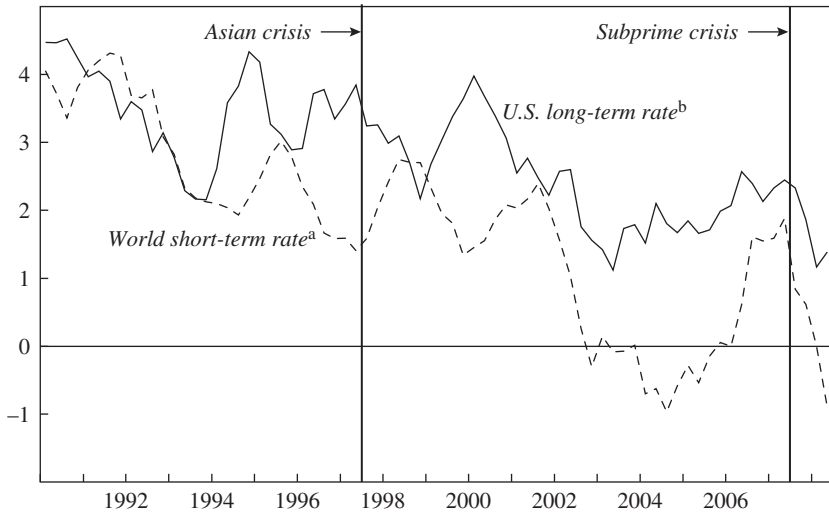
2. In recent years a significant portion of the capital flows from emerging markets to the United States took the form of official reserve accumulation. The composition of capital flows is not the focus of our analysis. Nonetheless, we observe that especially in the case of China, most of these reserves are indirectly held by local investors through low-return sterilization bonds.

3. Bernanke (2005).

4. See Brunnermeier (2009) and Greenlaw and others (2008) for detailed recent accounts of the subprime crisis.

**Figure 2. Real Interest Rates, 1990–2008**

Percent a year



Sources: World Bank, *World Development Indicators*; International Monetary Fund, *International Financial Statistics*; Organization for Economic Cooperation and Development; Survey of Professional Forecasters; authors' calculations.

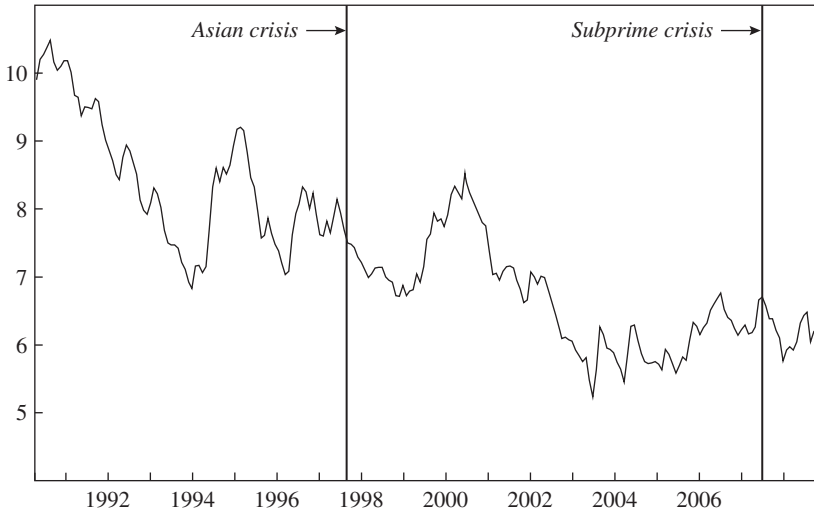
a. Average ex post rate for the previous four quarters on three-month national treasury bills of the Group of Seven countries. Averages across countries are weighted by GDP. Each country's nominal interest rate is deflated by its consumer price index.

b. Rate on 10-year U.S. Treasury bonds minus 10-year expected inflation from the Survey of Professional Forecasters.

By sometime in 2006, the rise in U.S. real estate prices had come to a halt, and the U.S. current account deficit began to turn around (see figures 1 and 4). Starting in earnest in June 2007, with the bailout of two hedge funds operated by the investment bank Bear Stearns that could not meet their margin calls, the world economy entered, with a certain fracas, into a period of significant global adjustment. Within weeks, funding dried up for entire segments of both the U.S. and the international banking sectors, especially asset-backed commercial paper (see figure 5), leading to major convulsions of credit and money markets, including the dramatic collapse and rescue of several major U.S. and European commercial and investment banking institutions. More than 12 months after the onset of the crisis, financial markets appear nowhere near stabilized. In fact, by the beginning of the summer of 2008, financial distress in major players had begun to accelerate, a process that started with the government rescue of the government-sponsored enterprises Fannie Mae and Freddie Mac in July and culminated

**Figure 3. Contract Interest Rate on 30-Year Fixed-Rate Conventional Home Mortgage Commitments, 1990–2008**

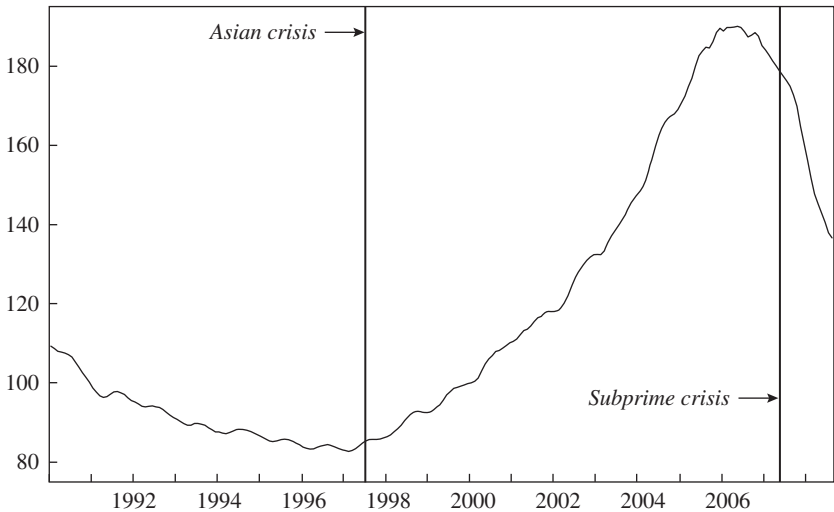
Percent a year



Source: Federal Reserve Statistical Release H.15, "Selected Interest Rates."

**Figure 4. Real S&P/Case-Shiller Composite 10 Home Price Index, 1990–2008**

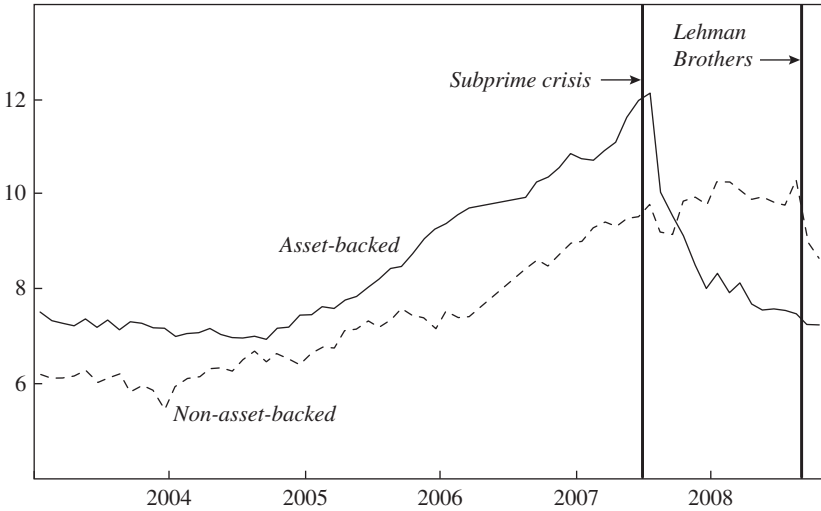
January 2000 = 100



Sources: Standard & Poor's; International Monetary Fund, *International Financial Statistics*; authors' calculations.

**Figure 5.** Commercial Paper Outstanding, 2003–08

Trillions of dollars



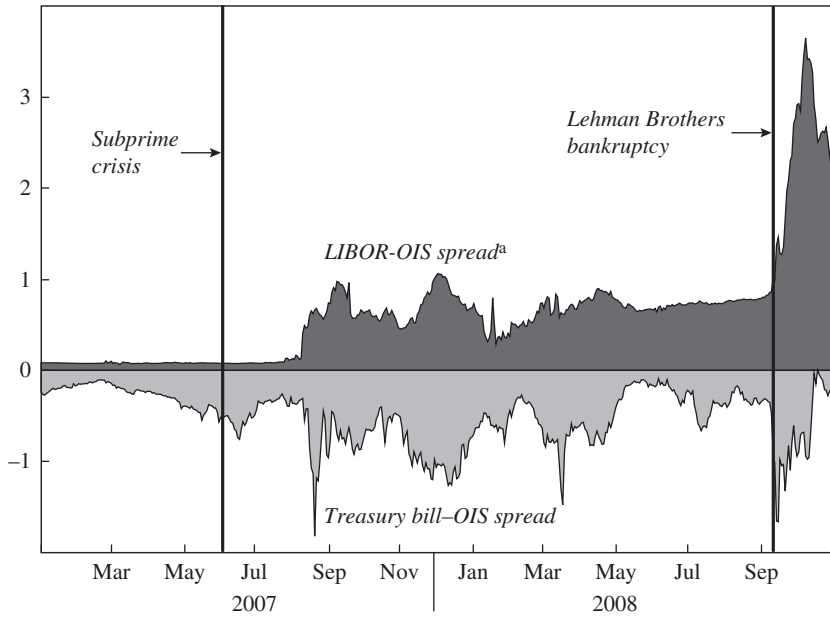
Source: Federal Reserve Board.

with the failure of the investment bank Lehman Brothers on September 15. This was a watershed moment. Until then, the crisis had been severe but largely contained within the financial sector. Following the collapse of Fannie and Freddie and of the entire U.S. broker-dealer industry, the seizing up of wholesale money markets reached unprecedented proportions. Figure 6 decomposes the spread between the three-month London interbank offer rate (LIBOR) and the three-month Treasury yield (the TED spread) into two parts: a LIBOR-overnight index swap (OIS) spread, which measures interbank credit risk, and a Treasury-OIS spread, which captures the flight to liquidity. In the weeks following the collapse of Lehman Brothers, both components of the spread increased dramatically, with the Treasury-OIS spread reaching 165 basis points on September 17 and the LIBOR-OIS spread reaching 365 basis points on October 10. With credit markets on life support, the crisis quickly spread to the rest of the economy.

It is most likely that the strong U.S. capital inflows of the last few years contributed to the significant weakening of U.S. credit markets. The eventual recognition of their degraded performance was one of the triggers of the current crisis. However, this weakening is in itself part of the endogenous

**Figure 6.** Components of the TED Spread, January 2007–November 2008

Percentage points

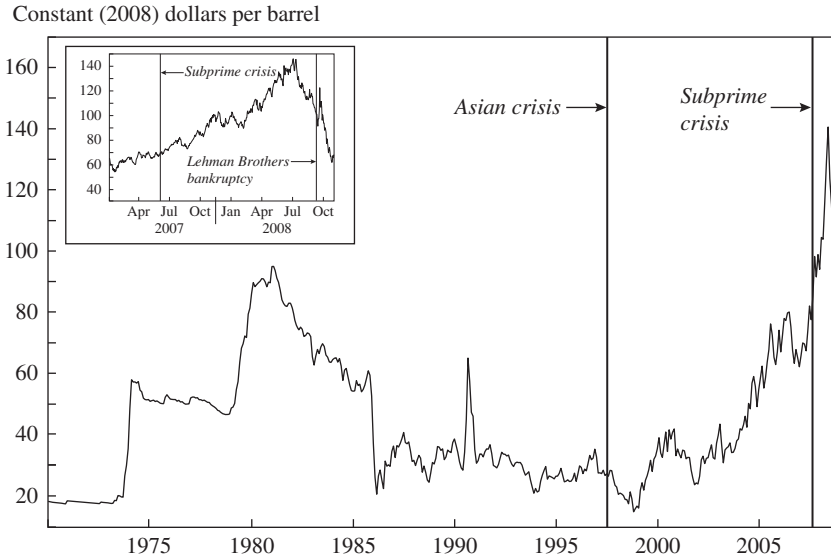


Source: MorganMarkets; authors' calculations.

a. OIS, overnight index swap.

response of U.S. financial markets to world financial conditions. In effect, U.S. assets became stretched as U.S. markets tried to accommodate the world's excess demand for assets. Therein lies the structural problem. This chronic excess demand for assets derives from financial underdevelopment in emerging markets and most commodity-producing economies, rather than from macroeconomic imbalances. Excess asset demand leaves an unmistakable signature in low real interest rates, which in turn provide a fertile ground for bubbles to emerge. Thus an alternative, if perhaps metaphorical, interpretation of the sequence of events is that the bubble located in emerging markets during the 1990s migrated to the U.S. housing and credit markets (and before that the NASDAQ) following the emerging market crisis of the late 1990s and the coming on line of capitalist China.<sup>5</sup>

5. See Caballero and Krishnamurthy (2006) for a model of bubbles and capital flows in emerging markets based on financial underdevelopment.

**Figure 7.** Price of West Texas Intermediate Oil, 1970–2008

Sources: Global Financial Data; International Monetary Fund, *International Financial Statistics*; authors' calculations.

With the U.S. financial crisis, that bubble collapsed as well. Initially, the excess asset demand that produced it did not. Indeed, emerging markets and commodity producers found themselves more than ever in search of investment opportunities—witness the long list of sovereign wealth funds that have recently been formed in many emerging markets and the enormous financial means at their disposal. According to Deutsche Bank,<sup>6</sup> these state-owned funds managed \$3 trillion in assets as of September 2007 and were expected to be managing an additional \$7 trillion within 10 years. (These figures are now being revised downward as a result of the brutal slowdown in world economic growth.) Another bubble was likely to appear as the endogenous response of a world economy seeking to increase the global supply of financial assets. We argue that it did so quickly, in the form of a commodity bubble. Figure 7 tracks the real price of a barrel of West Texas Intermediate (WTI) crude oil since 1970, in 2008 dollars. Between June 2007 and June 2008, the real price of WTI increased by almost 100 percent. During the summer of 2008, however, as the financial

6. Deutsche Bank (2007).

crisis spread and economic growth started to decline, commodity prices suffered a dramatic collapse. Between July 2008 and October 2008, the real WTI price declined by almost 53 percent, bringing it back to its level of June 2007.<sup>7</sup>

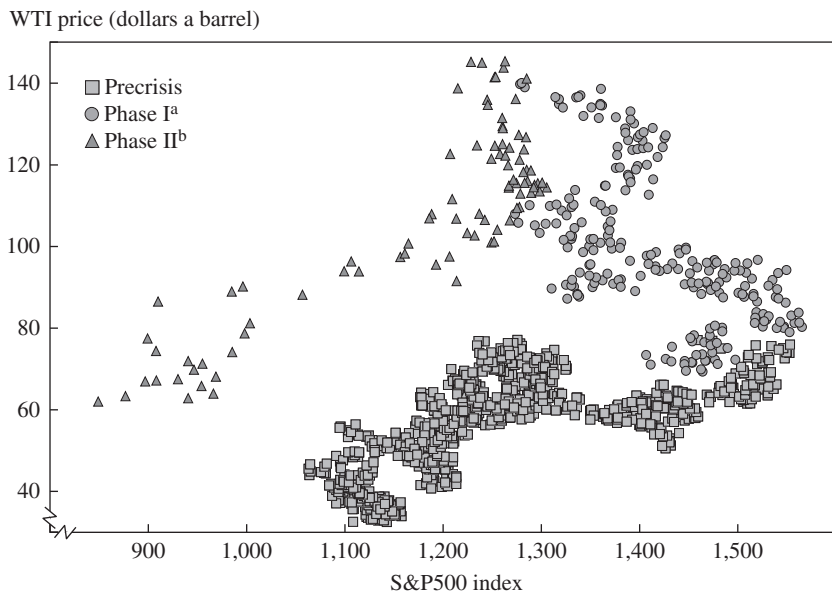
Essentially, in the first phase of the crisis the *combination* of tight commodities markets and the decline in equilibrium real interest rates made it worthwhile, from the point of view of private economic agents, to transform commodities into an asset (or even a new bubble). The mechanism is related (but not identical) to that described by Harold Hotelling more than 70 years ago:<sup>8</sup> Sufficiently low real interest rates make inventory accumulation profitable and drive up the price of exhaustible resources. However, in the second phase the market tightness precondition disappeared, which in turn destroyed the asset accumulation incentive behind the feverish rise in commodity prices, triggering their collapse.

A scatterplot of daily observations of WTI prices against the S&P500 index from 2004 to 2008 (figure 8) clearly illustrates the different phases of the crisis. Before June 2007 the correlation between oil prices and U.S. stock prices was positive. During the first phase of the crisis, from July 2007 to June 2008, the correlation turned strongly negative. Finally, since July 2008, the correlation has again become strongly positive. The negative correlation during the first phase of the crisis is especially interesting from our point of view. Explanations of the surge in commodity prices driven purely by demand for commodities would predict a positive correlation between stock and commodity prices. Later in this paper we provide evidence from instrumental variables estimations to support the claim that the negative correlation in this phase is due not to oil supply shocks but to the financial mechanism we describe.

Let us now return to the implications of these developments for global imbalances. According to the framework developed in our earlier paper, the sharp contraction in U.S. asset supply caused by the subprime crisis

7. This price pattern is quite general across commodities. It is apparent for energy commodities (coal, gasoline, heating oil) and for foodstuffs used as biofuels, such as corn. It is also present for most metals (aluminum, copper, gold, and silver) with the exception of lead, zinc, and nickel, whose prices peaked earlier in 2007. We find it also for most food prices (wheat, soybeans, coffee, tea, cocoa, barley, rice, palm oil, groundnuts, and rapeseed oil, less so for sugar, cattle, and hogs). Our model provides a broad-brush picture of the general evolution of commodity prices. Yet individual commodities might also be affected by other factors—supply disruptions, weather, and commodity-specific demand shocks. We also note that high energy prices generally push up food prices through higher production costs and stronger competition for acreage from biofuels.

8. Hotelling (1931).

**Figure 8.** West Texas Intermediate Oil Price and S&P500 Index, 2004–08

Sources: Global Financial Data; authors' calculations.

a. July 1, 2007, to June 30, 2008.

b. July 1, 2008, to November 8, 2008.

should lower equilibrium interest rates and trigger a rebalancing away from now-“toxic” U.S. assets.<sup>9</sup> The resulting decline in U.S. wealth reduces domestic consumption and improves the trade balance and the current account. This is in line with what has happened since June 2007: annual U.S. long-term real interest rates fell from 2.3 percent to 1.4 percent by June 2008 (figure 2). The current account deficit improved from 5.6 percent of GDP to 5.0 percent, and the trade deficit from 5.2 percent of GDP to 5.0 percent, from June 2007 to 2008.

Although our prediction is qualitatively correct, the initial response of the trade balance and the current account was muted relative to what our basic view implies. That is, if the relative financial appeal of the United States is what is behind the initial imbalances, the subprime crisis should have led to a sharper turnaround in the U.S. current account. Why didn't it? Again, we argue that the answer lies in the *endogenous* response of commodity prices. Because commodity inventories were initially very low, a

9. Caballero, Farhi, and Gourinchas (2008). The model also predicts a simultaneous move toward “safe” U.S. assets. This flight to quality is an important feature of our analysis.

by-product of the strong demand arising from the robust growth of emerging economies, net asset creation from the commodity mechanism was initially small. In contrast, the strong impact of the price rise on the income of commodity-producing economies led to a sharp rise in their demand for stores of value, which further depressed real interest rates and stabilized capital outflows to the United States in the short run.<sup>10</sup>

In the current, second phase of the crisis, external imbalances may or may not increase. Two offsetting forces are at play. On the one hand, the decline in economic growth reduces asset supply. This increases capital outflows to the United States. Simultaneously, the collapse in commodity prices makes commodity producers poorer, hence reducing asset demand. For low levels of inventories, we find that this second effect dominates, so that external imbalances fall.

The rest of this paper provides a model and a quantitative assessment of the story and mechanisms just described. The model adds commodities to our earlier framework. It has two regions,  $U$  and  $M$ . We interpret  $U$  as the United States and  $M$  as the rest of the world, with an emphasis on emerging market economies and commodity producers. The model features two goods: a nonstorable good  $X$ , produced by both regions, and a storable commodity  $Z$ , produced by  $M$  only. The supply of  $X$  grows exogenously whereas the supply of  $Z$  is constant. This feature is meant to capture the growing demand pressures on commodities that arise from robust world economic growth. We set up the model so that a bubble develops initially in  $U$ . As discussed above, we interpret this bubble metaphorically as the extent to which asset markets in  $U$  are stretched to provide financial assets to the rest of the world. With the bubble, the United States runs a larger current account deficit and world interest rates are low.

The original event in our model is the U.S. financial crisis: The bubble bursts at  $t = 0$ , leaving savers scrambling for alternative stores of value. The resulting decline in real interest rates has two effects. First, it increases the value of “good”  $U$  assets. This translates into a flight to quality, from the bubble assets to the “good”  $U$  asset. Second, and more important, it triggers the commodity markets into action. As speculative hoarding takes place, the prices of commodities jump, resulting in a wealth transfer from  $U$  to  $M$ . But  $M$  needs good stores of value. Thus a significant portion of that newfound wealth finds its way back into  $U$ . The resulting capital inflows

10. The reader may wonder why the rise in the price of oil is not simply a transfer of income from oil consumers to producers and hence has no impact on asset demand. The answer is in our choice of numeraire, which is the noncommodity good. This will be clearer once we describe the model but, as with all normalizations, it has no substantive implications.

further boost the value of  $U$  assets and cushion the impact of the bubble's bursting. Eventually, and gradually, the increase in asset supply due to growing commodity inventories pushes up interest rates, which forces rebalancing in  $U$ . To capture the second phase of the crisis, we assume that somewhere along this process the financial crisis compromises global growth. The decline in global growth removes the excess demand in asset markets, leading to a decumulation of inventories and a rapid collapse in commodity prices along with asset prices.

Before turning to the details, it is worth clarifying two modeling subtleties that are important in interpreting our formal discussion. First, although the commodity side of our model shares some of Hotelling's seminal insights, our model does not rely on his key stock constraint (an exhaustible resource). Instead, the model includes a flow extraction constraint which is insufficient to meet demand growth. This mismatch is the main factor behind the structural trend in commodity prices. In this context the subprime collapse superimposes on the previous trend a speculative reason for rising commodity prices. The collapse in global growth in the second phase of the crisis undermines the structural reason (the trend) supporting the bubble. Second, this speculative factor raises the effective opportunity cost of resource extraction for producers, since there is now an asset opportunity cost, as in Hotelling's model, which reduces their extraction incentives. The latter response means that, in equilibrium, there need not be any rise in measured inventories, and hence inventories throughout this paper are defined to include previously unextracted commodities.

The rest of the paper is organized as follows. The first section describes the basic mechanism connecting the financial crisis to commodity prices. The second section focuses on long-run global imbalances, and the third discusses short-run imbalances and presents some back-of-the-envelope estimates of the effects we describe. The fourth section calibrates the model and explores its dynamic implications. The fifth section presents evidence supporting the speculative nature of the rise in oil prices following the subprime crisis and of the recent drop in these prices. The final section offers some conclusions. Appendices A and B expand the discussion in the penultimate section to explore further the possible role of futures markets and antispeculative policies, and of inventory trends, respectively. Appendices C and D present formal derivations of some of the equations in the second, third, and fourth sections.<sup>11</sup>

11. Appendices C and D may be found online via the Brookings Papers website ([www.brookings.edu/economics/bpea/bpea.aspx](http://www.brookings.edu/economics/bpea/bpea.aspx)).

## Global Capital and Commodity Markets

We begin by describing the main features of our model for the world economy.

### *The Model for the World Economy*

In our model, time evolves continuously. Infinitesimal agents (households or traders) are born at a rate  $\theta$  per unit of time and die at the same rate; population mass is constant and equal to one. Agents receive some endowment at birth, which, for simplicity, they save in its entirety until they die. Denote by  $W_t$  the savings accumulated by households at date  $t$ . In every period, aggregate consumption  $C_t$  is then a constant fraction  $\theta$  of these accumulated savings:<sup>12</sup>

$$(1) \quad C_t = \theta W_t.$$

Households consume a basket of two goods: an  $X$  good (the numeraire) and a  $Z$  good. Intratemporal preferences over these two goods are of the constant-elasticity-of-substitution type:

$$(2) \quad C_t = \left[ C_{X,t}^{(\sigma-1)/\sigma} + \alpha^{1/\sigma} C_{Z,t}^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}.$$

Here  $\sigma > 0$  is the elasticity of substitution, and  $\alpha > 0$  controls the equilibrium share of expenditure on the  $Z$  good.

Given a relative price  $p_t$  of the  $Z$  good, households split their consumption between the two goods as follows:

$$(3) \quad C_{X,t} = \frac{\theta W_t}{1 + \alpha p_t^{1-\sigma}} \text{ and } C_{Z,t} = \frac{\alpha p_t^{-\sigma} \theta W_t}{1 + \alpha p_t^{1-\sigma}}.$$

The  $X$  good is a conventional nonstorable good, whereas the  $Z$  good is a storable commodity. Denote by  $I_t \geq 0$  the outstanding inventories of the  $Z$  good. Storing the commodity imposes an iceberg storage cost  $d \geq 0$  per unit of time and good stored. Denote by  $r_t$  the instantaneous interest rate (in terms of the  $X$  good). By arbitrage,  $p_t$  must satisfy

$$(4) \quad \frac{\dot{p}_t}{p_t} \leq r_t + d,$$

12. As we show in our earlier paper (Caballero, Farhi, and Gourinchas 2008), this can be interpreted equivalently as log-preferences over consumption streams.

with equality if  $I_t > 0$  or  $\dot{I}_t > 0$ , where a dot above a variable indicates its time derivative. This arbitrage equation is central to the analysis of storable commodities, as in Hotelling's analysis. It states that the rate of capital gains on commodities cannot exceed the interest rate, net of any convenience yield or carrying cost.

The endowment of the  $X$  good, denoted  $X_t$ , grows at rate  $g > 0$  over time. By contrast, we assume that the endowment of the  $Z$  good is constant through time ( $Z_t = Z$ ); this assumption allows us to capture the idea that demand pressures on commodities are growing over time.<sup>13</sup>

The  $Z$  good is assumed to be noncapitalizable unless it is transformed into inventories (below or above the ground). In contrast, a fraction  $\delta$  of the  $X$  good is capitalizable. We capture this feature as follows. At every point in time, there is a number  $X_t$  of identical trees with an aggregate market value of  $V_t$ . Each tree yields one unit of  $X$  good per unit of time, a fraction  $\delta$  of which is distributed to its current owners. Since the number of trees grows at rate  $g$ , the total value of new trees is  $gV_t$  per unit of time. The fraction of the output that is not capitalized is distributed to newborns, as are the new trees. Hence, the total endowment received by newborns per unit of time comprises  $(1 - \delta)X_t$  units of the  $X$  good,  $Z$  units of the  $Z$  good, and  $gX_t$  new trees. The value of this endowment is  $(1 - \delta)X_t + p_t Z + gV_t$ .

The return on existing trees is the dividend-price ratio  $\delta X_t/V_t$  plus the capital gain  $\dot{V}_t/V_t - g$ , which, in equilibrium, must equal the instantaneous interest rate in the economy  $r_t$ :

$$(5) \quad r_t V_t = \delta X_t + \dot{V}_t - g V_t.$$

In addition to the tree asset, some of our equilibria will exhibit rational bubbles,  $B_t$ , which must satisfy the arbitrage condition

$$(6) \quad \dot{B}_t = (r_t + \lambda) B_t,$$

where  $\lambda > 0$  is the hazard that the bubble will burst in the next instant. For simplicity we analyze the limit case as  $\lambda$  goes to zero and  $d > \lambda$ . These assumptions allow us to approximate the solution with the perfect-foresight case and to reduce the number of subcases we need to discuss.

13. Note that our model differs from Hotelling's in that we replace his stock constraint with a flow constraint on commodity production. This has important implications later, since it allows us to separate more cleanly the asset aspect of commodities from their goods aspect. Moreover, in our framework macroeconomic conditions determine whether one aspect or the other dominates in price determination. See Jovanovic (2007) for a Hotelling-based model of bubbles in exhaustible resources.

Savings decrease with withdrawals (deaths) and increase with the endowment allocated to new generations and the return on accumulated savings:

$$(7) \quad \dot{W}_t = -\theta W_t + (1 - \delta)X_t + p_t Z + gV_t + r_t W_t.$$

In equilibrium, savings must be equal to the value of all the assets in the economy:

$$(8) \quad W_t = V_t + p_t I_t + B_t.$$

Using equation 3 and imposing market clearing in the market for  $X$  goods, we obtain

$$(9) \quad \frac{\theta W_t}{1 + \alpha p_t^{1-\sigma}} = X_t \text{ and } \frac{\alpha p_t^{-\sigma} \theta W_t}{1 + \alpha p_t^{1-\sigma}} = Z - \dot{I}_t - dI_t.$$

In equilibrium, replacing equation 9 back into equation 7 yields the equilibrium interest rate (for the case with inventories; that is, when  $\max \langle I_t, \dot{I}_t \rangle > 0$ ):

$$(10) \quad r_t = \theta \frac{\left( \delta + g \frac{B_t + p_t I_t}{X_t} \right) - \left( \frac{p_t z}{x_t} - \alpha p_t^{1-\sigma} \right)}{1 + \alpha \sigma p_t^{1-\sigma}} + \varepsilon_d,$$

where  $\varepsilon_d$  is an expression that plays no role in our main discussion.<sup>14</sup>

The interest rate rises as  $\theta$  rises, because a higher  $\theta$  increases consumption and reduces asset demand. The two terms in parentheses in the numerator are central to our discussion below. The first of these terms represents asset supply: the interest rate rises with  $\delta$  and with  $B_t + p_t I_t$  because they increase asset supply. The second term represents the “petrodollar” effect and is present when inventories are being accumulated: when the price of commodities rises, the income of commodity producers rises more than the effective income of commodity consumers falls. This net income effect lowers interest rates because it raises asset demand.

Later on we will show that for plausible parameter values, the asset demand effect dominates the asset supply effect in the short run, so that an increase in the price of commodities puts downward pressure on real interest rates. Since commodity prices also rise when interest rates fall (see expression 4), the interaction between commodity prices and real interest rates gives rise to potentially large feedbacks.

14.  $\varepsilon_d \equiv -d(\sigma - 1)\alpha p_t^{1-\sigma}/(1 + \alpha \sigma p_t^{1-\sigma})$ .

### The $\sigma = 1$ Case

Although in practice the short-run elasticity of demand for the  $Z$  good is significantly smaller than one, it is useful to start with the case  $\sigma = 1$ , since it allows us to characterize explicitly the main mechanisms at work. We simplify things further by studying the case where  $d$  converges to zero (while preserving the assumption  $d > \lambda$ ).

Assume momentarily that the equilibrium has neither inventories nor bubbles. Then equation 10 yields a reference interest rate,  $r^{ref} = \theta\delta/(1 + \alpha)$ . Henceforth we shall assume that financial assets are sufficiently scarce ( $\delta$  is low) for the economy to be dynamically inefficient ( $r^{ref} < g$ ):

*Assumption 1:* The economy is dynamically inefficient:  $\delta < g(1 + \alpha)/\theta$ .

**BUBBLELESS EQUILIBRIUM.** Suppose for now that there are no bubbles; then the equilibrium *must have inventories*. To see this, note that if there are no inventories,  $r = r^{ref} < g$ . But in this case equation 9 requires  $p_t = \alpha X_t/Z$ , so the price of commodities grows at a rate  $g$ , which exceeds the equilibrium interest rate. Thus, there is a clear incentive to accumulate inventories, which contradicts the no-inventories premise.

From expression 4 and equation 9, the dynamics of the economy can be summarized in a simple system with variables  $I_t$  and  $q_t \equiv p_t/X_t$ :

$$(11) \quad \begin{cases} \dot{I}_t = Z - \alpha q_t^{-1} \\ \dot{q}_t = (r_t - g)q_t \end{cases}$$

where  $r_t$  is given by

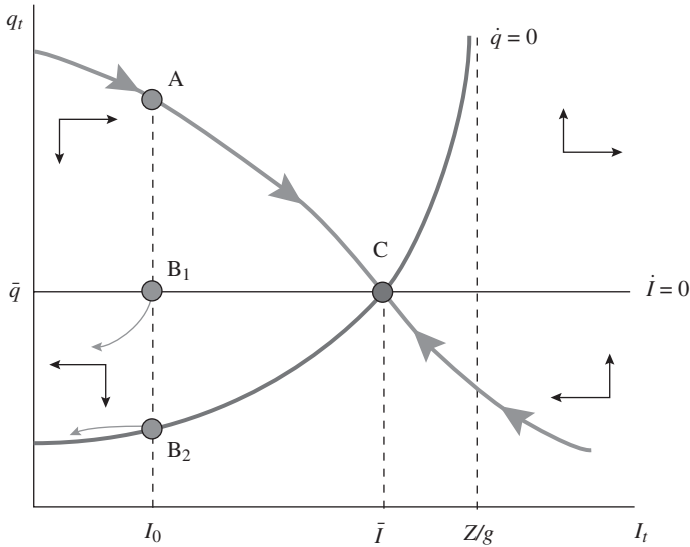
$$(12) \quad r_t = \theta \frac{\delta + \alpha - q_t(Z - gI_t)}{1 + \alpha}.$$

Asymptotically, the level of inventories stabilizes at a strictly positive level, which is proportional to the degree of dynamic inefficiency in the economy:

$$(13) \quad \lim_{t \rightarrow \infty} I_t = \bar{I} = \frac{1 + \alpha}{\alpha\theta g} (g - r^{ref})Z > 0.$$

The price  $p_t$  of the  $Z$  good grows at rate  $g$ , and the interest rate  $r_t$  converges to the growth rate  $g$  of the  $X$  good.

Figure 9. The Model with Inventories When  $\sigma = 1$



Source: Authors' model described in the text.

Figure 9 depicts the phase diagram associated with the dynamic system 11. The system exhibits the saddle path property.<sup>15</sup> This saddle path is downward sloping: when inventories are low ( $I_t < \bar{I}$ ), the price of commodities is high ( $q_t > \bar{q} \equiv \alpha/Z$ ) and decreasing ( $r_t < g$ ). Conversely, when inventories are abundant ( $I_t > \bar{I}$ ), the price of commodities is low ( $q_t < \bar{q}$ ) and increasing ( $r_t > g$ ).

A key element of our model lies in the slope of this saddle path. To understand why it is downward sloping, consider an initial inventory position  $I_0 < \bar{I}$  and suppose that the price is such that the commodity market is initially in equilibrium at that inventory level ( $\dot{I}_0 = 0$ , or  $q_0 = \bar{q}$ ). This is point  $B_1$  in figure 9. It is immediately apparent that the interest rate  $r_0$  that clears the asset markets at point  $B_1$  must be *below* the growth rate  $g$ . The economic intuition is that at  $q = \bar{q}$ , too few assets are created through inventories (whose value is  $\bar{q}I_0$ ). Equilibrium in global asset markets then requires a

15. Figure 9 is drawn for the case where  $\theta\delta/(1 + \alpha) < g < \theta(\delta + \alpha)/(1 + \alpha)$ , where the first inequality is a consequence of assumption 1. The case where  $g > \theta(\delta + \alpha)/(1 + \alpha)$  is similar and also features a downward-sloping saddle path, but the  $\dot{q} = 0$  schedule is downward sloping.

low interest rate. But when  $r_0 < g$ , the (normalized) price of commodities declines over time, and this increases demand for commodities and reduces inventories ( $\dot{I}_0 < 0$ ). Instead, the equilibrium requires that the price of commodities be sufficiently high initially to depress the demand for commodities and allow inventory accumulation ( $\dot{I}_0 > 0$ ). Equivalently, the price of commodities needs to rise sufficiently to depress equilibrium interest rates and make inventory accumulation profitable. This is represented by point A in figure 9. This high initial price depresses interest rates *below*  $r_0$ . Over time, since  $r_t < g$ , (normalized) commodity prices decrease, and this increases demand for commodities and slows inventory accumulation. The steady state is reached at point C.

The price of commodities performs a dual role in the model with inventories: it influences the demand for the  $Z$  good on the spot market, and it influences the global supply of assets in the economy ( $V_t + p_t I_t$ ). As in traditional models of portfolio balance, it is the tension between these two functions that generates interesting dynamics.<sup>16</sup>

**BUBBLES.** Now let us turn to the opposite extreme, where bubbles exist and do not vanish asymptotically relative to the size of the economy. In the limit, since we assumed  $d > \lambda$ , there are no inventories. Without inventories, the  $Z$  good is for consumption only, and its price rises at rate  $g$ . The interest rate  $r_t$  converges to  $g$ , and the bubble converges to

$$(14) \quad B_t \underset{t \rightarrow \infty}{\sim} \frac{1 + \alpha}{\theta g} (g - r^{ref}) X_t.$$

The size of the asymptotic bubble in expression 14 is the same as that of the asymptotic equilibrium inventories  $pI$  in the bubbleless equilibrium (equation 13). In both cases the endogenous increase in asset supply is just sufficient to increase the equilibrium interest rate to  $g$ .

**THE NO-INVENTORY ECONOMY (A BENCHMARK).** In our model the price of the  $Z$  good is both a relative price and, when inventories are nonzero, an asset price. To illustrate the importance of this dual role, we describe a benchmark economy where the inventory channel is turned off. That is, we assume that storage costs are prohibitive ( $d$  is very large), so the  $Z$  good cannot be stored.

This benchmark economy has two long-run steady states: a bubbly one and a bubbleless one. The bubbly steady state is exactly as above, with the same equilibrium prices and quantities. However, the bubbleless equilib-

16. See Kouri (1983) and, more recently, Blanchard, Giavazzi, and Sa (2005) for examples of portfolio balance models.

rium is different, since inventories cannot be accumulated. In the bubbleless equilibrium, market clearing for the  $Z$  good implies that  $p_t$  grows at rate  $g$ . Equilibrium in asset markets implies that the interest rate  $r_t$  is equal to  $r^{ref} < g$ .

Note that assumption 1 implies that the interest rate  $r^{ref}$  in the bubbleless equilibrium of the no-inventory economy is lower than the interest rate  $g$  in the bubbleless equilibrium of the economy with inventories. The reason for this difference is that total asset supply is smaller in the economy without inventories. Note also that  $p_t$  is the *same* in the bubbly equilibrium and in the bubbleless equilibrium without inventories. That is, the price is entirely determined by the relative endowments of the  $X$  good and the  $Z$  good and is completely decoupled from the asset market.

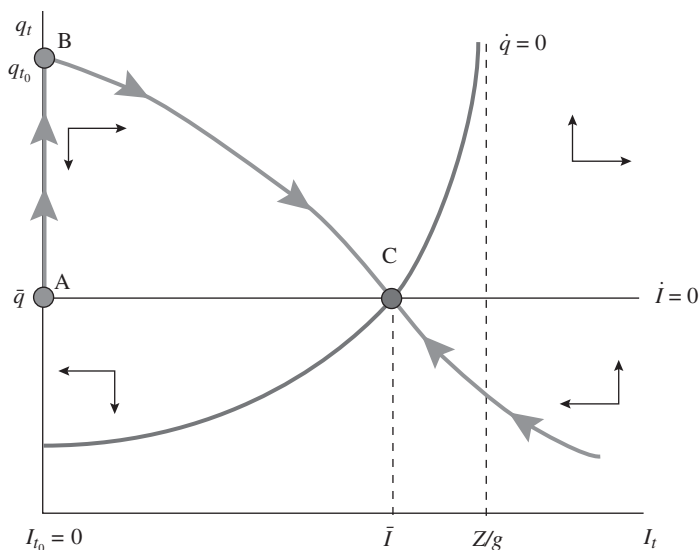
### *The Financial Crash and Commodity Boom (Phase I)*

Suppose now that a “subprime” shock takes place. This can be interpreted as the realization that financial instruments are less sound than they were previously perceived to be. It could result, *inter alia*, from the realization that corporate governance is less benign than once thought (excessive risk taking and poor risk management by investment banks) or that securitization and certification by rating agencies involve important agency problems; or from a significant loss of informed and intermediation capital (deleveraging of commercial and investment banks hit by losses); and so on. All of these factors and more have been mentioned in the events surrounding the recent subprime crisis.<sup>17</sup> We assume that this shock is completely unanticipated, but this is not crucial to our analysis as long as there is some degree of market incompleteness, preventing agents from fully hedging away their risk.

In the model we capture this shock with a bursting of the bubble  $B$  at date  $t_0$ . The dynamics that follow are described by those in the bubbleless system and are illustrated in figure 10 for the case where  $\sigma = 1$ . Right before the shock, the economy is at point A with  $q_{t_0} = \bar{q}$  and no inventories ( $I_{t_0} = 0$ ). When the crisis erupts, the price of commodities jumps to point B on the saddle path. With decreased demand in the spot market, the economy immediately begins to build inventories (which could be kept under the ground). The price of commodities remains high until the economy converges to the new steady state (point C).

The collapse of the bubble reduces asset supply and leads to a drop in the interest rate. Lower interest rates make more attractive the strategy

17. See Greenlaw and others (2008) and Brunnermeier (2009).

**Figure 10.** Subprime Crisis at  $t_0$  When  $\sigma = 1$ 

Source: Authors' model described in the text.

of storing the  $Z$  good so as to sell it in the future, which validates the buildup in inventories. Higher commodity prices during the transition to the new long-run equilibrium are required to lower demand and restore equilibrium in the  $Z$  good market. The commodity price jumps at  $t = t_0$  and then declines asymptotically from above to the same path as in the pre-crash economy.

The interest rate initially drops by

$$(15) \quad r_{t_0} - r_{\bar{t}_0} = -g \frac{B_{t_0}}{W_{t_0}} - \frac{\theta\alpha}{1 + \alpha} \left( \frac{p_{t_0}^+}{p_{t_0}} - 1 \right) < 0$$

and then converges smoothly back to the asymptotic level  $g$ . There are two terms on the right-hand side of equation 15. The first, “bubble-burst” term,  $-gB_{t_0}/W_{t_0}$ , is directly due to the collapse of the bubble. The second, “commodity-price-jump” term follows from the increase in the price of the  $Z$  good, which raises the rate of wealth accumulation. Since inventories are only gradually accumulated, an additional gap opens between asset supply and asset demand, which requires a further decline in interest rates.

In the benchmark no-inventory economy, the normalized price of commodities stays constant and equal to  $\bar{q}$ , so the economy remains indefinitely

at point A in figure 10. Since the price of commodities does not jump, the second term in equation 15 would equal zero, and the interest rate drop would be entirely given by the bubble-burst term.<sup>18</sup>

Note that there is a strong *flight-to-quality* feature in the model, since both the value of accumulated savings and the *total* value of assets are continuous at  $t = t_0$ :

$$W_{t_0} = (V_{t_0} + B_{t_0}) = W_{t_0} = V_{t_0} = \frac{1 + \alpha}{\theta} X_{t_0}.$$

This means that the decline in interest rates raises the value of the trees (the “good” asset) enough to fully offset the loss in value due to the collapse of the bubble. Later we will show that when  $\sigma < 1$ , the decline in the interest rate is more pronounced than in the  $\sigma = 1$  case, which further raises the value of the remaining “good” assets.<sup>19</sup>

### *The Growth Slowdown (Phase II)*

Eventually, the financial crisis starts to hurt global growth prospects. We capture this turn of events by assuming that at  $t = t_1$ , global growth slows unexpectedly and permanently from  $g$  to  $\hat{g} < g$ . In the long run the slowdown reduces inventories  $\bar{I}$ . In fact, from equation 13 we see that if the growth slowdown is sufficiently severe as to reverse assumption 1, the commodity bubble ultimately bursts, and  $\bar{I} = 0$ . We formalize this with the following assumption:

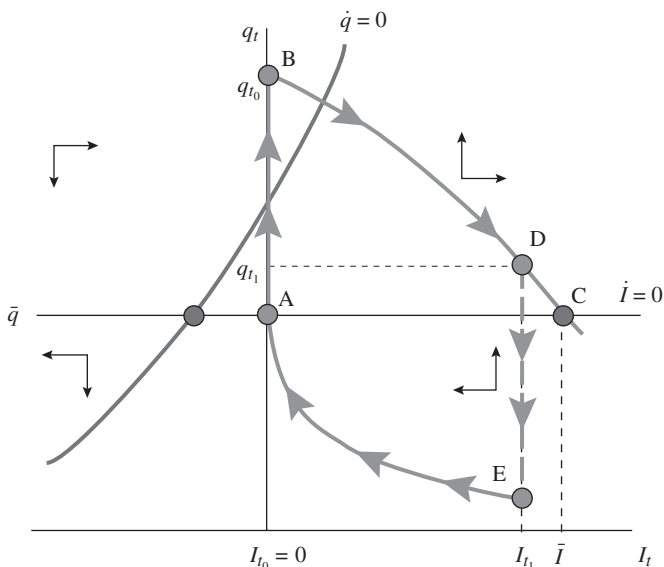
*Assumption 2:* A severe growth slowdown occurs:  $\hat{g} < \delta\theta/(1 + \alpha)$ .

Under assumption 2, inventories are not sustainable in the long run. The dynamics that follow the growth slowdown are illustrated in figure 11. At time  $t_1$  the economy is at point D, with inventory levels  $I_{t_1}$  and a commodity price  $q_{t_1}$ . Following the shock, the price of commodities needs to collapse so as to pick up the slack from the decreased rate of inventory accumulation. Equivalently, the collapse in commodity prices from point D to point E pushes equilibrium interest rates to  $r_t > \hat{g}$ , making inventory accumulation

18. We know from the previous analysis that the interest rate would drop to  $r^{ref} = \delta\theta/(1 + \alpha)$ .

19. Note that if we were to use a true consumer price index (rather than the price of good X) to deflate quantities, wealth would always drop in real terms after a crash. This alternative numeraire formulation, which we develop in appendix C (online), modifies the “language” but none of our substantive conclusions.

Figure 11. Growth Slowdown at  $t_1$  When  $\sigma = 1$



Source: Authors' model described in the text.

less profitable.<sup>20</sup> Over time, inventories converge to  $\bar{I} = 0$ , while commodity prices increase back to  $\bar{q}$  (point A), and the interest rate converges to  $r^{ref}$ .

By contrast, in the no-inventory economy, the commodity price and the interest rate would not be impacted at  $t = t_1$ . The economy would remain indefinitely at point A in figure 11.

### Global Imbalances in the Long Run

Let us now examine global equilibrium in a world with two large regions,  $i = \{U, M\}$ . We interpret region  $U$  as the United States, with initially good but perhaps fragile financial conditions, and region  $M$  as the set of emerg-

20. Note that although  $r_{i_t} > \hat{g}$ , the interest rate can increase or decrease when the growth shock hits, depending on the level of inventories  $I_t$ , because a decrease in commodity prices reduces both asset supply (the value of inventories decreases) and asset demand (the value of the flow of  $Z$  goods decreases). When  $I_t$  is small, the asset supply curve shifts less than the asset demand curve, requiring an increase in the interest rate to clear the asset market. We can compute the increase in interest rates,  $r_{i_t} - r_{i_t} = \frac{\theta}{1 + \alpha} \frac{Z}{X_{i_t}} (p_{i_t} - p_{i_t}) + \frac{\theta}{1 + \alpha} \frac{I_t}{X_{i_t}} (p_{i_t} \hat{g} - p_{i_t} g)$ ,

where the second term on the right-hand side is negligible if  $I_t$  is small. Note that despite this potential increase at impact, the interest rate eventually converges to a lower level, since  $r^{ref} < g$  under assumption 1.

ing and commodity-producing economies whose current account surpluses offset the U.S. deficit.

Each of the regions is described by the same setup as the world economy, with an instantaneous return  $r_t$  from hoarding a unit of either region's trees;  $r_t$  is common across both regions and satisfies

$$(16) \quad r_t V_t^i = \delta X_t^i + \dot{V}_t^i - g V_t^i,$$

where  $V_t^i$  is the value of region  $i$ 's trees at time  $t$ . We assume initially that both regions have common parameters  $g$ ,  $\delta$ , and  $\theta$ , but that the initial bubble is concentrated in the  $U$  region. The latter assumption captures the idea that the  $U$  region has more attractive assets than the  $M$  region. Moreover, we assume that the  $Z$  good is produced only in the  $M$  economy and that the potential inventories are held in this region (perhaps under the ground; see the later discussion). These two features are all that differentiates the two regions, aside from scale.

Let  $W_t^i$  denote the savings accumulated by agents in region  $i$  at date  $t$ . By analogy with equation 7:

$$(17) \quad \dot{W}_t^i = -\theta W_t^i + (1 - \delta)X_t^i + gV_t^i + r_t W_t^i + 1_{\{i=M\}} p_t Z,$$

where  $1_{\{i=M\}}$  is an indicator for region  $M$ . Adding equations 16 and 17 for  $U$  and  $M$  shows that the world economy is exactly that described in the first section, with

$$W_t = W_t^U + W_t^M; \quad V_t = V_t^U + V_t^M; \quad X_t = X_t^U + X_t^M.$$

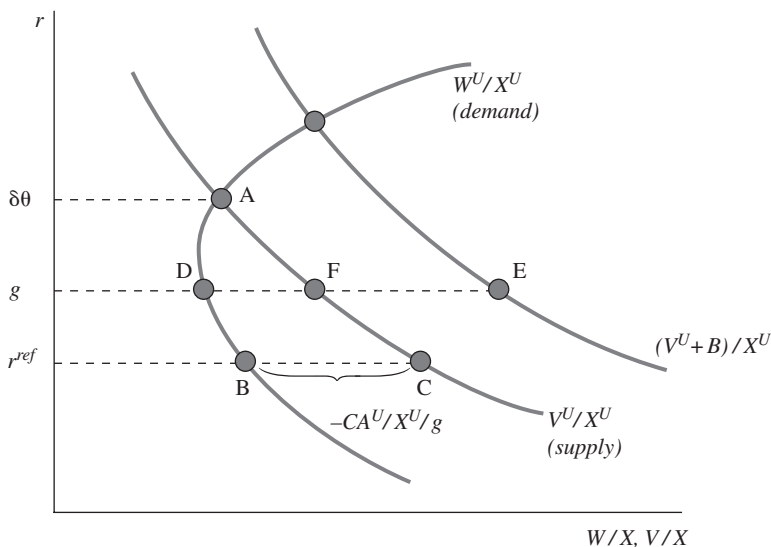
The current account balance  $CA_t^U$  of region  $U$  represents the net accumulation of assets by region  $U$  and is given by

$$(18) \quad CA_t^U = \dot{W}_t^U - \dot{V}_t^U - \dot{B}_t^U.$$

Let us start from the steady state with bubbles and  $\sigma = 1$  as described in the preceding section. Figure 12 represents graphically the external equilibrium in  $U$  in a Metzler diagram.<sup>21</sup> The curve labeled  $V^U/X^U$  represents the long-run value of the  $U$  tree, relative to output. It is equal to  $\delta/r$  and decreases with the interest rate  $r$ . The curve labeled  $W^U/X^U$  represents the long-run value of the savings-to-output ratio, as a function of the equilibrium

21. Metzler (1968).

Figure 12. Metzler Diagram When  $\sigma = 1$



Source: Authors' model described in the text.

interest rate. It is equal to  $(1 - \delta + g\delta/r)/(\theta + g - r)$ . It first decreases and then increases with  $r$ .<sup>22</sup>

Without bubbles or inventories, long-run financial autarky is achieved at point A, with  $r = \delta\theta$ . Under financial integration, but still without bubbles or inventories, the interest rate is lower, at  $r^{ref} = \delta\theta/(1 + \alpha)$ . The reason for the lower equilibrium interest rate is that a larger fraction of global output is not capitalized when there are commodities. The lower interest rate allows  $U$  to supply more assets to  $M$  and to run a current account deficit that is proportional to the distance between points B and C in figure 12.

In the presence of the bubble, the supply of assets increases from  $V^U/X^U = \delta/g$  to

$$\frac{V^U + B}{X^U} = \frac{\delta}{g} + \left( \frac{1 + \alpha}{\theta} - \frac{\delta}{g} \right) \frac{X_{t_0}}{X_{t_0}^U}$$

22. Although the asset demand schedule  $W^U/X^U$  can be downward sloping, the gap between  $W^U/X^U$  and  $V^U/X^U$ , equal to  $(1 - \delta\theta/r)/(\theta + g - r)$ , is always increasing with the interest rate. The downward-sloping part of the  $W^U/X^U$  curve comes from the impact of interest rates on asset demand through the new trees  $gV^U$ . When  $g < \delta\theta$ , the  $W^U/X^U$  curve has the shape shown in figure 12. When  $g > \delta\theta$ , the asset and demand curves cross on the downward-sloping part of the asset demand curve  $W^U/X^U$ .

so as to eliminate the dynamic inefficiency of assumption 1. The increase is such that the world equilibrium interest rate increases from  $r^{ref}$  to  $g$ . The current account deficit in the bubble equilibrium (proportional to the distance between points D and E) is always larger than in the no-bubble, no-inventories case (the distance between points B and C).<sup>23</sup> The reason for this larger current account deficit is that a disproportionate share of  $M$ 's income is noncapitalizable (because its commodity income,  $pZ$ , is non-capitalizable unless it is transformed into inventories), whereas  $U$  produces a disproportionate share of global assets.

### *Long-Run Imbalances with No Growth Slowdown*

As before, the subprime shock takes place at  $t = t_0$ . In the long run the presence of commodities leads to a larger global rebalancing in response to a subprime shock in the United States (region  $U$ ). Consider first what happens if there is no growth slowdown. In this case, since the asymptotic interest rate in the absence of bubbles is still  $r = g$ , the asymptotic current account deficit of the  $U$  region following the collapse of the bubble is smaller by *exactly* the size of the bubble:

$$\frac{CA_t^U}{X_t^U} \underset{t \rightarrow \infty}{\sim} g \left[ \frac{1}{\theta} - \frac{\delta}{g} \right].$$

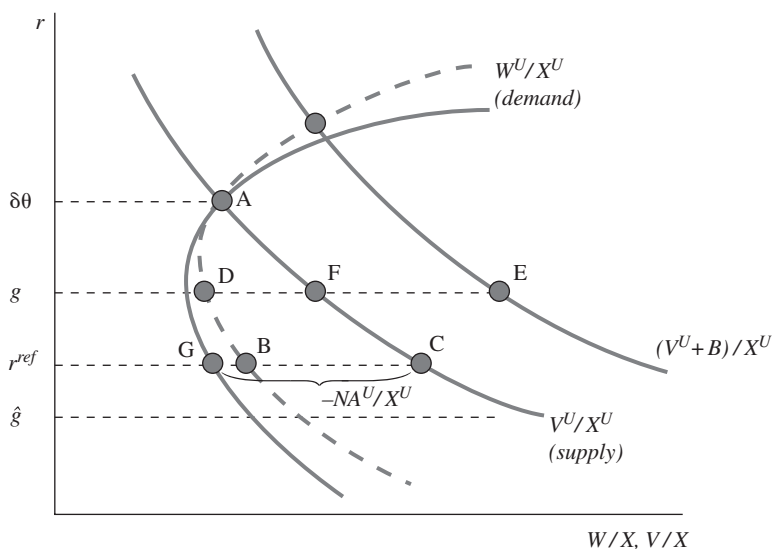
This asymptotic current account will be in deficit if the degree of dynamic inefficiency in the global economy is not too severe ( $\delta\theta > g$ ), as is assumed in figure 12. Otherwise the buildup in inventories is significant, which increases the supply of assets in region  $M$  and reduces its need to buy foreign assets as a store of value.

This buildup of inventories implies that endogenous commodity prices lead to *more* rebalancing in the long run. The reason is that inventories contribute to increasing asset supply in region  $M$  and hence endogenously reduce the effective asymmetry between the two regions. In terms of figure 12, the current account deficit contracts from D – E to D – F, as the bubble collapses and inventories are accumulated, whereas it would contract from D – E to B – C in the benchmark no-inventory economy. Therefore,

23. Indeed, the increase in the current account deficit in the presence of the bubble can be computed as

$$CA^{U, no-bubble} - CA^U = \frac{g - r^{ref}}{\theta / (1 + \alpha)} \left[ \frac{\alpha g}{(1 + \alpha)(\theta + g - r^{ref})} + \frac{X}{X^U} - 1 \right],$$

which is always positive under assumption 1.

**Figure 13.** Long-Run External Imbalances When  $\sigma = 1$ 

Source: Authors' model described in the text.

the inventory channel unambiguously leads to more rebalancing in the long run. We will see in the next section that this result can be overturned in the short run when  $\sigma < 1$ .

### *Long-Run Imbalances with a Growth Slowdown*

Let us now reintroduce the slowdown in growth. Under assumption 2 the asymptotic interest rate drops to  $r^{ref}$ . Figure 13 describes what happens to  $U$ 's asymptotic external imbalances as growth declines. The asset demand curve rotates clockwise around point A, so that asset demand decreases in the relevant range ( $r < \delta\theta$ ).

The asymptotic net foreign asset position  $NA^U/X^U = (W^U - V^U)/X^U$  can be read as the distance  $G - C$ . Since there are no inventories and  $r = r^{ref}$ , it is the same as in the benchmark no-inventory economy and worsens as the growth rate  $\hat{g}$  declines. Further, this asymptotic net foreign asset position is more negative with the growth slowdown ( $G - C$ ) than without it ( $D - F$ ). The reason is that slower growth eliminates the buildup in commodity inventories and hence curtails the expansion in asset supply in the  $M$  region. The inventory channel analyzed above, which reduces the asymmetry between the two regions, is now dampened, and the economy experiences less rebalancing in the long run. However, since growth is also slower in the

former case, the current account may or may not worsen asymptotically with a growth slowdown.<sup>24</sup>

## Global Imbalances in the Short Run

We now turn to a phase-by-phase analysis of the model's implications for short-run global imbalances.

### *Phase I: The Financial Crisis*

The behavior of the current account in the short run depends on the initial portfolios, the degree of home portfolio bias, and the degree of substitution between the commodity and the general consumption good. As in our earlier paper,<sup>25</sup> we assume an extreme form of home bias: at  $t = t_0$  all the assets held by agents in the  $U$  region are  $U$  assets. Moreover, we assume that domestic residents' portfolios are proportional to the relative value of trees and bubbles. The assumption of extreme portfolio home bias is a good approximation of actual conditions. As of 2005, Piet Sercu and Rosanne Vanpée found that the degree of home bias for equities varied between 0.31 for the Netherlands and 0.91 for Japan.<sup>26</sup> The assumption that domestic residents' portfolios are proportional to the relative value of trees and bubbles implies that  $M$  has a significant exposure to  $U$ 's bubble asset. Again, this is a reasonable assumption. The onset of the U.S. subprime crisis was marked by the failure of a small German bank, IKB, and a few months later by the collapse of Northern Rock, a U.K. bank, highlighting the exposure of foreign investors to tainted U.S. assets.<sup>27</sup>

Under these assumptions the degree of rebalancing on impact,  $CA_{t_0}^U - CA_{t_0}^U$ , is given by the sum of two terms: the adjustment in the trade balance  $X_t^U - \theta W_t^U$ , and the change in payments on external debt, through asset

24. The asymptotic current account deficit is now  $\frac{CA_t^U}{X_t^U} \underset{t \rightarrow \infty}{\sim} \frac{-\alpha \hat{g}}{\theta + \hat{g} - r^{*d}}$  and decreases with  $\hat{g}$ .

25. Caballero, Farhi, and Gourinchas (2008).

26. Sercu and Vanpée (2007). The degree of home equity bias is defined as one minus the ratio of the share of foreign equities in the domestic and world portfolios. It varies between zero (when the weight on foreign equities is given by their relative market capitalization) and one (when investors hold no foreign equities). It has declined in recent years but remains very high for most countries.

27. According to Beltran, Pounder, and Thomas (2008, table 6), foreigners hold 40 percent (\$2.4 trillion out of \$6 trillion) of outstanding U.S.-asset-backed securities and about 16 percent of all U.S. credit market instruments.

valuations and interest rates. The adjustment in payments on external debt is swamped by the adjustment in the trade balance when the external debt is initially small, so we focus on the trade balance. This is always positive and given by

$$(19) \quad TB_{t_0}^U - \bar{TB}_{t_0}^U = -\theta(W_{t_0}^U - \bar{W}_{t_0}^U) = \theta\mu_{t_0} (B_{t_0} + V_{t_0}^U - \bar{V}_{t_0}^U),$$

where  $\mu_{t_0} = W_{t_0}^U / (V_{t_0}^U + B_{t_0})$  represents the share invested in the domestic tree and the domestic bubble before the crash;  $\mu_{t_0} < 1$  when  $U$  is a net debtor at time  $t_0$ . At impact, the direct effect of the bubble collapse is a reduction in wealth  $W_{t_0}^U$ , which lowers consumption and improves the trade balance.<sup>28</sup> Note that there is always less trade rebalancing in this economy than in the benchmark no-inventory economy.<sup>29</sup> The change in the trade balance and the drop in  $W_{t_0}^U - \bar{W}_{t_0}^U$  are exactly proportional to the change in the value of the  $U$  assets,  $V_{t_0}^U + B_{t_0} - \bar{V}_{t_0}^U$ . As a starting point, note that when  $\sigma = 1$ , the decline in asset prices is exactly the same in the economy with endogenous commodity prices as in the economy without:

$$(20) \quad V_{t_0}^U + B_{t_0} - \bar{V}_{t_0}^U = B_{t_0} (1 - x_{t_0}^U) \geq 0,$$

where  $x_{t_0}^U = X_{t_0}^U / X_{t_0}$  is the share of  $U$  in world output. This result is peculiar to the case  $\sigma = 1$  because the share of  $X$  goods in consumption is invariant to the price  $p_t$  of  $Z$  goods.<sup>30</sup>

### *Phase II: The Growth Slowdown*

Consider now the effects of the growth slowdown shock. We maintain the assumption of extreme home bias, so that immediately before the

28. However, in equilibrium the drop in wealth is dampened because interest rates plummet, raising the value of the “good”  $U$  asset and making up for part of the drop in wealth.

29. In appendix D (online) we show that the difference in trade rebalancing between these two economies is strictly less than the direct effect of the change in the terms of trade resulting from speculation in commodities, holding imports and exports constant. In other words, imported and exported quantities adjust by more in the economy with endogenous commodity prices than in the no-inventory economy.

30. In contrast, we show in appendix C (online) that in the more realistic  $\sigma < 1$  case, the increase in the price of  $U$  assets in response to the subprime shock,  $V_{t_0}^U - \bar{V}_{t_0}^U$ , is larger when commodity prices are endogenous than when they are not. The reason for the larger increase in the value of  $U$  assets is that the share of  $X$  goods in value added decreases, which raises asset demand relative to asset supply. As a result of this gap, asset supply has to increase by more in equilibrium. This “petrodollar” channel will prove crucial later in our quantitative exercises. This effect is absent in the benchmark no-inventory economy, which would as a result experience a greater amount of rebalancing in the short run.

growth slowdown shock hits, all of  $U$ 's wealth is invested in  $U$  assets. The adjustment in the trade balance is always positive:

$$TB_{t_1}^U - TB_{t_0}^U = -\theta(W_{t_1}^U - W_{t_0}^U) = \theta\mu_{t_1} \left( V_{t_1}^U - V_{t_0}^U \right),$$

where  $\mu_{t_1} = W_{t_1}^U/V_{t_1}^U$ . The change in the value of  $U$  assets can be computed as above. We show in appendix C (online) that when  $I_{t_1}$  is small and  $\sigma = 1$ , the impact of the growth slowdown on the trade balance is negligible. By contrast, when  $\sigma < 1$ , the decline in the value of  $U$  assets is accentuated, and the trade balance improves at impact. We show in the calibration section that most of this improvement originates in an improvement in the commodity component of the trade balance.

### *Back-of-the-Envelope Calculations*

This section gauges the order of magnitude of the effects discussed above. We focus here on the impact effect of the financial crisis, which we can develop analytically, and discuss the full dynamics in the next section. We find from this back-of-the-envelope exercise that our model can explain much of the observed decline in real interest rates and rise in the price of oil in the first phase of the financial crisis, as well as the sharp collapse in the price of oil in the second phase. The model also goes a long way toward explaining why the U.S. current account adjustment has been only modest so far, but it forecasts that the decline in the price of oil will reduce the trade deficit significantly in the future.

**PHASE I: THE FINANCIAL CRISIS.** We begin with the impact of the crisis on interest rates. According to figure 2, real interest rates declined by about 1.75 percentage points between September 2006, when home prices started to decline and the current account turned around, and June 2008.<sup>31</sup> With a unit elasticity of substitution,  $\sigma = 1$ , the change in interest rates is given by equation 15; when this elasticity is smaller than one, the drop in interest rates  $r_{t_1} - r_{t_0}$  can still be expressed as the sum of two terms: a bubble-burst term reflecting the direct impact of the collapse of the bubble on asset supply, and a commodity-price-jump term reflecting the impact of the increase in the price of commodities on global asset supply and demand.<sup>32</sup>

The starting point in assessing the role of the two terms is an estimate of the size of the perceived losses generated by the financial crisis, in relation to the world's financial wealth:  $B_{t_0}/W_{t_0}$ . Estimates of the perceived size of

31. The world short-term real interest rate dropped from 1.6 percent to -0.9 percent. The U.S. long-term real rate dropped from 2.4 percent to 1.4 percent.

32. See appendix C (online) for an expression for the commodity-price-jump term.

the initial collapse of the bubble are difficult to come by and necessarily imprecise. A key issue is that the endogenous response of interest rates offsets the impact of the crash in  $B_t$  on global wealth.<sup>33</sup> Empirically, this means that the estimates of the size of the initial bubble that we obtain are likely to be biased downward.

Direct losses in U.S. mortgage markets alone are estimated to be in the vicinity of \$500 billion.<sup>34</sup> In its April 2008 *Global Financial Stability Report*,<sup>35</sup> the International Monetary Fund reaches a similar estimate of aggregate losses in the U.S. residential mortgage market. Adding to this the potential losses to broader credit markets, the IMF calculates aggregate losses from writedowns of U.S. loans and securitized assets of about \$945 billion.<sup>36</sup> To these losses we add the declines in asset values generated by the broad process of deleveraging and the associated contraction in lending across markets. For instance, David Greenlaw and coauthors estimate an overall contraction of \$2.3 trillion in intermediaries' balance sheets.<sup>37</sup> Moreover, mortgage market losses reflect only the increased rate of delinquencies on prime mortgages and commercial real estate (as well as the declining value of foreclosed properties). To this we add the decline in housing wealth for residential borrowers that remain in good standing on their mortgages. Estimates of the latter significantly exceed the direct losses in mortgage markets. For instance, the Federal Reserve estimates households' housing wealth at \$19.4 trillion as of June 2006.<sup>38</sup> In terms of the Case-Shiller U.S. Composite 10 home price index, U.S. housing prices declined 19.8 percent in nominal terms between September 2006 and June 2008 (see figure 4). If this decline is across the board, it implies that at least an additional \$3.8 trillion was wiped out in U.S. housing wealth alone.<sup>39</sup>

Adding these estimates yields a total loss in U.S. housing wealth and mortgage markets in the range of \$2 trillion to \$4 trillion. What is relevant in our calculation is the ratio of these initial losses to the world's financial wealth  $W_{t_0}$ . We construct a crude estimate of the latter at the onset of the

33. For instance, we have seen that in the case of a unit elasticity ( $\sigma = 1$ ), aggregate wealth remains unchanged at impact.

34. Greenlaw and others (2008).

35. IMF (2008a).

36. In its October 2008 report (IMF 2008b), the IMF revised its estimate of U.S. declared losses on loans and securitized assets to \$1.4 trillion.

37. Greenlaw and others (2008).

38. See table B.100 of the March 2008 release of the Flow of Funds Accounts.

39. This figure is calculated under the extreme assumption that all mortgage market losses are housing market losses. Of course, foreclosures and repossessions generate additional losses beyond the decline in housing values.

**Table 1.** Predicted Change in World Interest Rates for Different Parameter Values<sup>a</sup>  
Percentage points

| Elasticity of substitution $\sigma$ | Change in commodity prices, $p_{it}/p_{it_0}$ |       |       |       |       |
|-------------------------------------|---|-------|-------|-------|-------|
|                                     | 1.0   | 1.2   | 1.5   | 2.0   | 3.0   |
| 0.05                                | -2.22   | -2.23 | -2.25 | -2.28 | -2.37 |
| 0.1                                 | -1.02   | -1.04 | -1.08 | -1.16 | -1.33 |
| 0.2                                 | -0.44   | -0.48 | -0.55 | -0.69 | -1.00 |
| 0.5                                 | -0.12   | -0.21 | -0.37 | -0.66 | -1.27 |
| 1.0                                 | -0.06   | -0.23 | -0.50 | -0.93 | -1.80 |

Source: Authors' calculations based on the model described in the text.

a. Each cell reports the model-predicted initial change in the world interest rate  $r_t - r_{t_0}$  associated with the indicated change in commodity prices at the indicated value of  $\sigma$ . Italicized numbers correspond to the authors' preferred calibration.

crisis as the sum of U.S. household net worth of \$51.7 trillion at the end of 2005, and an estimate of the financial wealth of the rest of the world of \$80.7 trillion.<sup>40</sup> This indicates an initial size of the bubble of between 1.5 and 3.0 percent of the world's financial wealth. In what follows we assume an initial bubble equal to 2 percent of the world's financial wealth.

It is immediately apparent that the bubble-burst term in equation 15, equal to  $-gB_{t_0}/W_{t_0}$ , is relatively small: at an output growth rate of around 3 percent, it is equal to only -0.06 percent. On the other hand, the commodity-price-jump term can be substantial. To show this, table 1 reports estimates of the decline in  $r$  for different values of the elasticity of substitution  $\sigma$  and different estimates of the increase in commodity prices. The calculation of the commodity-price-jump term requires an estimate of the average expenditure share of commodities  $s_{z_{t_0}}$ . In constructing the table we assume that  $s_{z_{t_0}} = 0.04$ , which corresponds to the average share of oil expenditure in world GDP in 2005 and 2006.<sup>41</sup>

40. See table B.100 of the June 2008 issue of the Federal Reserve's Flow of Funds Accounts for the U.S. figure. To obtain an estimate of the financial wealth of the rest of the world in 2006, we calculate the ratio of output to financial wealth for the United States, the European Union, and Japan between 1982 and 2004. We find a GDP-weighted average of 2.48 (see Caballero, Farhi, and Gourinchas 2008 for additional details). Applying this ratio to the GDP of the rest of the world in 2005, we obtain \$80.7 trillion. To the extent that many countries are less financially developed than the United States, Europe, or Japan, this estimate likely overstates the world's financial wealth. This would further bias downward our estimate of  $B_{t_0}/W_{t_0}$ .

41. According to the Energy Information Administration's *International Petroleum Monthly* (table 2.4, World Petroleum Demand), world demand for oil in 2005 was 83.8 million barrels a day. At a WTI price of \$56.64 a barrel, this corresponds to \$1.7 trillion a year, or 3.8 percent of world GDP. In 2006 the share of oil in total expenditure was 4.16 percent. The remaining parameters are discussed in more detail in a later section.

Between September 2006 and June 2008 the price of a barrel of WTI in constant 2008 dollars increased from \$67.81 to \$140.82 (figure 7). Interpreting this surge as the direct effect of the crisis yields  $p_{t_0}/p_{t_0^-} = 2.08$ . The associated decrease in real interest rates in table 1 is consistent with what we see in the data. For a realistically low level of the short-term price elasticity of demand  $\sigma = 0.1$ , we find a decline in interest rates of 1.16 percentage points, smaller than the 1.75 percentage points observed over that period, but much larger than the 0.06-percentage-point decline associated with the direct effect of the collapse of the bubble. Most of the decline in interest rates comes from the indirect effect of higher commodity prices, hinting that the endogenous response of commodity prices to the subprime crisis is critical in understanding the global macroeconomic environment.

We now turn to the effect of the crash on commodity prices. We can compute the decline in  $U$ 's financial wealth and find an expression for the jump in commodity prices as a function of the decline in  $U$ 's wealth and the size of the original collapse of the bubble (see online appendix C):

$$(21) \quad \frac{P_{t_0^+}}{P_{t_0^-}} = \left[ 1 + \frac{W_{t_0^+}^U - W_{t_0^-}^U}{X_{t_0^-}^U} \frac{\theta}{\mu_{t_0^-}} \frac{1 - s_{z_{t_0^-}}}{s_{z_{t_0^-}}} + \frac{1}{s_{z_{t_0^-}}} \left( \frac{1}{x_{t_0^-}^U} - 1 \right) \frac{B_{t_0^-}}{W_{t_0^-}} \right]^{1/(1-\sigma)}.$$

We already have estimates for  $B_{t_0^-}/W_{t_0^-}$  and  $s_{z_{t_0^-}}$ . We estimate the decline in U.S. financial wealth  $W_{t_0^+}^U - W_{t_0^-}^U$  from the Federal Reserve Flow of Funds Accounts. Between June 2007 and March 2008, U.S. households' financial wealth declined by \$1.65 trillion, or 11.5 percent of output.<sup>42</sup> Next we construct an estimate of  $\mu_{t_0^-}$ , the share of domestic financial wealth invested in the domestic tree and the domestic bubble before the crash. In 2005 the net foreign liabilities of the United States amounted to \$1.85 trillion, or 15 percent of U.S. GDP.<sup>43</sup> This corresponds to  $(W_{t_0^-}^U - V_{t_0^-}^U - B_{t_0^-})/X_{t_0^-}^U$ . Substituting the expression for  $\mu_{t_0^-}$ , and using the fact that  $W_{t_0^-}^U/X_{t_0^-}^U = 4.16$ , we obtain  $\mu_{t_0^-} = 0.96$ .<sup>44</sup> Finally, we set the ratio of U.S. to world output in 2005 at approximately 0.25.<sup>45</sup> Table 2 reports estimates of the increase in com-

42. See table B.100 of the June 2008 Federal Reserve Flow of Funds estimates. Household net worth was \$57.6 trillion in June 2007 at the onset of the crisis and only \$55.9 trillion in March 2008.

43. From table 2 of the Bureau of Economic Analysis's International Investment Position. The net asset position is estimated at market value.

44. This represents an overestimate of the share of U.S. assets held by U.S. investors, since we assume an extreme form of home bias.

45. U.S. GDP in 2005 was \$12.4 trillion, and world GDP was about \$45 trillion, for a ratio of 0.276. Although the theoretical model refers only to  $U$  and  $M$ , in this back-of-the-envelope exercise and the simulations that follow, it is natural to include other countries as part of  $M$ .

**Table 2.** Predicted Effect of the Subprime Crisis on Commodity Prices<sup>a</sup>  
Percentage points

| Elasticity of substitution $\sigma$ | Initial size of the financial bubble as share of world financial wealth, $B_{t_0}/W_{t_0}$ (percent) |      |      |       |       |
|-------------------------------------|--|------|------|-------|-------|
|                                     | 1  | 2    | 3    | 4     | 5     |
| 0.05                                | 1.11   | 1.91 | 2.73 | 3.57  | 4.42  |
| 0.1                                 | 1.11   | 1.98 | 2.89 | 3.83  | 4.80  |
| 0.2                                 | 1.13   | 2.16 | 3.30 | 4.53  | 5.83  |
| 0.5                                 | 1.21   | 3.42 | 6.76 | 11.22 | 16.81 |

Source: Authors' calculations based on the model described in the text.

a. Each cell reports the model-predicted change in commodity prices  $p_c - p_c$  associated with the indicated size of the original bubble at the indicated value of  $\sigma$ . Italicized numbers correspond to the authors' preferred calibration.

modity prices as a function of the elasticity  $\sigma$  and the size of the initial bubble collapse  $B_{t_0}/W_{t_0}$ .

The results in table 2 support our view that the collapse in the U.S. housing market and the contraction in credit markets played a significant role in explaining the surge in commodity prices that followed the subprime crisis. We find that for our benchmark estimate of the size of the bubble of 2 percent, commodity prices increase by 98 percent when the short-run elasticity of substitution equals 0.1, which is very close to the 108 percent observed in the data. Recall that without an asset channel (in the benchmark no-inventories economy), commodity prices would not jump when the crisis occurs.

Turning to the external accounts, between September 2006 and June 2008 the U.S. trade deficit on goods and services decreased from -5.96 percent of U.S. GDP to -4.94 percent, a 1.02-percentage-point improvement.<sup>46</sup> Can the model explain this very limited rebalancing? We answer this question by rewriting the trade balance equation (equation 19) as

$$\frac{TB_{t_0}^U - TB_{t_0}^U}{X_{t_0}^U} = \frac{\mu_{t_0}}{1 - s_{\sigma_0}} \left\{ \frac{B_{t_0}}{W_{t_0}} \left( \frac{1}{x_{t_0}^U} - 1 \right) - s_{\sigma_0} \left[ \left( \frac{P_{t_0}^*}{P_{t_0}} \right)^{1-\sigma} - 1 \right] \right\}.$$

The first term inside the curved brackets represents the direct impact of the collapse of the bubble on the trade balance. It contributes positively to global rebalancing. The second term reflects the contribution of commodity

46. See the Bureau of Economic Analysis's National Income and Product Accounts, table 4.1.

**Table 3. Predicted Effect of the Subprime Crisis on the Region *U* Trade Balance<sup>a</sup>**  
Percent of GDP

| Change in commodity<br>prices, $p_{r_0}/p_{r_0}$ | Initial size of the financial bubble as share of world<br>financial wealth, $B_{r_0}/W_{r_0}$ (percent) |       |      |       |       |
|--|---|-------|------|-------|-------|
|  | 1   | 2     | 3    | 4     | 5     |
| 1.0  | 3.01  | 6.02  | 9.04 | 12.05 | 15.06 |
| 1.2  | 2.30  | 5.31  | 8.32 | 11.33 | 14.34 |
| 1.5  | 1.24  | 4.26  | 7.27 | 10.28 | 13.29 |
| 2.0  | -0.47   | 2.55  | 5.56 | 8.57  | 11.58 |
| 3.0  | -3.77   | -0.75 | 2.26 | 5.27  | 8.28  |

Source: Authors' calculations based on the model described in the text.

a. Each cell reports the model-predicted change in the region *U* trade balance relative to the region's output  $(TB_r^y - TB_r^y) / X_r^y$  associated with the indicated size of the original bubble and the indicated change in commodity prices, at an assumed elasticity of substitution  $\sigma = 0.1$ . Italicized numbers correspond to the authors' preferred calibration.

prices. Table 3 reports the sum of the direct and indirect impacts of the subprime crisis on the trade balance as a function of the commodity price surge  $p_{r_0}/p_{r_0}$  and the size of the initial bubble  $B_{r_0}/W_{r_0}$  for an elasticity of substitution  $\sigma$  equal to 0.1.

The first line of the table reports the change in the trade balance in the benchmark no-inventory economy (which coincides with the direct effect). We find a large and implausible improvement in the trade balance. For instance, for an initial bubble equal to 2 percent of world financial wealth, the no-inventory economy predicts an improvement in the trade balance equal to 6.02 percent of output. This is a far cry from the 1.02 percent observed in the data. Again, once we introduce the "petrodollar" channel, the required rebalancing drops significantly. For instance, the trade balance improves by "only" 2.55 percent of output, instead of 6.02 percent when commodity prices double. If instead we consider a tripling of commodity prices, or a smaller initial bubble collapse, it is possible for the trade balance to worsen on impact. Although our preferred numbers are on the high side (2.5 percent of output compared with 1.02 percent), it is apparent that the model has the capacity to rationalize the very limited global rebalancing that we are witnessing.<sup>47</sup>

All in all, we conclude that the model is in the right ballpark and can account for the broad features of the global economy in the first phase of the crisis.

47. Calculations for the current account are very similar since when  $\mu_{r_0}$  is close to 1, interest payments remain small.

**Table 4.** Predicted Effect of the Growth Slowdown on Commodity Prices<sup>a</sup>  
Percent

| Elasticity of substitution $\sigma$ | Change in region U financial wealth,<br>( $W_t^U - W_t^U$ ) / $X_t^U$ (percent) |       |       |       |
|-------------------------------------|---|-------|-------|-------|
|                                     | -0.05   | -0.10 | -0.15 | -0.17 |
| 0.05                                | 0.72  | 0.44  | 0.17  | 0.07  |
| 0.1                                 | 0.70  | 0.42  | 0.16  | 0.06  |
| 0.2                                 | 0.67  | 0.38  | 0.12  | 0.04  |
| 0.5                                 | 0.53  | 0.21  | 0.03  | 0.01  |

Source: Authors' calculations based on the model described in the text.

a. Each cell reports the model-predicted change in commodity prices  $p_c/p_c$  associated with the indicated change in region U financial wealth at the indicated value of  $\sigma$ . Italicized numbers correspond to the authors' preferred calibration.

PHASE II: THE GROWTH SLOWDOWN. We now ask whether the model can account for the broad features of the data following the slowdown in economic activity. In real terms, between July and November 2008 oil prices declined by 53 percent (see figure 7). We can use equation 21 to write the change in commodity prices as

$$(22) \quad \frac{p_{it}^U}{p_{it}^U} = \left[ 1 + \frac{W_{it}^U - W_{it}^U}{X_{it}^U} \frac{\theta}{\mu_{it}^U} \frac{1 - s_{\sigma\Gamma}}{s_{\sigma\Gamma}} \right]^{1/(1-\sigma)}$$

The change in commodity prices is a function of the drop in U's financial wealth. Reasonable estimates of the financial losses incurred since July 2008 are not available yet. Instead, table 4 reports predicted declines for a range of estimates of  $(W_{it}^U - W_{it}^U)/X_{it}^U$  and different values of the short-run demand elasticity for commodities.

It is immediately apparent that commodity prices are extremely sensitive to the drop in financial wealth. For  $\sigma = 0.1$ , a modest decline in U.S. financial wealth equal to 10 percent of output triggers a staggering 58 percent ( $0.42 - 1$ ) decline in commodity prices. This is remarkably close to the 53 percent decline observed in the data.

Table 5 reports the predicted change in the trade balance as a function of the decline in U.S. financial wealth. Since  $TB^U = X^U - \theta W^U$ , this calculation is independent of  $\sigma$ . This part of the analysis is necessarily more speculative. It indicates that the model predicts a significant rebalancing of the trade balance, equal to about 2.2 percent of output, as a consequence of the growth slowdown.

**Table 5. Predicted Effect of a Growth Slowdown on the Region *U* Trade Balance<sup>a</sup>**  
Percent of GDP

|   | <i>Change in region U financial wealth,</i><br>$(W_t^U - W_{t-1}^U) / X_t^U$ (percent of GDP) |       |       |       |
|---|---|-------|-------|-------|
|   | -0.05   | -0.10 | -0.15 | -0.17 |
| Change in region <i>U</i> trade balance,<br>$(TB_t^U - TB_{t-1}^U) / X_t^U$ | 1.09  | 2.18  | 3.27  | 3.70  |

Source: Authors' calculations based on the model described in the text.

a. Each cell reports the model-predicted change in the region *U* trade balance relative to the region's output associated with the indicated change in region *U* financial wealth. Italicized numbers correspond to the authors' preferred calibration.

## Calibration and Dynamics

We now turn to an analysis of full general-equilibrium dynamic simulations. We begin with a discussion of plausible short- and long-run elasticities of demand for commodities. We then present the results from dynamic simulations of the financial crisis with and without a growth slowdown.

### *Short- and Long-Run Elasticities*

A key parameter of our model is the elasticity of substitution  $\sigma$ . William Nordhaus finds low "apparent" short-run price elasticities of demand of around 0.3 at the time of the 1973 oil price shock.<sup>48</sup> Long-run elasticities are typically higher, since with time, energy users can substitute away from energy-intensive technology. Nordhaus notes that for many components of the physical capital stock, energy substitution is possible only when the existing capital is scrapped. In the transportation sector, for instance, in which energy consumption depends in large part on the fuel efficiency of the outstanding stock of vehicles, energy consumption responds gradually as old vehicles are slowly replaced with more-fuel-efficient ones. Similarly, in the case of electric power generation, there is almost no possibility for substitution in the short run, but in the long run utilities can switch to other sources such as nuclear or wind power.

More recent studies confirm the "crude" estimates in Nordhaus's analysis for the short run while finding higher long-run estimates.<sup>49</sup> The typical estimates for short-run price elasticities vary between 0.05 and 0.35; long-run estimates vary between 0.21 and 0.86.<sup>50</sup>

48. Nordhaus (1980).

49. See Roy and others (2006) and Dahl and Sterner (1991) for older surveys.

50. See Hamilton (2008) for a recent discussion of crude oil prices, and the references therein.

**Table 6.** Apparent Price Elasticity of U.S. Petroleum Demand<sup>a</sup>  
Percent a year

|   | 1988–2003 | 2003–07 |
|---|-----------|---------|
| Change in real price of petroleum products <sup>b</sup> | 1.44      | 8.55    |
| Change in U.S. demand for petroleum products            | 0.84      | 0.61    |
| Apparent elasticity <sup>c</sup>                        | 0.04      |         |
| Memorandum: average change in U.S. real GDP             | 2.83      | 2.90    |

Sources: Energy Information Administration, *Annual Energy Review*, tables 3.1 and 3.3; *Monthly Energy Review*, tables 2.2–2.6.

a. All data are compound annual averages.

b. Consumer price estimate through 2005; fossil fuel composite price after 2005.

c. Assumes a sectoral elasticity with respect to GDP of unity.

Table 6 provides an update on Nordhaus’s “apparent” price elasticity estimates for the period around the recent increase in oil prices. The table reports recent data on U.S. petroleum consumption and prices before and after 2003, where the break in oil prices is apparent in figure 7. Between 2003 and 2007, petroleum prices increased by an average of 8.55 percent a year, a sharp break from the 1.44 percent average annual increase between 1988 and 2003. Nevertheless, annual growth in demand for petroleum products slowed only from 0.84 percent to 0.61 percent. The “apparent” price elasticity is calculated as by Nordhaus, under the assumption of a unit elasticity of petroleum product demand to GDP, as the (opposite of the) percentage slowdown in energy demand corrected for the percentage change in real output growth, divided by the percentage acceleration in prices.<sup>51</sup> We obtain an estimate of 0.04, on the low end of available empirical estimates.<sup>52</sup> This is consistent with recent empirical estimates that find an even smaller short-run price elasticity now than in the 1970s.<sup>53</sup>

A simple way of capturing this time variation in  $\sigma$  is to assume that the elasticity of substitution remains significantly smaller than 1 until the share of expenditure on the  $Z$  good reaches a certain exogenous level  $\bar{s}_Z$ . When

51. The income elasticity of petroleum demand is largely irrelevant in these calculations, since output growth was essentially the same over both subperiods. This elasticity in industrial countries has declined significantly since the oil price shocks of the 1970s and is now closer to 0.5. However, the income elasticities of emerging markets and oil-producing countries appear to be much closer to, or even above, unity. See Gately and Huntington (2002) and the discussion in Hamilton (2008).

52. Interestingly, the same calculations for residential demand for petroleum products (not reported here) yield a much larger apparent elasticity of 0.78. The price elasticity is lowest for the industrial and transport sectors, for which it is close to zero.

53. Hughes, Knittel, and Sperling (2008) find a short-run price elasticity of between 0.03 and 0.08 between 2001 and 2006.

that level is reached, we assume that the elasticity of substitution becomes equal to 1. This transition is fully anticipated by economic agents. Continuity of the demand schedule also requires that  $\alpha$  differ as the economy transitions from  $\sigma < 1$  to  $\sigma = 1$ .<sup>54</sup> We denote  $\alpha'$  as the preference parameter after the switch to  $\sigma = 1$ .

### *The Dynamic System and the U.S. Financial Shock*

We now characterize the full dynamic path of the economy in response to a U.S. financial collapse. We start the economy on the dynamic path of the bubble equilibrium with  $\sigma < 1$  and a given level of global imbalances. At  $t = t_0$ , the bubble collapses and the economy jumps to the dynamic path of the bubbleless equilibrium. Appendix D (online) provides a complete exposition of the dynamic system and the transitions that occur between the different regimes.

Calibration of the dynamic path requires that we provide values for the following parameters: the capitalization ratio  $\delta$ , the growth rate of the economy  $g$ , the relative sizes of  $U$  and  $M$ , the elasticity of substitution  $\sigma$ , the propensity to consume out of financial wealth  $\theta$ , and the share of commodity expenditures  $\bar{s}_z$  when the elasticity of substitution becomes unitary. We adopt a mixed approach, setting the values of some parameters on the basis of plausible values and calibrating others so as to reproduce key features of the data.

We start by setting the growth rate of the  $X$  good to  $g = 0.03$ , which is close to the average annual real growth rate of output in the United States between 1950 and 2007 (3.28 percent). As discussed above, we assume that  $U$  represents a quarter of the world's output. We set  $\sigma$  equal to 0.3. This is significantly higher than the apparent elasticity estimate in table 6. Nonetheless, as argued above, it is well within the range of estimates in the empirical literature. Furthermore, this value of  $\sigma$  produces realistic levels of adjustment in commodity prices in the model. It also implies that the price of commodities increases initially at  $g/\sigma = 10$  percent in the equilibrium with bubble, accounting for some of the rapid increase in commodity prices observed *before* the U.S. financial crisis.

We set  $\bar{s}_z = 0.1$ , so that the long-run model takes over when the expenditure share of commodities reaches 10 percent. This seems a reasonably high value. In the data the share of oil in world output reached 4.16 percent in 2006, up from 1.29 percent in 1998. In the simulation it would take

54. To see this, suppose that the transition occurs at some time  $T$ . Aggregate demand for  $X$  goods right before  $T$  is given by  $W_{T^-} = [(1 + \alpha p_T^{1-\sigma}) X_T]/\theta$ . Right after the switch, it is equal to  $W_{T^+} = [(1 + \alpha') X_T]/\theta$ . Continuity of commodity prices and wealth requires that  $\alpha p_T^{1-\sigma} = \alpha'$ .

around 10 years before the expenditure share reached 10 percent. This yields  $\alpha' = 11.11$  percent. Finally, we set the value of the world capitalization index  $\delta$  to 0.15, which corresponds to about half of the share of capital in national accounts. As discussed in our previous paper,  $\delta$  should be substantially lower than the capital share, since many forms of capital do not generate capitalizable streams of revenue.<sup>55</sup> We then calibrate each region's  $\delta$  so as to stabilize global imbalances before the crisis erupts. We obtain  $\delta^U = 0.144$  and  $\delta^M = 0.152$ .<sup>56</sup>

The two remaining parameters to calibrate are  $\theta$  and  $\alpha$ . We set their values so as to control both the size of the initial bubble relative to aggregate wealth at  $t = 0$ ,  $B_0/W_0 = \beta_0$ , and the limit size of the bubble that would emerge in the bubbly equilibrium under  $\sigma = 1$ ,  $\beta_1 \equiv \lim_{t \rightarrow \infty} B_t/W_t$ . From equation D2 in appendix D (online), we obtain  $\lim_{t \rightarrow \infty} B_t/W_t = 1 - \delta\theta/g(1 + \alpha')$ . For given values of  $\beta_0$  and  $\beta_1$ , we infer back the corresponding values of  $\theta$  and  $\alpha$ .

In practice we set  $\beta_0 = 0.02$ , so that the collapse of the bubble represents roughly 2 percent of the world's wealth, as estimated in the previous section. We set  $\beta_1 = 1.01\beta_0$ , so that the economy is not far from its long-run steady state when the bubble collapses. (This ensures that the share of commodities in expenditure is not too small.) We obtain  $\theta = 0.22$  and  $\alpha = 0.40$ . We view these values as plausible. As a point of reference, our earlier paper, using data on U.S. household sector net worth and U.S. GDP, computed a value of  $\theta = 0.25$ . ( $\theta$  can be interpreted as the output-to-financial wealth ratio.) These values imply that the economy is slightly dynamically inefficient, since  $\delta\theta/(1 + \alpha') = 2.94$  percent  $< g = 3$  percent. Finally, we set the initial net foreign asset position relative to U.S. output  $\eta = -0.15$ , in line with estimates of the U.S. net external debt position in 2006. Table 7 summarizes the parameter values.

Figure 14 reports the simulation obtained with these parameter values. Before the crisis the real interest rate is slightly above 3.4 percent and increasing, commodity prices (normalized) are equal to their steady-state value  $\hat{q} \equiv (\alpha/Z)^{1/\sigma}$ , and both the trade balance and the current account are in deficit and improving (−3.5 percent and −4 percent of output, respectively).

At  $t = 0$  the financial crisis hits, wiping out 2 percent of aggregate financial wealth. The response of interest rates is quite stark (top left panel of figure 14): they drop from about 3.5 percent to 2.7 percent. This decline is

55. Our earlier paper (Caballero and others, 2008) assumed  $\delta = 0.12$ , at which the results are largely unchanged.

56. Although the calibration sets  $\delta^U$  slightly lower than  $\delta^M$ , the “perceived” capitalization index in  $U$  in the presence of the bubble  $B$  is much larger, equal to  $\hat{\delta}^U = [\delta - (1 - x_{t_0}^U)\delta^M] / x_{t_0}^U = 0.156$ . In that sense the calibration is extreme in that it assumes that  $U$  has no fundamental advantage in supplying stores of value.

**Table 7.** Parameter Values Used in the Simulation

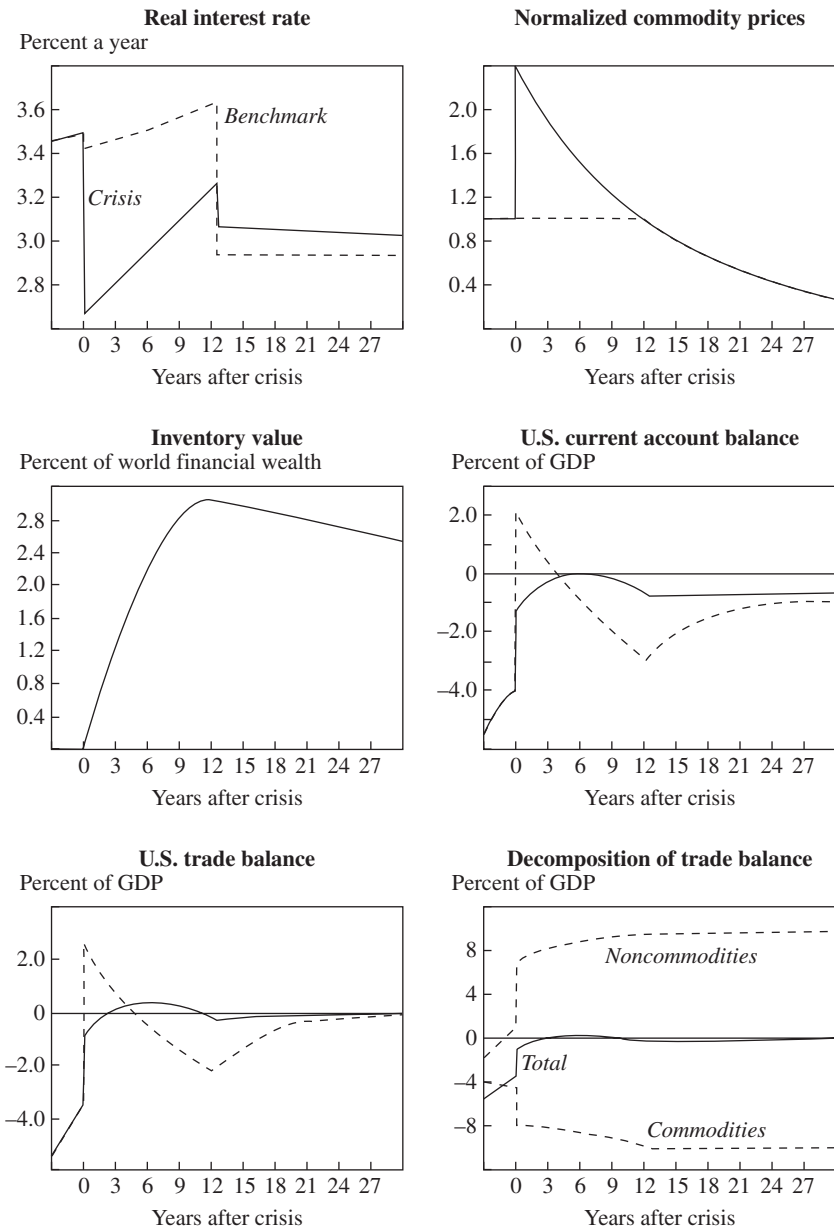
| <i>Parameter</i>  | <i>Value</i> |
|---|--------------|
| Growth rate of output $g$   | 0.03         |
| Elasticity of substitution $\sigma$   | 0.3          |
| Share of $U$ region output in world output $X^U/X$  | 0.25         |
| Long-run expenditure share of commodities in output $\bar{s}_x$   | 0.1          |
| Capitalization ratio $\delta$   | 0.15         |
| Initial value of financial bubble as a fraction of world financial wealth at time of financial crisis $\beta_0$ | 2 percent    |
| Long-term value of financial bubble as a fraction of world financial wealth in the bubbly equilibrium $\beta_1$ | 2.02 percent |
| Initial net foreign asset position in $U$ region as a fraction of region's output $\eta$                        | -0.15        |
| <i>Inferred parameters</i>  |              |
| Preference for commodities $\alpha$   | 0.40         |
| Propensity to consume out of financial wealth $\theta$  | 0.22         |
| Capitalization ratio in the $U$ region $\delta_U$   | 0.144        |
| Capitalization ratio in the $M$ region $\delta_M$   | 0.152        |

much larger than the mere 6 basis points in the benchmark economy (dashed line in the top left panel). The fall in interest rates in the simulated economy is strong enough to trigger inventory accumulation. As the top right panel shows, the normalized price of commodities  $\hat{q}_t = p_t/X_t^{1/\sigma}$  jumps 2.3-fold and gradually converges back over the next 12 years. By contrast, in the benchmark economy, the (normalized) price of commodities remains unchanged and equal to  $\hat{q}$ .<sup>57</sup> The jump in prices lowers the demand for commodities and allows inventory accumulation. We find that starting from  $I_0 = 0$ , inventories rise relatively slowly: it takes 12 years before their market value  $pI$  peaks at 3.2 percent of world financial wealth (middle left panel). In the initial periods after the shock, in particular, inventories remain very low, contributing little to the global supply of assets.

The middle right panel of figure 14 reports the current account balance relative to output in the simulated economy and in the benchmark economy. In both cases the current account improves as a result of the collapse of the bubble. However, as conjectured in the previous section, the rebalancing is much smaller in the economy with inventories. In the benchmark economy the current account balance jumps from -4 percent of output to +2 percent, an instant rebalancing of 6 percentage points. This is not surprising, given that the bubble is located in the United States: the reduction in asset supply

57. This still implies that in the benchmark economy,  $p_t$  increases at the rate  $g/\sigma$ , faster than the rate of economic growth.

**Figure 14.** Dynamics of the Subprime Crisis Response in the Short and the Long Run without a Growth Slowdown



Source: Authors' calculations.

**Table 8.** Change in the U.S. Trade Balance, Selected Periods  
Percent of GDP

|  | 1980–89 |         | 1999–2008 |         |
|--|---------|---------|-----------|---------|
|  | 1980–87 | 1987–89 | 1999–2006 | 2006–08 |
| Total change in the trade balance              | -2.5    | 1.5     | -2.8      | 0.8     |
| Of which:                                      |         |         |           |         |
| Change in balance of nonoil goods and services | -4.4    | 1.5     | -1.4      | 1.5     |
| Change in oil balance                          | 1.9     | 0.0     | -1.4      | -0.7    |

Source: Authors' calculations from Bureau of Economic Analysis data.

leads agents to move part of their financial investments to  $M$ . By contrast, in the simulated economy the rebalancing is “only” from  $-4$  percent to  $-1.4$  percent of GDP. As we discussed earlier, this is larger than the rebalancing observed in the data, but of a similar order of magnitude.

Eventually, the rebalancing must become larger in the simulated economy, to achieve a long-run current account balance of  $-0.6$  percent compared with  $-0.9$  percent in the benchmark no-inventory economy. Nevertheless, the role of commodities is to stabilize capital outflows for the first four years after the initial shock. The bottom left panel of figure 14 shows that the implications for the trade balance are very similar, as discussed earlier. The bottom right panel further decomposes the trade balance into its non-commodity component,  $X_t^U - \theta W_t^U / (1 + \alpha p_t^{1-\sigma})$ , and its commodity component,  $-\alpha p_t^{1-\sigma} \theta W_t^U / (1 + \alpha p_t^{1-\sigma})$ . Underlying the muted response of the trade balance, both the commodity and the noncommodity trade balances adjust sharply. The commodity balance falls from  $-4.6$  percent to  $-7.9$  percent of output, while the noncommodity balance jumps from 1.0 percent to 6.9 percent of output.

This asymmetric response of the commodity and noncommodity components of the trade balance is consistent with the empirical evidence. Table 8 reports the change in the U.S. trade balance during the last two rebalancing episodes: 1987–89 and 2006–08.<sup>58</sup> The table shows that the recent improvement in the U.S. trade balance comes entirely from the nonoil component, which improved by more than 1.5 percent of GDP. By contrast, the oil balance worsened by 0.7 percent of GDP. When this rebalancing episode is compared with the previous episode, centered around 1987, it is striking to note that oil prices played no role in attenuating the external

58. Milesi-Ferretti (2008) presents additional evidence on the contrast between the two episodes.

rebalancing then: the deficit of the oil balance did not change between 1987 and 1989.

### *The Dynamic System and a Global Slowdown*

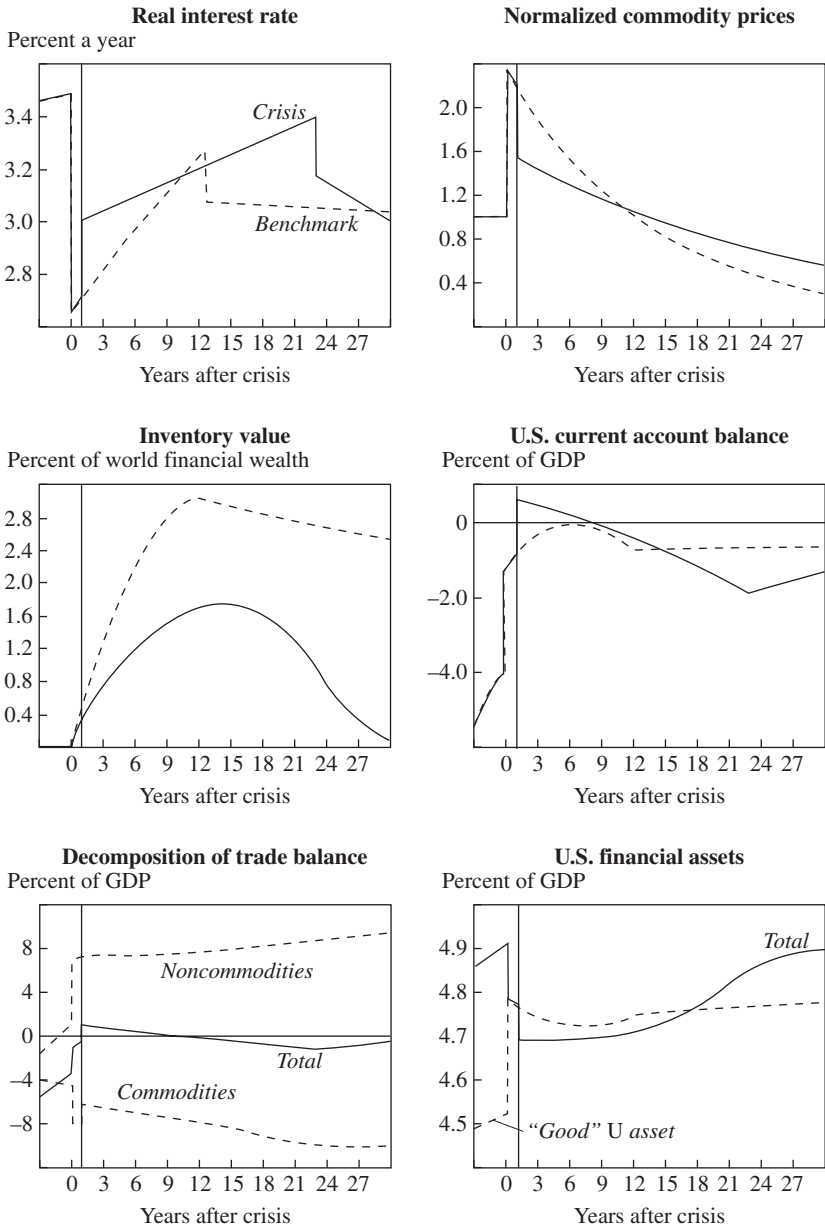
The preceding results account for the negative correlation between U.S. financial assets and commodity prices that emerged in the first phase of the U.S. financial crisis. Starting in July 2008, however, commodity prices retreated dramatically. Bad news for commodities was also bad news for U.S. and world financial markets.

Of course, this global collapse has many causes, and a host of overshooting mechanisms are at work, from balance sheet multipliers, to margin calls, to Knightian uncertainty, all of which contribute to the overall process of deleveraging. Our framework is not suited to addressing the role of each of these factors. Instead, we emphasize here the dramatic impact of a global economic slowdown. To do so, we recalibrate our model assuming that a moderate slowdown—a fall in annual global output growth from 3 percent to 2 percent—takes place unexpectedly one year after the beginning of the U.S. financial crisis.

Such a decline in global growth is sufficiently large to ensure that assumption 2 is satisfied, so that the tightness in global asset markets is relieved. Figure 15 presents the results. In each panel the solid line reports the simulation with a growth slowdown, and the dashed line reports the simulation from figure 14, without a growth slowdown. The collapse in global growth at  $t = 1$  has dramatic consequences for asset and commodity prices. First, slower growth reduces asset values. In the short run, however, it leads to an even larger decline in asset demand. The result is an *increase* in interest rates (top left panel) and a decline in asset prices (bottom right panel).<sup>59</sup> This decline in asset demand arises from the sudden decline in commodity prices (top right panel), which makes commodity producers poorer. As discussed previously, this collapse in commodity prices arises from a downward adjustment in sustainable long-run equilibrium inventories (middle left panel). The growth slowdown eliminates the dynamic inefficiency of the economy and thus the need to hold inventories in the long run. Inventory holders immediately reduce the rate of accumulation of inventories, which leads to a collapse in the price of commodities. As before, the decline in commodity prices is reinforced by the short-run increase in interest rates that makes commodity accumulation less profitable.

59. The bottom right panel reports the total value of  $U$  assets, including the bubble for  $t \leq 0$ , both in the case with and in the case without a growth slowdown. It also reports the value of the “good”  $U$  asset in the case with a growth slowdown.

**Figure 15.** Dynamics of the Subprime Crisis Response in the Short and the Long Run with a Growth Slowdown



Source: Authors' calculations.

The impact on external imbalances is also interesting. Whereas the previous discussion indicated that external imbalances could increase or decrease when growth slows down, we find that for these parameter values, the decline in commodity prices accelerates the process of global rebalancing (middle right panel), largely through an improvement in the commodity component of the trade balance (bottom left panel).

The growth slowdown generates a pattern of positive co-movements for asset prices and commodities that closely matches what the world economy has experienced since July 2008. In our framework the decline in global economic growth shrinks or even eliminates the bubble by reducing global asset demand. However, it is important to recall that this experiment assumes that the growth slowdown is permanent, a highly unlikely situation. Once real economic conditions recover, our model predicts that asset demand will rebound, re-creating the chronic shortage of assets, and the cycle will start again.

## **Inventories, Oil Prices, and Asset Supply: Some Evidence**

We now examine in more detail the role of inventories and the empirical evidence on the linkage between financial factors and commodity prices.

### *Inventories*

One objection to stories like ours, where asset demand for oil plays an important role in price determination, is that measured oil inventories did not rise during the recent price spike. Petroleum inventories in the OECD countries increased from 3.74 billion barrels in January 2000 to 4.08 billion barrels in April 2008. However, this increase mostly occurred between 2000 and 2006. After the onset of the subprime crisis, OECD petroleum inventories declined from 4.25 billion barrels in September 2006 to 4.08 billion barrels across the board.<sup>60</sup>

60. In the United States, petroleum and crude oil stocks increased between January 2000 and September 2006 by 307 million and 168 million barrels, respectively. Between September 2006 and April 2008, U.S. petroleum stocks declined from 1.79 billion to 1.67 billion barrels, while crude oil inventories remained relatively constant at around 1 billion barrels. A closer look, however, reveals that nonstrategic crude oil inventories decreased by 13.6 million barrels. The only component of U.S. petroleum stocks that increased between September 2006 and April 2008 is the Strategic Petroleum Reserve (SPR; see Energy Information Administration, *Monthly Energy Review*, tables 3.4 and 11.3). This change in the SPR is a consequence of the Energy Policy Act of 2005, which mandated a gradual increase in the reserve from 700 million to 1 billion barrels. In May 2008, in response to the rapid increase in oil prices, Congress voted to stop depositing oil in the SPR.

Yet there are at least two reasons why the absence of a rise in measured inventories need not be a serious concern. First, observed inventories are the result of two opposing forces: the asset market force, which leads to an increase in inventories, and a demand force, which does the opposite. In appendix B we show that if the long-run elasticity of substitution exceeds 1, inventories follow a nonmonotonic path—rising first and afterward declining—in response to speculation.

Second, as argued by Jeffrey Frankel and others,<sup>61</sup> producers are the most efficient inventory holders, since they do not need to extract the oil in order to hold it. In our model this amounts to assuming  $d^{\text{oilproducer}} < d$ , which implies that *all* inventories are held under ground.

Our model is amenable to several interpretations where inventories are just oil in the ground. Suppose, for example, that new reserves of the  $Z$  good are discovered every period. More precisely, the stock of discovered reserves increases by  $Z$  per unit of time. The economy cannot consume resources that have not been discovered yet. In addition, suppose that the rights to these new reserves are not capitalized, either because they accrue to new entrants, or because they are likely to be expropriated, or because they embody unmodeled uncertainty. This economy would be exactly equivalent to our simulated economy. Under this interpretation there are no physical inventories of  $Z$  goods. Inventories reflect only discovered and not-yet-consumed reserves of the  $Z$  good.

Another, more abstract interpretation is that of a social contract in region  $M$ . This (implicit) contract specifies that each generation is entitled to an endowment  $Z$  of  $Z$  goods. They can decide when to sell it. If they do not sell it immediately, they can store it. Moreover, they can trade rights to future consumption claims on their endowment; that is, they can sell the  $Z$  good forward. They can also acquire the  $Z$  good from agents of the same or a different generation in  $M$ : they can then treat these newly acquired goods exactly as their own endowment. This economy is once again completely isomorphic to our economy. Inventories are just goods in the ground. As we show in appendix A, the underground inventory holding view has important implications for the effectiveness of recent proposals to tax speculative transactions in commodities.

### *The Empirical Link between Oil Prices and Asset Supply*

The asset role of oil suggests a negative correlation between oil prices and the value of assets negatively affected by financial shocks, and a posi-

61. Frankel (2006).

tive correlation between oil prices and economic growth. As a starting point for investigating this question, we run the following simple regression using ordinary least squares (OLS):

$$(23) \quad \Delta p_t = \alpha + \beta \Delta S+P_t + \gamma \Delta y_t + \varepsilon_t,$$

where all variables are in logarithms,  $p_t$  denotes the spot price of crude oil,  $S+P_t$  is the S&P500 index, and  $y_t$  is the monthly U.S. industrial production index. In the model a decline in the value of bubble assets that lowers stock prices leads to a reallocation of assets toward commodities, and so we expect to find  $\beta < 0$ . A decline in growth should also push down commodity prices, and so we expect  $\gamma > 0$ . Table 9 reports the results of this simple regression for the period from January 1984 to November 2008. We find a negative but statistically insignificant link between oil prices and stock market performance, and a positive and mostly insignificant link between growth and oil prices.

There are two obvious issues with the OLS regression. First, as shown in figure 8, the apparent correlation is strongly negative only in the first phase of the crisis. In the second phase, as explained above, the collapse in global growth reduces both asset and commodity prices. Second, there is an obvious reverse causality concern. For instance, an exogenous increase in oil prices could increase the chances of a recession, leading to a decline in stock returns, or push up inflation rates, leading to a tightening of monetary policy, which would also send equities tumbling. To control for this we use two instruments: the price of gold and the performance of financial stocks relative to the broader market. Increases in the price of gold are often associated with flight-to-quality episodes. In fact, since gold itself provides little services or yield, it is the perfect example of an asset held for speculative reasons. The relative performance of financials captures the fact that financial crises impact the financial sector more directly, whereas there is no reason for oil shocks to affect this service sector more than, for example, the energy-intensive transportation or manufacturing sectors.

The top panel of table 10 presents our instrumental variables estimates. Notice that the coefficient on equities is much larger than in the OLS estimate and strongly significant at the daily, weekly, monthly, and quarterly frequencies. The elasticity is always in excess of one. The coefficient on growth has the correct sign at the quarterly and annual frequencies but appears to be insignificant. The bottom panel reports the first stage of the instrumental variables regression.

**Table 9. OLS Regressions of Oil Prices on U.S. Stock Prices and Industrial Production<sup>a</sup>**

| <i>Independent variable</i>                                 | <i>Regression</i> |                 |                 |                 |                 |                 |                 |                 |                 |                 |           |
|---|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------|
|   | 9-1               | 9-2             | 9-3             | 9-4             | 9-5             | 9-6             | 9-7             | 9-8             | 9-9             | 9-10            |           |
| Change in log S&P500 index                                  | -0.06<br>(1.41)   | -0.01<br>(0.13) | -0.07<br>(0.37) | -0.45<br>(1.59) | -0.44<br>(1.42) | -0.06<br>(1.39) | -0.02<br>(0.17) | -0.11<br>(0.72) | -0.50<br>(1.73) | -0.63<br>(2.57) | Annual    |
| Change in industrial production index                       |                   |                 | 1.30<br>(1.25)  | 3.10<br>(2.04)  | 1.81<br>(1.23)  |                 |                 | 1.03<br>(1.05)  | 2.23<br>(1.11)  | -0.59<br>(0.27) | Quarterly |
| Change in log S&P500 index,<br>lagged one period            |                   |                 |                 |                 |                 | 0.06<br>(1.58)  | -0.07<br>(0.83) | -0.07<br>(0.43) | 0.67<br>(0.29)  | 0.22<br>(0.67)  | Annual    |
| Change in industrial production index,<br>lagged one period |                   |                 |                 |                 |                 |                 |                 | 2.68<br>(2.02)  | 1.07<br>(0.57)  | 2.43<br>(0.97)  | Quarterly |
| Data frequency  | Daily             | Weekly          | Monthly         | Quarterly       | Annual          | Daily           | Weekly          | Monthly         | Quarterly       | Annual          | Annual    |
| No. of observations   | 6,233             | 1,296           | 297             | 295             | 286             | 6,232           | 1,295           | 296             | 294             | 285             | 285       |
| R <sup>2</sup>  | 0.000             | 0.000           | 0.001           | NA              | NA              | 0.001           | 0.001           | 0.004           | NA              | NA              | NA        |

Source: Authors' regressions.

a. The dependent variable is the change in the logarithm of the spot price in dollars of a barrel of West Texas Intermediate oil. The sample period is January 1, 1984, to November 8, 2008. Changes at all intervals are measured from the end of one period to the end of the next. Quarterly and annual regressions are run on overlapping monthly data. Eicker-White robust *t* statistics are reported in parentheses for the daily, weekly, and monthly regressions and Newey-West *t* statistics for the quarterly and annual regressions, with windows of 2 and 11 months, respectively. Constant terms are included in all regressions (results not reported).

**Table 10.** Instrumental Variables Regressions of Oil Prices on U.S. Stock Prices and Industrial Production<sup>a</sup>

| <i>Independent variable</i>   | <i>Regression</i>               |                 |                 |                 |                 |
|---|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|   | <i>10-1</i>                     | <i>10-2</i>     | <i>10-3</i>     | <i>10-4</i>     | <i>10-5</i>     |
|   | <i>Second-stage regressions</i> |                 |                 |                 |                 |
| Change in log S&P500 index  | -1.14<br>(4.95)                 | -1.52<br>(3.45) | -2.96<br>(3.12) | -3.08<br>(3.71) | -3.74<br>(1.98) |
| Change in industrial<br>production index                                  |                                 |                 | -0.94<br>(0.40) | 3.86<br>(1.25)  | 7.99<br>(1.39)  |
|   | <i>First-stage regressions</i>  |                 |                 |                 |                 |
| Log change in S&P500<br>financials index less change<br>in overall S&P500 | 0.29<br>(8.55)                  | 0.28<br>(5.56)  | 0.29<br>(2.96)  | 0.29<br>(2.75)  | -0.01<br>(0.06) |
| Log change in price of gold   | -0.11<br>(3.87)                 | -0.08<br>(1.91) | -0.09<br>(0.94) | -0.11<br>(1.21) | -0.28<br>(1.83) |
| Data frequency  | Daily                           | Weekly          | Monthly         | Quarterly       | Annual          |
| No. of observations   | 6,098                           | 1,296           | 297             | 295             | 286             |
| R <sup>2</sup>  | 0.06                            | 0.06            | 0.06            | NA              | NA              |

Source: Authors' regressions.

a. The dependent variable in the second-stage regressions is the change in the logarithm of the spot price in dollars of a barrel of West Texas Intermediate oil. The dependent variable in the first-stage regressions is the change in the logarithm of the S&P500 index. Changes at all intervals are measured from the end of one period to the end of the next. Quarterly and annual regressions are run on overlapping monthly data. Eicker-White robust *t* statistics are reported in parentheses for the daily, weekly, and monthly regressions and Newey-West *t* statistics for the quarterly and annual regressions, with windows of 2 and 11 months, respectively. Constant terms are included in all regressions (results not reported).

Financial relative performance has the right impact on equilibrium asset values at all frequencies but annual: conditional on growth, bad news in U.S. financial markets is good news for oil as an asset. Conversely, good news in U.S. financial markets is bad news for oil.<sup>62</sup>

## Discussion

The prevailing view of financial disruptions is one of central bank excesses and mistakes leading to excess liquidity, speculative bubbles, and unavoidable crises. This seems overstated: central banks, when reasonable, are not nearly that powerful. In this paper we take a contrarian view and provide an entirely private sector account of the main facts, without any role for monetary factors. Reality is probably in between.

62. The results are similar if we restrict the sample to the period before July 2008, preceding the second phase of the crisis.

Our framework builds on the idea that the world economy entered the present crisis with chronic excess demand for financial assets; the subprime market developments may have been merely a (failed) market attempt to bridge this gap. Within this perspective we argue that the sharp rise in oil prices following the subprime crisis—nearly 100 percent in just a matter of months, and in the face of recessionary shocks—was the result of a speculative response to the financial crisis itself, in an attempt to rebuild asset supply. That is, the global economy was subjected to one shock with multiple implications rather than to two separate shocks (financial and oil).

Eventually, the persistent financial crisis and its many multipliers severely hurt growth prospects, and recognition of this fact triggered an implosion in commodity prices and asset demand more broadly. However, by the same token, when real conditions recover, our model predicts that asset demand is likely to rebound, re-creating the chronic shortage of assets, and the cycle will start again. Regulation, unless distortionary enough to depress growth, is no match for these market forces. The real problem is more macroeconomic in nature and unlikely to go away until the world economy's ability to generate sound stores of value catches up with its potential income growth. In other words, like so much else these days, the outcome depends largely on developments within China and other emerging markets.

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## APPENDIX A

### **Speculation and Policy**

In this appendix we expand on the paper's penultimate section and analyze the effect of introducing futures markets, as well as the effects of policies aimed at curtailing "speculation."

#### *Futures*

Let us start by introducing (fully collateralized) futures contracts on the *Z* good. We make two simple and related points: first, the payoff of the

strategy that consists in buying the  $Z$  good and storing it can be replicated by simple futures positions; second, in our model the introduction of a futures market has no impact on the equilibrium.

By covered interest parity, the forward rate  $f_{t+s}$  is equal to

$$f_{t+s} = p_t \exp \int_t^{t+s} (r_u + d) du .$$

Consider the strategy of buying a forward contract at  $t$  with maturity  $t + s$  and reselling it at date  $t + s' < t + s$ . The payoff at  $t + s'$  is

$$p_{t+s'} - p_t \exp \int_t^{t+s} (r_u + d) du \exp^{-\int_{t+s'}^{t+s} (r_u + d) du} = p_{t+s'} - p_t \exp \int_t^{t+s'} (r_u + d) du ,$$

which, in net present value, is exactly the same as that from buying one unit of the  $Z$  good at  $t$ , storing it until  $t + s'$ , and then selling it on the spot market. To the extent that there is heterogeneity in the cost of storing the  $Z$  good, all the inventories will be held by the agents with the lowest storage costs—typically the producers, who can leave at least some of the  $Z$  good in the ground. Agents with higher storage costs will prefer to buy futures contracts from the producers.

### *Equilibrium and Policy*

However, the introduction of futures contracts has absolutely no effect on the equilibrium of our economy. Futures do not increase asset supply: every long position is offset by a corresponding short position, and there are no agents with biased beliefs deviating from the perfect-foresight price path. As a result, the imposition of a tax on futures trading, or the prohibition of such trading, would have absolutely no moderating effect on commodity prices.

In order for a tax to have any consequence in our model, it must affect the agents with the lowest storage costs, that is, those who actually hold the inventories. Thus, let us consider the effect of taxing producers for holding inventories. Although in practice this is extremely hard to do, since producers are likely to hold most of their inventories under ground, it is a useful positive exercise to gauge the potential impact of this type of policy.

It turns out that taxes on the value of inventory holdings are almost isomorphic with the holding cost parameter  $d$ , except that under the tax interpretation, the proceeds can be rebated as a lump sum to the agents at no resource cost. We take the latter route here and let  $\tau$  denote the tax rate per unit of value of inventories (that is, the tax per unit of inventory is  $\tau p_t$ ).

We maintain the assumption that  $\sigma = 1$  but strengthen the dynamic inefficiency assumption (assumption 1 in the text) to the following:

$$\text{Assumption 3: } g - \tau > \frac{\theta\delta}{1 + \alpha}.$$

Under assumption 3, the bubbleless steady state of the economy is now such that the interest rate is given by

$$r_t = g - \tau,$$

the price grows at rate  $g$ :

$$p_t = \alpha \frac{X_t}{Z},$$

and long-run inventories are constant:

$$I_t = \frac{1 + \alpha}{\alpha} \frac{1}{\theta(g - \tau)} [g - \tau - r^{ref}] Z.$$

The long-run level inventory function  $I(\tau)$  is decreasing with respect to  $\tau$ , whereas the price of oil is unaffected, since the relative consumption of  $X$  and  $Z$  goods is unchanged in the long run. However, in the short run the imposition of a tax  $\tau$  lowers inventories and the price of oil, which is equal to  $p_t = \alpha X_t / (Z - \dot{I}_t)$ .

In summary, a tax on inventories reduces inventories and succeeds in temporarily depressing the price of the  $Z$  good but does not affect it in the long run. Note also that the tax reduces the equilibrium interest rate and aggravates dynamic inefficiency in the bubbleless equilibrium, at a cost to the economy. The intuition is transparent. A dynamically inefficient economy is characterized by a scarcity of assets. A tax on inventories discourages the accumulation of inventories and hence reduces asset supply. The interest rate has to adjust downward to clear the asset market.<sup>63</sup>

## APPENDIX B

### Declining Inventories

In this appendix we expand on a remark in the paper's penultimate section and analyze formally the consequences for inventory accumulation of allowing the short-run and the long-run elasticities of substitution between

63. Note that the bubbly equilibrium of the economy is not affected by  $\tau$ . Moreover, if assumption 3 is violated, then the bubbleless equilibrium becomes identical to that of the benchmark no-inventory economy.

good  $X$  and good  $Z$  to differ. In most analyses of commodity price and inventory dynamics, the forward curve for commodity prices plays a central role. In our model, after the shock, the world is deterministic and risk-neutral. At date  $t$  the forward price  $s$  periods ahead,  $f_{t+s}$ , is simply the future spot price  $p_{t+s}$ . In our case it will prove more convenient to reason in terms of the log-forward curve, which traces  $\log f_{t+s} = \log p_{t+s}$  as a function of maturity  $s$ .

The decision to accumulate inventories is determined by comparing the slope of the log-forward curve  $\frac{\dot{p}_t}{p_t}$  of the price for the  $Z$  good with the

interest rate  $r_t$ . The steeper that slope, the higher the expected increase in price of the  $Z$  good, and the more attractive storage becomes. Similarly, the lower the interest rate, the more attractive storage becomes. The elasticity  $\sigma$  of the demand for the  $Z$  good is a key parameter governing the slope of the log-forward curve. The higher  $\sigma$ , the flatter the log-forward curve.

Key to our analysis is the basic idea that the short-run elasticity of demand for commodities  $\sigma$  is low in the short run but high in the long run. Let us denote the short- and long-run elasticities by  $\sigma^{short}$  and  $\sigma^{long}$ , respectively, with  $\sigma^{short} < 1 < \sigma^{long}$ . The switch from  $\sigma^{short}$  to  $\sigma^{long}$  is typically gradual and potentially governed by a number of time- and state-dependent factors. If  $\sigma^{long}$  for the  $Z$  good is high enough, then inventories will eventually be undone. This is formalized by the following assumption:

$$\text{Assumption 4: } \frac{g}{\sigma^{long}} < \delta\theta.$$

This assumption is more likely to be verified, the higher is  $\sigma^{long}$ . When it is verified, the long-run steady state of the economy features no inventories. In the long-run steady state, the interest rate is  $\delta\theta$ . The price of the  $Z$  good is given by  $(\alpha X_t / Z)^{\frac{1}{\sigma^{long}}} = p_t$  and rises at a rate  $g/\sigma^{long}$ , which is too low to make the accumulation of inventories worthwhile. The share of the  $Z$  good in total consumption converges to zero, and the economy effectively behaves as an economy without commodities.

Turning to transitional dynamics, imagine that the economy enters the region where  $\sigma = \sigma^{long} > 1$  with positive inventories  $I_t > 0$ . The presence of inventories affects both the goods market and the asset market: the total intertemporal supply of the  $Z$  good is higher, which depresses the price  $p_t$  of the  $Z$  good. Asset supply is higher, since inventories act as a store of value, resulting in a higher interest rate  $r_t$ . These two forces trigger a process of inventory reduction, and the economy eventually converges to a steady state with no inventories.

## References

- Beltran, Daniel O., Laurie Pounder, and Charles Thomas. 2008. "Foreign Exposure to Asset-Backed Securities of U.S. Origin." International Finance Discussion Paper 939. Washington: Board of Governors of the Federal Reserve System.
- Bernanke, Ben. 2005. "The Global Saving Glut and the U.S. Current Account Deficit." Sandridge Lecture, Virginia Association of Economics, Richmond, Va. (March).
- Blanchard, Olivier, Francesco Giavazzi, and Filipa Sa. 2005. "International Investors, the U.S. Current Account, and the Dollar." *BPEA*, no. 1, pp. 1–49.
- Brunnermeier, Markus K. 2009. "Deciphering the Liquidity and Credit Crunch 2007–08." *Journal of Economic Perspectives* 23, no 1.
- Caballero, Ricardo J., and Arvind Krishnamurthy. 2006. "Bubbles and Capital Flow Volatility: Causes and Risk Management." *Journal of Monetary Economics* 53, no. 1: 35–53.
- Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas. 2008. "An Equilibrium Model of 'Global Imbalances' and Low Interest Rates." *American Economic Review* 98, no. 1: 358–93.
- Dahl, Carol, and Thomas Sterner. 1991. "Analysing Gasoline Demand Elasticities: A Survey." *Energy Economics* 13, no. 3: 203–10.
- Deutsche Bank. 2007. "Sovereign Wealth Funds—State Investments on the Rise." *Current Issues* (September 10).
- Frankel, Jeffrey A. 2006. "The Effect of Monetary Policy on Real Commodity Prices." Working Paper 12713. Cambridge, Mass.: National Bureau of Economic Research (December).
- Gately, Dermot, and Hillard G. Huntington. 2002. "The Asymmetric Effects of Changes in Price and Income on Energy and Oil Demand." *Energy Journal* 23, no. 1: 19–55.
- Greenlaw, David, Jan Hatzius, Anil K Kashyap, and Hyun Song Shin. 2008. "Leveraged Losses: Lessons from the Mortgage Market Meltdown." U.S. Monetary Policy Forum Report No. 2. Initiative on Global Markets, University of Chicago Graduate School of Business, and Rosenberg Institute for Global Finance, Brandeis International Business School.
- Hamilton, James. 2008. "Understanding Crude Oil Prices." University of California, San Diego (May).
- Hotelling, Harold. 1931. "The Economics of Exhaustible Resources." *Journal of Political Economy* 39, no. 2: 137–75.
- Hughes, Jonathan E., Christopher R. Knittel, and Daniel Sperling. 2008. "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand." *Energy Journal* 29, no. 1: 113–34.
- International Monetary Fund. 2008a. *Global Financial Stability Report: Containing Systemic Risks and Restoring Financial Soundness*. Washington (April).
- . 2008b. *Global Financial Stability Report: Financial Stress and Deleveraging: Macroeconomic Implications and Policy*. Washington (October).

- Jovanovic, Boyan. 2007. "Bubbles in Prices of Exhaustible Resources." Working Paper 13320. Cambridge, Mass.: National Bureau of Economic Research (August).
- Kouri, Pentti. 1983. "Balance of Payment and the Foreign Exchange Market: A Dynamic Partial Equilibrium Model." In *Economic Interdependence and Flexible Exchange Rates*, edited by Jagdeep Bhandari and Bluford Putnam. MIT Press.
- Metzler, Lloyd A. 1968. "The Process of International Adjustment under Conditions of Full Employment. A Keynesian View." In *Readings in International Economics*, edited by Richard Caves and Harry G. Johnson. Homewood, Ill.: Irwin.
- Milesi-Ferretti, Gian Maria. 2008. "Fundamentals at Odds? The Dollar and the U.S. Current Account Deficit." Prepared for the Siena Conference on the Impact of Global Financial Imbalances, Siena, Italy, September.
- Nordhaus, William D. 1980. "Oil and Economic Performance in Industrial Countries." *BPEA*, no. 2: 341–88.
- Roy, Joyashree, Alan H. Sanstad, Jayant A. Sathaye, and Raman Khaddaria. 2006. "Substitution and Price Elasticity Estimates Using Inter-Country Pooled Data in a Translog Cost Model." *Energy Economics* 28, no. 5–6: 706–19.
- Sercu, Piet M., and Rosanne Vanpée. 2007. "Home Bias in International Equity Portfolios: A Review." Katholieke Universiteit Leuven.

## *Comments and Discussion*

### COMMENT BY

**KATHRYN M. DOMINGUEZ** This ambitious paper by Ricardo Caballero, Emmanuel Farhi, and Pierre-Olivier Gourinchas seeks to explain, in one model, all that is wrong in the global economy. The culprit is underdeveloped financial markets in emerging Asia and the oil-producing countries. U.S. fiscal and monetary policies play no role. The three stylized phenomena explained and linked in the model are the large U.S. current account deficits (and the counterbalancing large surpluses in emerging Asia and oil-producing countries), financial bubbles, and volatile commodity prices. The model intriguingly suggests that all three features can persist in equilibrium.

The model begins by dividing the world into two regions, one with developed financial markets, which the authors label  $U$  (for the United States), and one with underdeveloped financial markets, labeled  $M$ . The  $M$  countries extract and consume commodities  $Z$ , while  $U$  only consumes  $Z$ . The model starts with the formation and bursting of a financial bubble in  $U$  (although where the bubble starts turns out to be unimportant). With the bursting of the bubble, global savers flee the bubble assets in search of new stores of value in  $U$ . Note that savers flee to safer assets in  $U$  and not to the  $M$  countries, because financial markets are more developed in  $U$ . These capital flows (from  $M$  to  $U$ ) lead to a decline in real interest rates in  $U$ . Low real interest rates, in turn, lead to speculative commodity hoarding and commodity price jumps, resulting in wealth transfers from  $U$  to  $M$ .  $M$ 's new wealth, however, again finds its way to  $U$ , which has comparative advantage in quality asset creation. These capital inflows further lower real interest rates in  $U$  and allow  $U$  to run ever larger current account deficits.

Changes in interest rates are the driving force in this model. The bursting of the initial financial bubble and the consequent scramble by global

savers to place their wealth in higher-quality assets in  $U$  lead to lower real interest rates. It is these low interest rates that make commodity inventory accumulation profitable, driving up commodity prices and leading in turn to wealth transfers from  $U$  (the consumers of commodities) to  $M$  (the commodity producers). The link between low real interest rates and high commodity prices comes from Harold Hotelling's insight that for resources in fixed supply with zero extraction costs, extraction in equilibrium is characterized by resource prices that increase at the interest rate.<sup>1</sup> If a resource is in fixed supply and its future price is expected to be high, then low interest rates drive up current prices in order to induce owners to sell.

In the authors' model the resource,  $Z$ , is *not* assumed to be in fixed supply, but instead there is a flow extraction constraint that is insufficient to meet demand growth and acts to limit supply. The tricky aspect of this assumption is that expectation formation in this sort of model is less straightforward than in the standard Hotelling fixed-supply setup. The link between the interest rate and the commodity price posited by Hotelling will be broken if expectations of future commodity prices systematically change with the same forces that affect interest rates. The paper suggests that the rise in commodity prices in early 2008 and the more recent precipitous decline in oil prices (and many other commodity prices) fit well with their model, in that when demand for these commodities was high, the flow extraction constraint was binding, and when demand growth declined, so did commodity prices as the flow constraint ceased to bind. What is more difficult to connect in this version of Hotelling's model is the role of interest rates. At the same time that global demand growth declined, countercyclical policies in the United States were targeted at reducing real interest rates, so that interest rates remained low, while commodity prices first spiked and then fell. In the first seven months of 2008, commodities posted their best performance in 35 years, rising by 35 percent; then, in August, they had their worst month in 28 years, falling by 11 percent, followed by an even more precipitous decline of 41 percent in the four months through November. These extreme movements suggest that expectations, rather than interest rates, have played a dominant role.

The version of this paper presented at the September 2008 Brookings Panel conference was written before commodity prices collapsed, so this

1. Harold Hotelling, "The Economics of Exhaustible Resources," *Journal of Political Economy* 39, no. 2 (1931): 137–75.

aspect of the story (which the paper terms the “second phase” of the crisis) is new. Whereas in the earlier version the bursting of the financial bubble did not lead to a fall in global growth, but only a slowdown in  $U$ , in the new version it is this global slowdown that removes the excess demand in asset markets, leading to a decumulation of commodity inventories and a fall in commodity prices. Interestingly, in the earlier version commodity prices were predicted to fall only if the U.S. financial crisis subsided. In this version it is the ongoing crisis and its effects on global economic growth that lead to a collapse in commodity prices and asset prices more generally.

Wealth transfers play another key role in this paper. Savers always prefer to invest in  $U$ , where financial markets are more developed. Consequently, even when the  $M$  countries are doing well (that is, when commodity prices are high), capital flows to  $U$ . The focus in the paper is exclusively on the private sector, so that, strictly speaking, these wealth transfers do not include government flows. Data from the International Monetary Fund’s *Balance of Payments Statistics*, however, suggest that foreign governments and official institutions have dramatically increased their role in U.S. capital inflows in recent years through their foreign reserve accumulations. Interestingly, in a recent paper I report evidence that it is precisely those countries with less developed financial markets that hold high levels of foreign reserves, the bulk of which are invested in U.S. assets.<sup>2</sup> This suggests that including the government sector in the model might well strengthen the results (more on this to come).

Is there evidence that  $U$  has comparative advantage over  $M$  in creating high-quality financial assets, as the authors’ model assumes? One testable hypothesis that follows from this assumption is that countries with higher-quality financial markets pay lower premiums on their assets. Joseph Gruber and Steven Kamin examine this hypothesis and find that real long-term interest rates and expected earnings yields on bonds and equities are no lower in the United States than in other industrial countries.<sup>3</sup> Their paper does not examine asset premiums in  $M$  countries, which are surely

2. Kathryn M. Dominguez, “International Reserves and Underdeveloped Capital Markets,” University of Michigan (September 2008).

3. Joseph Gruber and Steven Kamin, “Do Differences in Financial Development Explain the Global Pattern of Current Account Imbalances?” International Finance Discussion Papers 2008-923 (Washington: Board of Governors of the Federal Reserve System, March 2008).

higher than those in industrial countries, but this evidence does suggest there is little reason for capital to flow to the United States in preference over other industrial countries.

Along with providing an intriguing model that connects the present financial crisis with commodity price movements and global imbalances, this paper also presents some suggestive empirical work, consisting of back-of-the-envelope impact estimates as well as a calibration exercise to work through the implications of the model dynamics. The paper marshals an impressive array of estimates from the literature, starting with the size of the perceived losses generated by the financial crisis, to explore what the model can explain (and what it misses). The results of these exercises suggest that although the model does a fairly good job of explaining the first phase of the crisis (through the summer of 2008), harder work is needed to connect the crisis with the global slowdown, the consequent dramatic reversal in commodity prices, and the implications of both for global imbalances. To be fair, few economists predicted the downward spiral of events of the past year, with or without the aid of a model, and the authors of this paper do not claim to be clairvoyant.

In its conclusion the paper notes that by taking a “contrarian view” and assuming no role for government policy, it is likely to overstate the role of the private sector in the current global crisis. It seems incumbent on the discussant, therefore, to describe some alternative explanations that the model ignores.

One of the stylized facts that the model attempts to explain is the sustained U.S. current account deficit. A country’s current account balance is equivalent to the difference between its domestic saving and its investment. Private saving and public saving in the United States have been unusually low in recent years, relative to other industrial countries and relative to U.S. history. Since 2000 the U.S. personal saving rate has averaged 2 percent of personal disposable income (in the 1980s it was 9 percent, and in the 1990s it was 5 percent; currently it is close to zero), and U.S. net national saving, at negative 2 percent of GDP, is at its lowest rate since the Great Depression. One explanation for the low private saving rate, at least through 2007, was that rapid increases in the stock market and in residential property led to a wealth effect. In the paper this wealth effect is driven by capital inflows from  $M$  countries, due to the scarcity of quality financial assets outside of  $U$ . The model, however, does not include a rationale (or a role) for low *public* saving. Historically, when private saving has been low, public saving has tended to provide an offsetting force.

That this is not true in the current context works in the model's favor, although it begs the question of whether fiscal policy can in the future provide a stabilizing role.

There is no money in the model, and therefore no banks and no role for central bank monetary or exchange rate policy. Although recently banks seem not to be playing their usual role as intermediaries, their absence in a model of financial crises is jarring. Likewise, although the role of expansionary monetary policy during the Greenspan era may be overplayed, it seems likely that the low real interest rates that are at the heart of the paper's commodity price story are driven at least in part by U.S. central bank policy decisions. Further, the desire on the part of many *M* countries to keep their currencies stable against the dollar can provide an additional rationale for why capital has continued to flow from *M* to *U* even as asset prices in *U* have deteriorated.

The paper purposely ignores the role of money and government policy in order to highlight the role of differences in financial market development. The argument is that the lack of financial development in *M* countries, in and of itself, can lead to global financial market dislocation. The key implication is that as long as financial development lags in *M*, the current patterns of global imbalances will persist. One reason to be a bit suspicious of this dire prediction is that this asymmetry in financial market development existed long before global imbalances ballooned after 1998. If one measures financial development according to the relative size of bond and equity markets, the gap between industrial countries and developing countries is apparent starting in the late 1980s, yet the U.S. current account ran small deficits in those years—and even a small surplus in 1991. Of course, if the current financial crisis continues for much longer, financial markets in *U* may well shrink to such an extent that financial markets in *M* will finally catch up.

This paper attempts to provide a “one model fits all” explanation of recent global economic events. This is a tall order. Policymakers are likely to have mixed views on the paper's message. On the one hand, by focusing on financial market development rather than policy mistakes, the paper may seem to give monetary and fiscal authorities an opportunity to dodge responsibility for the current mess. On the other hand, the impotence of policy in the model is unlikely to make it popular in current policy circles. The contribution of the paper, therefore, is less in its lessons for policy and more in the insights it provides regarding the critical role of private sector capital flows in a world of differentially imperfect financial markets.

## COMMENT BY

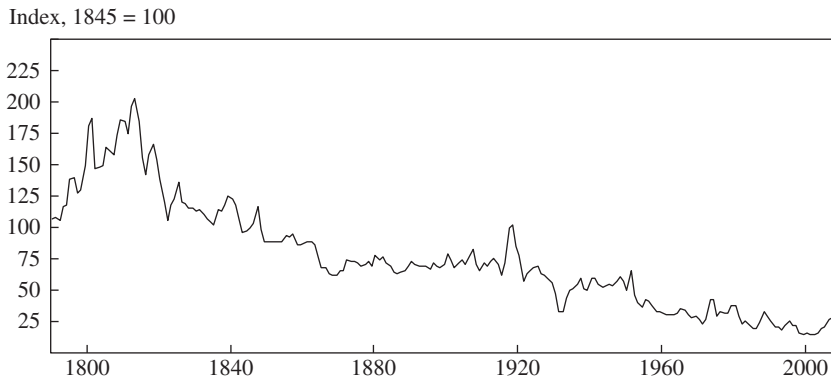
**CARMEN M. REINHART** I appreciate the opportunity to discuss this paper by Ricardo Caballero, Emmanuel Farhi, and Pierre-Olivier Gourinchas. This paper was described to me as a mix of theoretical and empirical work that attempts a hat trick: explaining the joint combination of global imbalances, the deflation of the housing price bubble that created the sub-prime crisis, and volatile oil prices. Given the scope of this undertaking, it is not really surprising that the authors deliver only on the theoretical part—the empirical analysis takes up only about 5 of the paper’s 55 pages. Because this is a paper mainly about theory, I will devote my comments mostly to the framework the authors present, with particular emphasis on the basic assumptions made.

The paper rests on two building blocks familiar from the authors’ earlier work. First, emerging market economies are increasing their demand for sound and liquid financial assets over time. Essentially, the residents of those countries want a safe store for their newfound wealth. This demand is treated by the authors entirely as a private sector phenomenon, but governments play a role because safe, liquid assets are in scarce supply. Indeed, one government alone, that of the United States, creates the Treasury instruments that are especially prized in investors’ portfolios.<sup>1</sup> Second, fluctuations in commodity prices (or oil prices—the authors refer to both interchangeably) are explained to an important extent by speculative hoarding.

The model that the authors build to explain these features can be described succinctly. There are two regions. One, the United States, is endowed with “trees.” The other, the emerging market economies, has a fixed endowment of an unspecified commodity. Only these two goods exist, and people in both regions consume both. Little trees grow at a positive rate. Commodity supplies do not grow at all. The last two assumptions imply a secular increase in the stock of trees relative to that of the commodity, so that the price of the latter rises over time.

The inconvenient fact, however, is that the actual run-up in world commodity prices relative to the prices of other goods is a very recent phenom-

1. An influential paper by Gourinchas and H el ene Rey, “From World Banker to World Venture Capitalist: US External Adjustment and the Exorbitant Privilege,” Working Paper 11563 (Cambridge, Mass.: National Bureau of Economic Research, 2005), examines the consequences of this “exorbitant privilege” (a phrase that, the authors note, originated not with Charles de Gaulle, as is commonly held, but with his then-finance minister Val ery Giscard d’Estaing) whereby the United States alone is able to issue what are viewed as the safest of assets.

**Figure 1.** Real Commodity Prices, 1790–2007

Source: Carmen M. Reinhart and Kenneth Rogoff, *This Time Is Different: Eight Centuries of Financial Folly* (Princeton University Press, forthcoming), drawing on various sources.

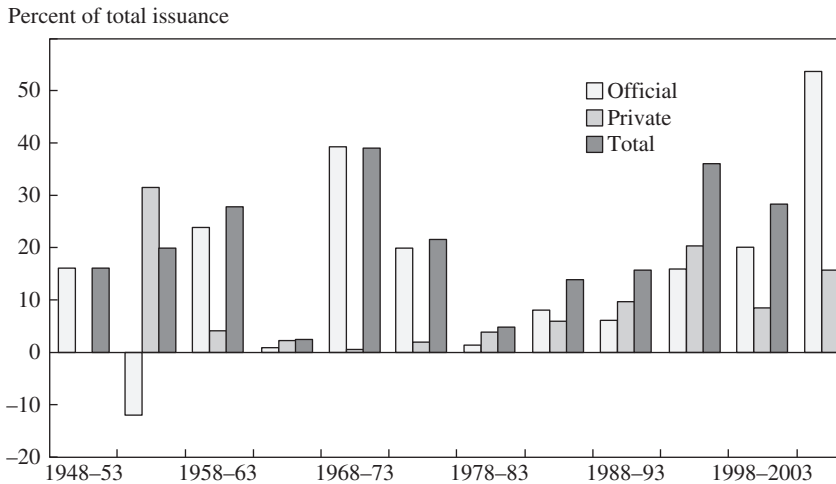
enon (which in recent months has abruptly unraveled). In fact, since about the turn of the eighteenth century, real commodity prices have been on a secular decline, as shown in my figure 1, taken from a recent paper I co-wrote with Kenneth Rogoff.<sup>2</sup> Thus, the model is broadly at odds with the big picture that emerges from this roughly two-and-a-quarter-century history. However, since this implication of the model fits well with the *cyclical* pattern of commodity prices between about 2000 and 2007 (the period the authors are most interested in explaining), I will focus my remarks on some of the core model’s other simplifying assumptions that I find more problematic.

**THE MODEL LACKS A FINANCIAL SECTOR.** The paper purports to examine a financial crash, and the word “financial” is used liberally throughout. Dictionary.com defines “financial” as “1. pertaining to monetary receipts and expenditures; pertaining or relating to money matters; pecuniary: financial operations; 2. of or pertaining to those commonly engaged in dealing with money and credit.” Thus, the authors’ use of the word is difficult to reconcile with the fact that their model is a real model, with neither money, nor credit, nor financial intermediaries, nor exchange rates—in short, without a financial sector.

**THE MODEL LACKS AN OFFICIAL SECTOR.** Further, lacking a financial sector, the model has no scope for the stockpiling of international reserves by the

2. Carmen M. Reinhart and Kenneth Rogoff, *This Time Is Different: Eight Centuries of Financial Folly* (Princeton University Press, forthcoming).

**Figure 2. Foreign Purchases of U.S. Government Securities, 1948–2008<sup>a</sup>**



Source: Carmen M. Reinhart and Vincent Reinhart, “Is the US Too Big to Fail?” (VoxEU, 2008). [www.voxeu.com/index.php?q=node/2568](http://www.voxeu.com/index.php?q=node/2568).

a. As reported in the Federal Reserve’s Flow of Funds Accounts.

central banks of emerging market economies. Yet given that the worst financial crises of the late 1990s originated in emerging markets (followed in the next decade by crises in Argentina and Uruguay), it is worth noting that the key driver of the demand for U.S. Treasury securities *from emerging markets* has been the official sector (central banks trying to build a war chest), not the private sector as stressed in the model. Private demand for U.S. assets in the run-up to the 2007 crisis came primarily from other developed economies. The clear manifestation of the United States’ “exorbitant privilege” can be seen in the fact that foreign official acquisitions of U.S. government securities have accounted for an increasing share of total issuance (figure 2).

This massive accumulation of foreign exchange reserves would seem central to understanding recent developments regarding the global imbalances between the developed economies and emerging markets—notably in Asia, as Vincent Reinhart and I have discussed elsewhere.<sup>3</sup> This role for the official sector is something that the authors may want to incorporate in

3. Carmen M. Reinhart and Vincent Reinhart, “Is the US Too Big to Fail?” (VoxEU, 2008). [www.voxeu.com/index.php?q=node/2568](http://www.voxeu.com/index.php?q=node/2568).

a future variant of their framework, as it provides another important argument for one of their central premises, namely, that “safe assets” are in short supply in emerging markets.

**THE DETERMINANTS OF SAVING ARE OVERSIMPLIFIED.** To explain aggregate saving, the authors have to assume that it results from the birth of new generations and the return on accumulated savings. There is no role for financial liberalization (and the related issue of liquidity constraints) or wealth effects.<sup>4</sup> Specifically, the only way the saving rate can decrease in the model is with an increase in the death rate. How can such a model possibly explain the roughly 7-percentage-point reduction in the U.S. saving rate over the past two decades? In light of the model’s emphasis on cross-border saving differentials and asset demands, revisiting this rather restrictive premise is called for.

**THERE IS NO UNCERTAINTY IN THE MODEL.** Lastly, there is no uncertainty in the authors’ model, and thus no reason for a risk premium to exist, let alone to rise during a crisis, and the value of the nonstorable good as collateral should always be known. Hence the key event analyzed in the model is hard to reconcile with the model. We are told that a subprime shock “can be interpreted as the realization that financial instruments are less sound than they were previously perceived to be.” In the absence of financial instruments and uncertainty, it is hard to imagine how such a shock would take place.

In fact, the subprime crisis as depicted in the model is an exogenous and adverse terms-of-trade shock. The structure of the model precludes overborrowing, leveraging, or excessive risk taking. Similarly ruled out are herding behavior by investors and the nonlinearities that produce self-fulfilling prophecies. Thus, absent in this framework are any of the mechanisms crucial to this or any other financial crisis. As for the key mechanism, the U.S. terms of trade, its decline began in 1999, and so it matches neither the timing nor the magnitude of the current financial crisis.

I find this an important paper that offers two key insights. The first is the importance of understanding the scarcity of safe “saving vehicles” in the emerging (and the not-so-emerging) world, and of the United States as the provider of such assets. (The stampede into U.S. Treasury securities

4. See Klaus Schmidt-Hebbel and Luis Servén, “Saving across the World: Puzzles and Policies,” Discussion Paper 354 (Washington: World Bank, 1997), for cross-country evidence on these issues.

in the fall of 2008 attests to this scarcity.)<sup>5</sup> The second is that this scarcity is related to the commodity price dynamics of recent years. This is not, however, a framework that lends itself to explaining or understanding *financial crashes* in general. In particular, it does not add to our understanding of traditional banking crises or the problems that produced the current subprime crisis.

My preferred diagnosis of the subprime financial crisis in the United States is spelled out simply in the following quotation: “[Overindebtedness] may be started by many causes, of which the most common appears to be *new opportunities to invest at a big prospective profit . . .* such as through new inventions, new industries, development of new resources, opening of new lands or new markets. Easy money is the great cause of over-borrowing.” That the essence of the problem can be captured so simply is encouraging. What is discouraging is that this insight was made by Irving Fisher in 1933.<sup>6</sup> Crises recur, but the best explanations are eternal.

**GENERAL DISCUSSION** Lawrence Summers noted that the idea is already widely accepted that high rates of saving in emerging markets have pushed real interest rates down in the rest of the world, leading to the large U.S. current account deficit and a series of market bubbles. What is of interest in the paper is its development of a coherent, consistent, and well-designed intertemporal general equilibrium model that articulates this idea. Of even greater interest is determining whether this model is the appropriate way to think about the performance of the U.S. and world economies over the past five years. The central argument in the paper is not new; it goes back to Harold Hotelling, was used by Summers himself and Robert Barsky in the 1980s to explain the behavior of gold and other commodities, and was recently used by Jeffrey Frankel in analyzing the commodities boom. The paper would be more convincing, Summers

5. See Reinhart and Reinhart, “Is the US Too Big to Fail?” on this episode: “If this had happened to any other government in the world whose national financial institutions were in as deep disarray as those of the US, investors would have run for the hills—cutting off the offending nation from global capital markets. But for the US, just the opposite has happened. Rather than facing prohibitive costs of raising funds, US Treasury Bills have seen yields *fall* in absolute terms and markedly in relative terms to the yields on private instruments. This has been called a ‘flight to safety.’ But why do global investors rush into a burning building at the first sign of smoke?”

6. Irving Fisher, “The Debt-Deflation Theory of Great Depressions,” *Econometrica* 1, no. 4 (1933): 348 (italics in original).

argued, if it engaged more definitively with the dynamics of commodity markets. He suggested that rather than simply demonstrating the consistency of their explanation with the observed facts, the authors should place more emphasis on proving that the factors they identify are indeed the central ones in accounting for this complex phenomenon.

Bradford DeLong contended that it was reserve accumulation by central banks that had pushed real interest rates down from a dynamically efficient to a dynamically inefficient level. He admired the authors' model for its simplicity but thought it would be of even greater value if it incorporated more factors into a five- or six-dimensional system rather than the present two-dimensional system of equations. He felt that the recent behavior of foreign central banks fit with the authors' model but that the recent actions of the Federal Reserve and the Treasury with respect to the financial crisis did not. A larger, more elaborate model might do a better job.

Robert Hall suggested that the United States was experiencing not a major financial crisis but rather the popping of a huge housing bubble. He, too, praised the authors' model for the simplicity with which it modeled the bubble. He noted that monetary policy cannot deal with asset price bubbles directly but rather must provide a nominal anchor, such as an interest rate. He also wished the model were more comprehensive, in order to better address the level of U.S. saving relative to the world economy, even in situations without asset price bubbles.

Richard Cooper remarked that the authors' model is primarily about private behavior and assumes that the private sector faces a shortage of financial assets. He objected to that idea, noting that there is plenty of money, a financial asset, available, although he conceded that assets offering high yields may be in short supply. He suggested revising the model's assumptions so as to deemphasize the shortage of assets and instead focus on the excess saving that has led to low real interest rates. He suggested further that the model include the rest of the developed world, as well as the demographic factors that have contributed to a decline in investment, focusing primarily on the private sector, which accounts for the large majority of foreign investment in the United States.

Kristin Forbes complimented the authors on the richness of their model but questioned its fidelity to certain accepted stylized facts. In the model, oil supplies are somewhat elastic with respect to interest rates, but in the real world, oil supplies are not responsive to movements in interest rates since exploration and drilling take time and old wells become less productive over time. She proposed an alternative model that could explain the stylized facts in a manner consistent with the short-term inelasticity of oil

supply. Like the authors' model, hers would assume that emerging markets have a limited supply of financial assets and want to invest in the United States, and that foreigners withdraw their money when a financial crisis occurs in the United States. In her model, the dollar would depreciate as a result of the withdrawal, and since oil is priced in dollars, demand for oil in foreign countries would increase, and oil prices would rise substantially. She believed her model would better explain the pattern in oil prices seen in the weeks before the conference, when a decline in oil prices followed an appreciation of the dollar.

Frederic Mishkin recommended that the authors consider the financial crisis in its historical context, particularly with respect to financial innovation. In the long run such innovation produces better and more efficient financial systems, but in the short run it can cause major problems. He believed that the massive interventions of the Federal Reserve and the Treasury had mitigated the current crisis and prevented it from becoming another Great Depression or worse.

Michael Woodford was intrigued by the paper's implication that the subprime crisis had caused the large increase in oil prices. He recommended that the authors stress the impact on oil, rather than on commodities in general, since it is unlikely that the mechanism works identically for all commodities. He wondered about the necessity of using a model based on the notion of a persistent rational bubble. He believed the model includes a structural situation where, in the absence of bubbles or inventories, the equilibrium real interest rate is lower than the growth rate, allowing for the possibility of a rational bubble that could last forever. Yet it is not necessary to invoke rational bubbles in order to explain the current financial crisis; the bubble could be an irrational one yet still have the same effects as the story told in the model.

Hélène Rey commented on the model's interesting implication regarding the adjustment of the U.S. current account deficit: in the model, the bursting of the bubble in the United States moves the current account toward balance, while at the same time rising commodity prices lead to massive wealth transfers to commodity-producing economies, which in turn reinvest part of their gains in the U.S. financial markets, thus slowing the adjustment process. Since the model is essentially a two-country model, she suggested that the authors discuss the more complex real-world situation more thoroughly elsewhere in the paper. In the recent past, the Asian economies were the United States' main creditors, but as the increase in commodity prices has transferred wealth to the commodity producers, the latter have become the major creditors. These economies tend to have

different investment preferences than the Asian countries, which could affect the adjustment process—a consequence not considered in the model’s benchmark case.

William Nordhaus further addressed the oil dimension. He argued that the presence of oil-related assets in a hedge fund’s portfolio is evidence either of incompetence or of a bubble. In the context of the Hotelling model, the idea presented in the paper that price growth equals a risk-adjusted interest rate would not hold for a commodity unless there are zero extraction costs, zero unproduced reserves, and only one grade of the commodity. He also pointed out that hedge funds do not actually hold the underlying asset. Commenting on the increase in oil price volatility over the past forty years, he ascribed that volatility to two factors: the shift from a situation of excess supply to one of scarcity and inelastic supply, and the low short-run price elasticity of demand for crude oil. The only ways to reduce that volatility are to find a more elastic source of production or to return to a situation of excess capacity.

Christopher Carroll, citing a recent article in *The Onion* titled “Recession-Plagued Nation Demands New Bubble to Invest In,” questioned the authors’ choice of a limited time frame. The recent period has been characterized by a series of bubbles: the tech bubble, the linked housing and subprime bubbles, and the oil bubble. He wondered whether the authors thought the economy would ever make the transition from the present state of affairs, where low interest rates translate into bubbles, to one where they translate into higher investment in real productive capital.