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The Impact on the United States of the Rise in Energy Prices: Does the Source of the Energy Market Imbalance Matter?

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This paper uses a variant of the IMF's Global Economy Model (GEM) to illustrate how the macroeconomic impact on the United States of the rise in energy prices since the end of 2003 may vary depending on the source of the energy market imbalance. If oil market supply-side factors are driving prices higher, GDP will be permanently lower than it otherwise would be. However, if higher energy prices reflect primarily increased demand due to rising labor supply or tradable sector productivity growth in emerging Asian economies, for example, then GDP in the United States could actually rise in the long run. This occurs because the United States receives some positive terms-of-trade effects coming through nonenergy tradable goods prices that offset the negative implications for GDP of permanently higher energy prices. [JEL E3, E52]
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The rise in energy prices since end-2003 has had an important impact on the large industrial countries. Inflation, which had long been subdued, even during the high-tech boom years of the late 1990s, has accelerated and GDP growth, although still healthy, has slowed relative to expectation. This

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paper outlines the extensions to the IMF's Global Economy Model (GEM) that enable it to be used to examine the economic impact of rising energy prices. Simulation experiments are presented that estimate the macroeconomic impact in the United States of the run-up in energy prices since end-2003. Further, the model is used to consider whether the source of energy market imbalance has implications for the macroeconomic impact.

The model incorporates energy (oil and natural gas) as a final consumption good as well as a primary input in production. Because energy enters the consumption basket directly, increases in energy prices quickly affect households through their impact on the level of consumer prices and thus households' real wages. With energy entering production, increases in energy costs affect overall aggregate supply capacity as firms reduce output and factor utilization rates given the real increase in their costs structures. Because there is a fully specified market for energy in the model, the analysis can consider how the source of the imbalance between energy supply and demand influences the macroeconomic consequences.

The analysis of the impact of higher energy prices focuses on three issues: the implications for the level of economic activity; the direct impact on headline inflation; and how the source of the energy market imbalance affects the impact. The simulation results suggest that the increase in energy prices since end-2003 increased U.S. headline consumer price index (CPI) inflation by roughly 1 percentage point. Although in the short run the impact on GDP is negative, the long-run implications will depend on the factors underlying higher energy prices. If higher energy prices are being driven by nonenergy sector supply factors in emerging Asia, for example, the simulation results suggest that the long-run impact on U.S. GDP could be positive.

I. Energy in the GEM

GEM is a large multicountry macroeconomic model derived completely from optimizing foundations. The version used here characterizes the behavior of two countries, home (United States) and foreign (the rest of the world). Below, only a brief overview of GEM is presented and the interested reader can look to Hunt (2005) for a detailed description of the incorporation of energy into GEM as well as the calibration of the energy sector. Detailed descriptions of the model's general structure and properties can be found in Laxton and Pesenti (2003); and Hunt and Rebucci (2005).

Households

Households consume energy goods directly along with other tradable and nontradable goods. Households' final consumption bundle is given by

$$A = f(N, Q, M, Q_E, M_E), \tag{1}$$

where A is the bundle of final goods consumed by households, N represents nontradable goods, Q represents domestically produced tradable goods, M

represents imported tradable goods, Q_E represents domestically produced energy goods, and M_E represents imported energy goods. The function, f, is a nested constant elasticity of substitution (CES) aggregator. Because energy enters the final good directly, energy price shocks will have an immediate impact on headline inflation. However, because there is a distribution sector in energy, which uses nontradables to market traded goods and represents things like transportation and refining, the impact of changes in the producer price of energy on the final consumption price is muted.

Firms

Firms produce three types of goods: nontradable goods, nonenergy tradable goods, and a tradable energy good. Firms combine capital, labor, and energy to produce the tradable and nontradable goods. The production process is given by

$$Y = f(K, L, Q_E, M_E), \tag{2}$$

where Y denotes the output of tradable and nontradable goods (N, Q), K is the capital input, L is the labor input, Q_E is the domestically produced energy input, and M_E is the imported energy input. The production technology, f, embodies CES; however, firms face adjustment costs in both capital and energy that reduce the short-run elasticity of substitution below the long-run elasticity.

Energy producing firms combine capital, labor, and land to produce the tradable energy good. The production technology is given by

$$Q_E = f(K, L, Land), \tag{3}$$

where Q_E is domestically produced energy, K represents the capital input, L denotes the labor input, and *Land* is the known available reserve of energy (oil and natural gas). The production technology, f, embodies CES. It is assumed that there is monopolistic competition in energy production enabling firms to charge a markup over the marginal cost of production.

Calibration

Energy is assumed to represent oil and natural gas given the historical correlation in their prices. The shares in GDP of the consumption and production of energy valued at producer prices are calibrated to their levels as of end-2003 (Table 1). In the rest of the world, it is assumed that roughly one-third is consumed directly by households with the remaining two-thirds used by intermediate goods producers.

The calibration of the production of energy assumes that land is the primary input. The parameter that determines the share of land in production is set to 0.96. Parameters determining capital's and labor's shares are set at 0.025 and 0.015, respectively. In the United States, it is assumed that in energy production it is difficult to substitute among inputs, with the elasticity of substitution set at 0.2. In the rest of the world it is assumed that energy

Table 1. U.S. Energy Intensity at End-2003 as a Share of Nominal GDP
(Oil and natural gas valued at producer prices)

	Production	Imports	Total Available	Total Use	Input	Consumption	Net Exports
United States	1.50	1.26	2.76	2.72	1.23	1.49	−1.22

Sources: Organization for Economic Cooperation and Development (OECD); International Energy Agency; and IMF staff estimates.

Note: Data from OECD on indigenous production, imports, and exports. OECD conversion factor of 7.37 used for crude oil. Conversion: tons to barrels to dollar value using $30 per barrel. Natural gas conversion: cubic meters to dollar value using $162 per cubic meter.

production is Cobb Douglas. The production of intermediate goods is also assumed to be Cobb Douglas; however, because it is costly to adjust the amount of energy used in production, the short-run elasticity of substitution can be calibrated to be significantly below unity. The calibration of adjustment costs is set to yield an evolution in energy's share of GDP in United States similar to that witnessed after the oil price shock in 1973. In the absence of costly adjustment of energy in households' final consumption, it is assumed that the elasticity of substitution between energy and tradable intermediate goods is low, 0.175.

The elasticity of substitution between domestic and imported energy in intermediate goods production (100) and in final goods production (10) is chosen to ensure that given the calibration of the production of energy, the rest-of-world and U.S. prices of energy move in parallel. Further, over the business cycle, the relative price of energy is the most variable relative price, consistent with the data.

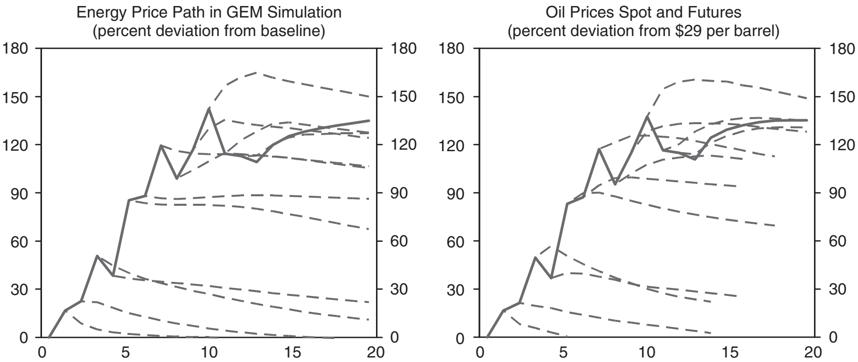
II. Simulation Experiments

The Rise in Oil Prices Since End-2003

Given the fully specified market for energy in GEM, the price of energy is the result of the interaction of supply and demand factors. To implement an increase in the price of energy in this section, factors on the supply side of the energy market are altered, the markup or available reserve of energy (*Land*). This implementation is consistent with the interpretation of the increases in energy prices that occurred in the 1970s.

To examine the macroeconomic implications of rising energy prices, an energy price increase that broadly matches that seen in oil prices over 2004:Q1 to 2007:Q1 is simulated. One important feature of the recent energy price increase has been the gradual evolution of expectations regarding its persistence. To capture the impact of gradually evolving expectations, the simulation in this section is built up, quarter by quarter, with an energy price

Figure 1. Energy Prices—Simulation and Data



Source: Bloomberg and GEM simulations.

Note: Solid line represents actual path and expected path beyond quarter 13. Dashed line represents expected path at each quarter prior to quarter 13.

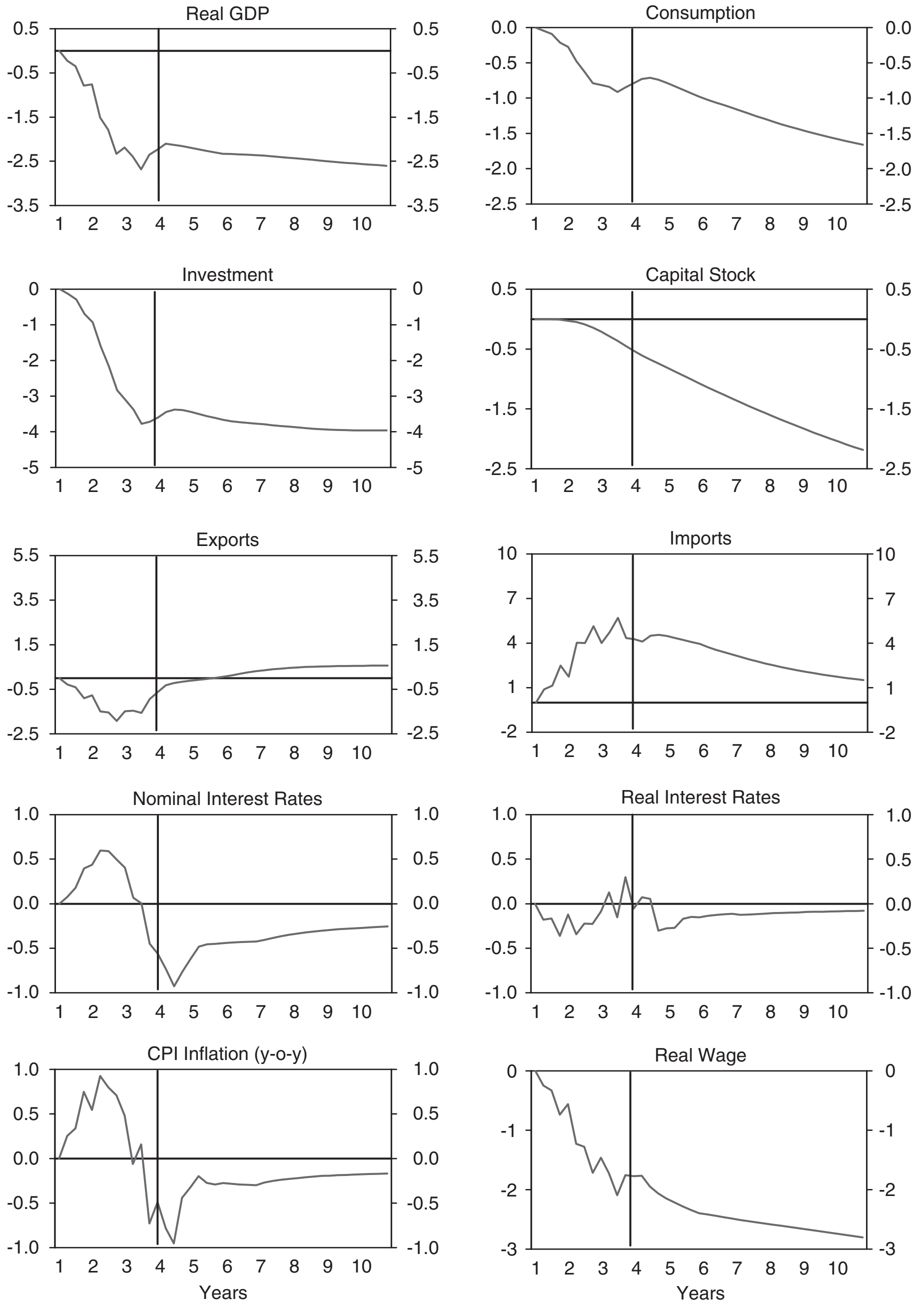
shock that matches that seen in the data both in terms of its magnitude and its expected persistence. The left-hand panel in Figure 1 presents the energy price shock considered, with the dashed lines denoting the expected persistence of the shock in each quarter. The right-hand panel in Figure 1 illustrates the actual increase in oil prices and the futures' market path in each quarter.

The simulations are run assuming that monetary policy follows an inflation-forecast-targeting rule, and the responses of the key macroeconomic variables to the multiperiod energy price increase are presented in Figure 2. The peak effect on year-over-year CPI inflation is roughly 1 percentage point, reflecting the energy intensity of final consumption. The peaks occur in the fifth quarter. Beyond that horizon, the impact on inflation moderates. Assuming oil prices follow the futures market path as of end-March 2007, the impact on year-over-year CPI inflation turns negative before returning toward baseline. Because of the model's structure, the direct impact of energy price changes is reflected immediately in the CPI. In reality, this pass-through is likely slower and, consequently, the precise quarterly dynamics should not be interpreted too literally.[1] The impact of the shock on GDP is negative and grows over time as the supply side of the economy adjusts to the permanently higher input cost.

One of the most striking features of this simulation is the very benign inflation outcome. This primarily reflects the fact that workers accept the decline in their real consumption wage. In GEM, the real wage is

[1]Because of the model's complete choice theoretic framework, there is no scope for making ad hoc changes to the dynamic adjustment properties to more closely match the pass-through properties in the data.

Figure 2. An Energy Price Increase Matching Recent History
(Percent deviation from baseline)



fundamentally pinned down by the interaction of households' preferences and firms' production technology. In the long run, the increase in the real factor cost, energy, leads to a reduction in the capital stock, a decline in the marginal product of labor and, consequently, a reduction in the real producer wage. Although costly adjustment of nominal wages slows the decline in the real wage, the real wage declines quickly. Households accept the decline in the real consumption wage from both the rise in energy prices and the decline in the real producer wage. Consequently, the increase in firm's energy costs is offset by lower real wages and there are no second-round effects flowing through to nonenergy intermediate goods prices and on to CPI inflation. As shown in Hunt, Isard, and Laxton (2002), if workers do not attempt to resist this decline in their real wage, then energy price shocks will not result in persistent inflation even if policymakers accommodate the direct impact of the shock on the price level. GEM simulations that consider alternative responses of both labor suppliers and monetary authorities that can lead to more persistent rises in inflation under these types of energy market supply-side price rises are presented in Hunt (2006).

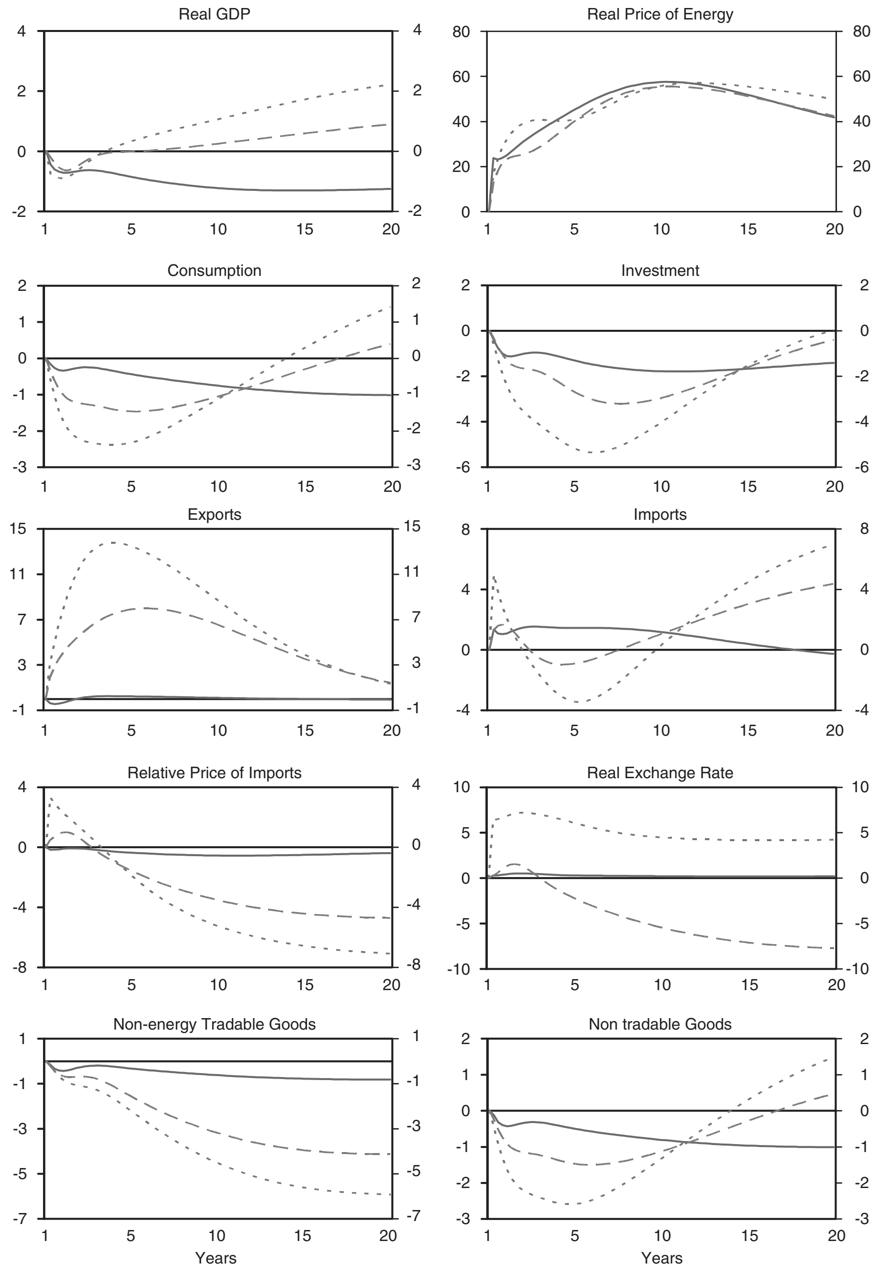
The Implications of the Source of the Energy Market Imbalance

The energy price shock considered to this point is generated by altering factors on the supply side of the oil market (markup and *Land*). This would be an appropriate characterization of the shock if demand was growing as expected, but the supply of energy was not. However, if demand for energy is growing faster than expected because of other factors in the nonenergy supply side of the economy, then the simulations will be ignoring an important dimension. Specifically, it is often claimed that faster than expected growth in emerging Asia is driving energy prices higher. This rapid growth in Asia is thought to be contributing to declining prices for many manufactured goods imported by industrial countries. Ignoring this effect would overstate the negative impact of higher energy prices on industrial country GDP because of the positive terms-of-trade effect of falling nonenergy import prices.

To consider how important this positive terms-of-trade effect might be, we compare three alternative energy price shocks of similar magnitude. The first shock is generated the same way as those previously considered, changing energy sector supply-side factors. The second is generated by increasing labor supply in the rest of the world. The third is generated by temporarily increasing tradable sector productivity growth in the rest of the world. The magnitudes of the shocks are chosen to generate an increase in the price of energy that rises over 10 years by a little over 50 percent with roughly half of that increase being permanent in the long run. The shocks are calibrated to obtain as similar as possible dynamic paths for the price of energy, but they are not identical.

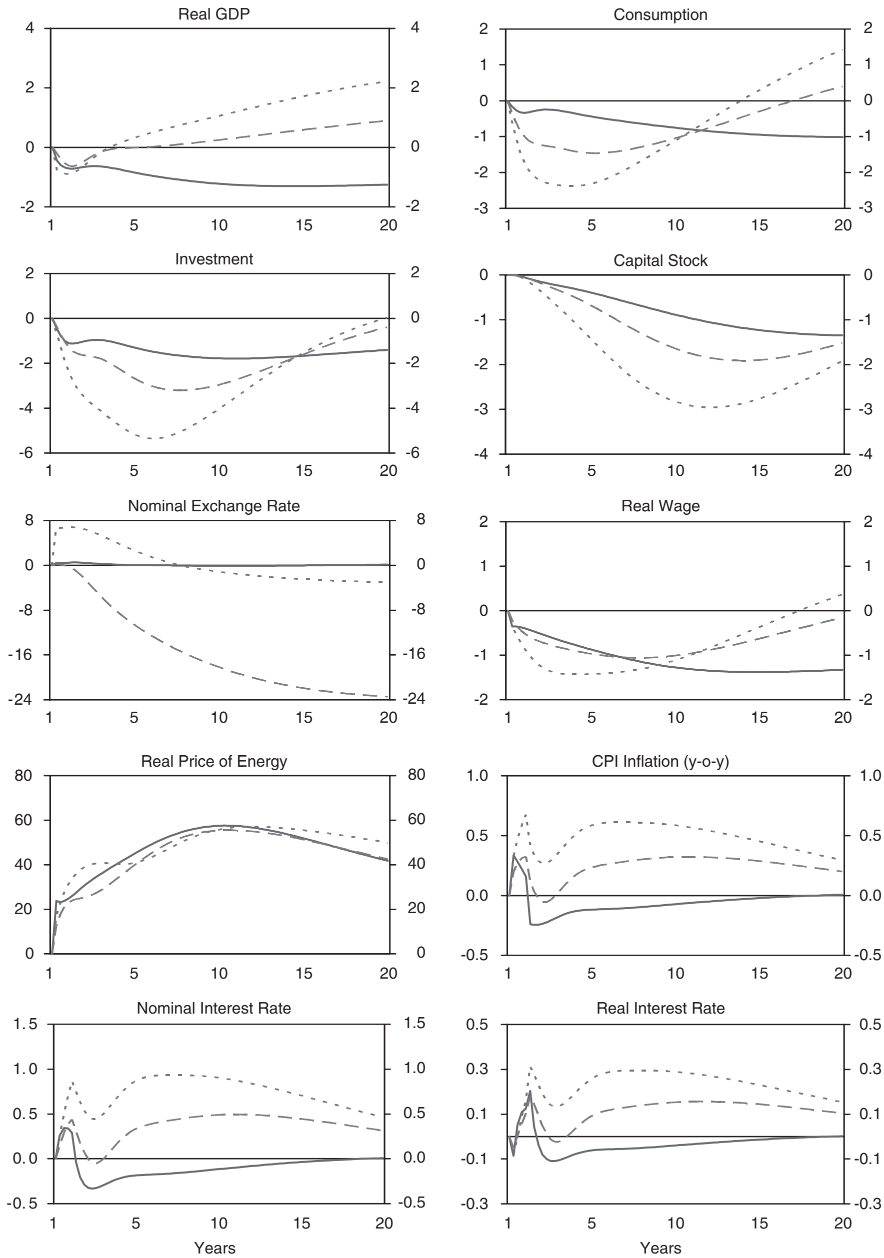
The results for some variables related to the output effect are presented in Figure 3. The solid line traces out the path when energy sector supply-side

Figure 3. Alternative Drivers of Higher Energy Prices
(Percent deviation from baseline)



Note: Solid line denotes energy sector supply; dotted line denotes rest-of-world nonenergy tradable sector productivity; dashed line denotes rest-of-world labor supply.

Figure 4. Alternative Drivers of Higher Energy Prices
(Percent deviation from baseline)



Note: Solid line denotes energy sector supply; dotted line denotes rest-of-world nonenergy tradable sector productivity; dashed line denotes rest-of-world labor supply.

factors alone are generating the higher prices. The dashed line traces out the impact when an increase in labor supply in the rest of the world is the source and the dotted line traces out the paths when the driver is an increase in productivity in the nonenergy tradable sector in the rest of the world. The first point to note is that in the short run, the impact on output is broadly similar. Initially GDP declines (as do investment and consumption) in all cases. However, the decline in GDP is temporary when nonenergy sector supply factors in the rest of the world are driving the shock and GDP rises above baseline after roughly five years. A key factor driving this result is export demand in the rest of the world. Quickly rising incomes fuel demand for U.S. exports. In addition, the falling prices of imports from the rest of the world increase the relative value of U.S. exports. Unlike under the pure energy sector shock, production in the United States switches away from tradables toward nontradables. In the pure energy sector supply shock, nonenergy tradables as a share of GDP in the United States rise because nonenergy tradables must pay for the now more expensive imported energy. Whether the nonenergy sector shock arises from labor supply or tradable productivity growth matters for the long-run value of the dollar. Under the labor supply shock, the U.S. real exchange rate appreciates in the long run. The appreciation helps generate the declining relative price of rest-of-world tradables sufficient to increase demand given greater supply capacity. Under the tradable sector productivity shock, the Balassa-Samuelson effect leads to a depreciation in the U.S. real exchange rate.

The variables graphed in Figure 4 illustrate a very interesting point about U.S. CPI inflation. Under the two nonenergy sector shocks, the rise in CPI inflation exhibits considerable persistence. This reflects the impact of growing demand in the rest of the world and the positive terms-of-trade component on the real wage. Under the energy sector shock, the real wage declines permanently. As noted previously, this reflects the fact that the permanent increase in a factor cost leads to a reduction in the utilization of all inputs, a lower marginal product of labor, and, consequently, a lower equilibrium real wage. Provided labor suppliers accept this reduction quickly, there is no persistence in the inflationary impact of higher energy prices. However, with rising demand for exports and the wealth effect of the terms-of-trade improvement, the long-run capital stock rises (beyond horizon shown in the charts) as does the real wage. The recovery in the real wage coupled with greater demand pressures leads to persistence in the rise in inflation. In fact, interest rates must rise and remain above baseline for an extended period under the nonenergy sector shocks to contain the inflationary consequences.

There are several reasons why these simulation results should be interpreted qualitatively rather than quantitatively. First, the magnitude of the positive long-run impact on U.S. GDP if nonenergy supply factors in emerging Asia are driving higher energy prices will depend on trade linkages. The stronger are the trade linkages between the United States and those emerging Asian countries driving the higher energy prices, the larger will be the positive effects. Second, the short-run inflationary consequences will depend on the behavior of the exchange rate, with China managing its exchange rate, the impact is likely to be different than in these simulations that assume a free floating exchange rate. Third, rising wealth in emerging Asia is probably also having an impact on the energy intensity of demand. This will have an impact identical to the pure energy sector supply shock, that is, driving up energy prices with no positive offsetting affects on industrial country GDP. Fourth, faster than expected growth in emerging Asia is likely only one of the factors driving higher energy prices. The actual results will depend on how important this is relative to energy sector supply factors. Finally, these shocks are done under certainty, although there is still considerable uncertainty about what is in fact driving higher energy prices and how persistent they are likely to be. Expectations will play an important role in shaping the dynamic adjustment paths, and future work should explore the implications of this carefully.

III. Conclusions

The simulations results suggest that the impact of higher energy prices on U.S. GDP will depend on the underlying factors driving energy prices. If increases in nonenergy sector supply factors in emerging Asia are an important component, then there will be some offsetting effects to the negative impact of a permanent increase in a factor cost. Headline inflation spikes up initially and persistent inflation effects can arise. Under the energy sector supply shock, persistent above-target inflation does not emerge. However, when higher energy prices are being driven by nonenergy supply factors in the rest of the world, then persistent inflation effects arise because of additional demand pressures and a long-run increase in real wages.

Although the simulation results from the rise in energy prices seen since end-2003 suggest that, for the United States, the initial negative implications for GDP are significant, there are reasons for optimism. If increases in other supply factors in the nonenergy sector in emerging Asia are driving energy prices higher, then the United States will reap some benefit from falling nonenergy import prices and rising demand for exports. In the long run, GDP could rise depending on the extent of trade linkages with emerging Asia and the extent to which higher energy prices are resulting from faster than expected growth in emerging Asia. Unlike the price rises in the early 1970s, which evidence suggests were driven by energy market supply factors, the current increase appears to be driven by increased demand for energy in emerging Asia (Kilian, 2006) owing to rapid productivity growth (Hunt, 2007). In addition, there has not appeared to be a significant increase in the energy intensity of demand in emerging Asia (Elekdag and others, 2007), raising the probability that positive long-run benefits will materialize. However, one interesting aspect in the simulations is that monetary authorities might have to be even more vigilant about the inflationary consequences if nonenergy market supply factors in the rest of the world are important drivers of higher energy prices.

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