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DYNAMIC EFFECTS OF OIL PRICE SHOCKS AND THEIR IMPACT ON THE CURRENT ACCOUNT

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We study the dynamic effects of an oil price shock on key economic variables and on the current account of a small open economy. We introduce time-nonseparable preferences into a standard model of a small open economy, where imported oil is used both as an intermediate input in production and as a consumption good. Using a plausible calibration of the model, we show that the changes in output and employment are quite small, and that the current account exhibits the J-curve property, both being in line with recent empirical evidence. After an oil price increase, employment falls and the current account first deteriorates. Over time, with gradually falling expenditures, the trade balance improves sufficiently to turn the current account into a surplus. The model thus provides a plausible explanation of recent empirical findings.

Keywords: Oil Price Shocks, Time Nonseparable Preferences, Current Account Dynamics

1. INTRODUCTION

In the recent past, the world saw a dramatic increase in the price of crude oil, which sky-rocketed by 140% between 2003 and 2007 and peaked at approximately 150 U.S.$/barrel in summer 2008. The world economic crisis, caused by the turmoil in world financial markets, led to a substantial decline of the oil price to around 40 U.S.$/barrel in early 2009, but from then onward, the oil price quickly recovered and climbed to up to 80 U.S.$/barrel in fall 2009 and over 100 U.S.$ in spring 2011. Oil prices are substantially higher, as they where a few years ago. With the development of emerging economies such as Brazil, China, India, and Russia and their growing demand for energy, most economists expect permanently higher energy prices in the future. Of course, these prospects of higher oil prices raise a lot of concern in oil-importing countries: How severely will the economy be affected? How does the higher oil bill impinge on the current account and the economy's international investment position? What are the consequences for people's welfare? These concerns cannot be downplayed, as there is convincing

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historical evidence regarding the relationship between oil prices and economic downturns [see, e.g., Hamilton (1983, 2003, 2011) and Dhawan and Jeske (2006)]. Of course, the price of imported raw materials such as oil has been a concern to economists since the 1970s, with the occurrence of supply shocks associated with the "oil crisis" of that period [see Barsky and Kilian (2004) for an overview].

Much of the recent research shows that the oil price shocks that occurred in the recent past years have had relatively small effects on real economic activity compared to the experience in the 1970s and 1980s. For example, the loss in output ranges between 1% and 5%, depending on the country and on the specific nature of the shock. One reason for this is that the energy intensity of production in developed economies has declined about 50% making economies less vulnerable to oil price shocks [see OECD (2004), Parry and Darmstadter (2004), Dhawan and Jeske (2006), Nordhaus (2007), Blanchard and Galí (2010), and Nakov and Pescatori (2010)]. Other explanations include better monetary policy and declining real wage rigidity [see, e.g., Blanchard and Galí (2010) and Nakov and Pescatori (2010)].

A surprisingly small theoretical and empirical literature has studied the impact of oil price shocks on an economy's external accounts (trade balance, current account, and net foreign asset position). Early work of Agmon and Laffer (1978) based on the monetary approach to the balance of payments found that the trade balance and the current account of industrialized countries deteriorated markedly immediately following an oil price increase, but improved after the initial deterioration. Moreover, the trade balance adjustments were almost exclusively in nonoil trade. However, the source of the reversal of trade balance and current account deficits was far from clear. Recently, Rebucci and Spatafora (2006) found that oil price shocks have a marked but relatively short-lived impact on current accounts and a noticeable effect on the net foreign asset position of countries. Kilian et al. (2009) estimated that the net foreign asset position of advanced oil-importing countries (with the exception of the United States) tends to decline after an oil market–specific demand increase, although the decline is not always statistically significant.

The focus of this paper is to identify how and through which channels oil price shocks affect not only output and employment, but also trade and the balance of payments. The model we shall employ is a variant of the class of representative-agent small open economy models with Hayashi (1982)-type investment, discussed in detail in Turnovsky (2002). We augment that model in several important and new directions:

First, we include an imported good, oil,[1] which is used (i) as a consumption good (e.g., fuel) and (ii) as an intermediate input in production of traded output.

Second, instead of restricting the production side of the economy to a Cobb–Douglas production structure, we use the more general constant elasticity of substitution (CES) production function approach. The reasons for doing this are twofold: (i) there is a lot of empirical evidence that the elasticity of substitution between productive inputs is less than unity [see, e.g., Papageorgiou (2008)], in particular if energy (e.g., oil) is included in the production function; see, for

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example, Kemfert (1998) and van der Werf (2008). (ii) A Cobb–Douglas production function would not be appropriate for the analysis of macroeconomic effects of an oil price shock, as it allows oil to be asymptotically replaced by the capital stock; see Edenhofer et al. (2005).

Third and most important, we include a reference consumption stock into the representative agent's utility function, which reflects time-nonseparable (habit-forming) preferences. The addition of habits is a significant augmentation of the standard model and leads to much more plausible results than from the standard model. A lot of empirical evidence has confirmed the importance of time-nonseparable preferences; see, e.g., Fuhrer (2000), Gruber (2004), Sommer (2007), and Carroll et al. (2011). As we shall show, the standard small open economy model without habit formation [i.e., with time-separable preferences (TSP)] predicts an increase in employment and an improving current account after an unfavorable oil price shock, which is clearly at odds with empirical evidence, whereas the introduction of consumption habits allows the model to match the empirical responses of employment and the current account to oil price shocks. We will restrict our attention to the "outward-looking" agent (i.e., to external habit formation), whose reference stock is based on the average level of consumption in the economy.

As the model is intractable to be fully studied analytically, we will apply numerical simulations to trace the time paths of key economic variables, using a plausible calibration. In the spirit of a large empirical and theoretical literature, we shall focus on a secular and permanent exogenous increase in the oil price. Of course, the exact nature of the recent oil price hike is unknown or at least highly uncertain, but both market expectations and an assessment of medium-term oil market fundamentals suggest that a considerable proportion of the shock will be permanent in nature.

There are several key results of our analysis that we want to stress at the outset. The most important finding is that the introduction of time-nonseparable preferences gives rise to plausible current account dynamics after an unfavorable oil price shock. The current account dynamics we derive is almost entirely driven by the goods (nonoil) trade balance. Its response reflects agents' reluctance to change their consumption expenditures. After an oil price increase, the current account shows the J-curve property by first deteriorating for a while and then improving. In line with recent empirical evidence, the reactions of other key economic variables such as output and employment are moderate. For example, using a plausible calibration of the model economy, on impact output and consumption drop by roughly 1%. In particular, employment falls on impact. In the long run, the responses of output and consumption are magnified (roughly -1.5% and -1.7%, respectively), as during transition the capital stock declines. Steady state employment is lower, too, albeit the steady state reduction is smaller than the impact response. The short-run and long-run welfare losses (measured in equivalent variations of consumption expenditures) are 3.2% and 2.3%, respectively. The model thus is able to explain both empirical current account dynamics and the small effects of current oil price shocks on economic activity.

By focusing on the long-run secular impact of oil price shocks, our analysis contrasts in several key respects with a growing literature analyzing the effects of oil shocks employing dynamic stochastic general equilibrium (DSGE) models, e.g., Kim and Loungani (1992), Backus and Crucini (2000), Balke et al. (2008), and Bodenstein et al. (2011). All this literature focuses entirely on large industrial countries and does not consider small open economies that are bystanders in the process of oil price determination between OPEC and large oil-importing countries. Nor does this literature address the longer-run consequences of oil price shocks with which this paper is concerned.

The paper is organized as follows. Section 2 sets out the basic structure of the model. In Section 3 we derive the macroeconomic equilibrium dynamics. Section 4 conducts a numerical analysis. In Section 5 some sensitivity analysis is performed. Section 6 summarizes the main findings.

2. ANALYTICAL FRAMEWORK

We build upon the one-sector open-economy model described in Turnovsky (2002), which we modify and extend in several ways. We abstract from growth and include a foreign import good, oil. The economy produces a traded good, Y, that can be consumed, invested, or exported. The imported input, oil, the relative price of which in terms of traded output is p, is used as an intermediate input in production, Z, and as a consumption good, M. The economy is small in the sense that the relative price of oil is determined in the world market. We shall assume that p (and the terms of trade, $1/p$) remains constant over time and analyze the dynamic effects of a one-time unanticipated permanent increase in p. Furthermore, we assume that the economy is populated with a large number N of identical agents.[2] Hence, we can concentrate on a representative agent.

The representative agent produces traded output, Y, using labor, $1-l$, imported oil, Z, and capital, K, according to the CES production function

$$Y = A\left[\alpha_1(1-l)^{-\rho} + \alpha_2 Z^{-\rho} + \alpha_3 K^{-\rho}\right]^{-1/\rho}, \tag{1a}$$

where A is a scale parameter and $\alpha_1 + \alpha_2 + \alpha_3 = 1$, $-1 \le \rho < \infty$. The constant elasticity of substitution is $\sigma \equiv 1/(1+\rho)$. The representative agent derives utility from leisure, l, and from consumption both of the domestically produced good, C, and of imported oil, M. Moreover, at any point in time, he derives utility from comparison of the current consumption bundle to a reference consumption bundle, denoted by H. As in Carroll et al. (1997, 2000), the representative household's objective is to maximize the intertemporal isoelastic utility function

$$\int_0^\infty \frac{1}{\epsilon}[(C^\nu M^{1-\nu})l^\theta H^{-\gamma}]^\epsilon e^{-\beta t}dt, \; -\infty < \epsilon < 1, 0 \le \gamma < 1, \theta \ge 0, 0 \le \nu \le 1, \tag{1b}$$

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where $(C^{\nu} M^{1-\nu})$ is a linearly homogeneous subutility function, which aggregates the domestic good and oil, the share of which is $1-\nu$, into a consumption bundle. The elasticity of leisure (labor) is denoted by θ. Following Ryder and Heal (1973), the imposed restriction on γ guarantees nonsatiation in utility. The long-run intertemporal elasticity of substitution (IES) with respect to the aggregator function (i.e., the consumption bundle $C^{\nu} M^{1-\nu}$) is equal to $1/[1-(1-\gamma)\epsilon]$. In the conventional case of TSP ($\gamma = 0$), the IES is $1/(1-\epsilon)$. Empirical evidence overwhelmingly suggests that the IES is smaller than unity; hence we restrict our attention to $\epsilon < 0$. In this case, the long-run IES under time-nonseparable preferences exceeds the conventional IES.

The representative agent is outward-looking (external habit formation), as the reference stock H depends on the economywide average consumption of all agents, $\bar{C} = (1/N)\sum_{i=1}^{N} C$, and $\bar{M} = (1/N)\sum_{i=1}^{N} M$; see Carroll et al. (1997, 2000).[3] Because agents are atomistic, they ignore the effect of their individual consumption decisions on the time path of the reference stock, taking it as exogenous. Hence, the reference stock H is an externality. It evolves according to

$$\dot{H} = \zeta(\bar{C}^{\nu}\bar{M}^{1-\nu} - H). \tag{1c}$$

The speed of adjustment, ζ, parameterizes the relative importance of recent consumption levels in determining the reference stock. The higher ζ, the more weight is given to recent consumption, the faster the reference stock adjusts, and the lower is the level of persistence in habits.[4]

The representative agent accumulates physical capital, K. Investment, I, is associated with convex adjustment costs, resulting in a total–investment cost function

$$\Phi(I, K) = I + \Psi(I, K) = I + h\frac{I^2}{2K} = I\left(1 + \frac{h}{2}\frac{I}{K}\right), \tag{1d}$$

where adjustment costs $\Psi(I, K)$ are convex in I and proportional to the rate of investment per unit of installed capital, I/K. Letting δ denote the rate of depreciation of the capital stock, the rate of capital accumulation is given by

$$\dot{K} = I - \delta K. \tag{1e}$$

In addition, domestic agents have access to a perfect world capital market, allowing them to accumulate world bonds, denominated in terms of the traded good and paying a fixed given world interest rate, r. The representative agent's flow budget constraint, expressed in terms of the traded good, is

$$\dot{B} = rB + Y - C - pM - pZ - \Phi(I, K), \tag{1f}$$

where $B > 0$ denotes his (net) holdings of foreign traded bonds.[5] According to (1f), to the extent that the agent's income from production, Y, plus net interest, rB, exceeds his expenditures on consumption, $C + pM$, on the imported input, pZ,

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and on investment, $\Phi(I, K)$, he accumulates bonds. For simplicity, we abstract from taxes and from a government.

The agent maximizes intertemporal utility (1b) by choosing the rates of consumption C, M, investment I, the share of time devoted to leisure l, oil input Z, and the rates of bonds and capital accumulation, subject to (1e) and (1f),[6] and the given initial stocks of capital and traded bonds, $K(0) = K_0$ and $B(0) = B_0$, respectively, leading to the following optimality conditions:

$$\nu C^{\epsilon\nu-1} M^{\epsilon(1-\nu)} H^{-\epsilon\gamma} l^{\epsilon\theta} = \lambda, \tag{2a}$$

$$(1-\nu) C^{\epsilon\nu} M^{\epsilon(1-\nu)-1} H^{-\epsilon\gamma} l^{\epsilon\theta} = p\lambda, \tag{2b}$$

$$\theta C^{\epsilon\nu} M^{\epsilon(1-\nu)} H^{-\epsilon\gamma} l^{\epsilon\theta-1} = \lambda \frac{\partial Y}{\partial l}, \tag{2c}$$

$$\frac{\partial Y}{\partial Z} = p, \tag{2d}$$

$$1 + h\frac{I}{K} = q, \tag{2e}$$

$$\frac{\dot{\lambda}}{\lambda} = \beta - r \quad \Longleftrightarrow \quad \lambda = \bar{\lambda}, \tag{2f}$$

$$\frac{\frac{\partial Y}{\partial K}}{q} + \frac{\dot{q}}{q} + \frac{(q-1)^2}{2hq} - \delta = r, \tag{2g}$$

$$\lim_{t\to\infty} \lambda B e^{-\beta t} = \lim_{t\to\infty} q\lambda K e^{-\beta t} = 0, \tag{2h}$$

where λ is the shadow value of wealth in the form of internationally traded bonds, and q is the value of capital in terms of the (unitary) price of foreign bonds, and can be interpreted as Tobin's q. Equation (2d) equates the marginal product of oil in production to the oil price. Equation (2f) implies that for a finite interior steady state value for the marginal utility of wealth, we require $\beta = r$, from which it follows that $\lambda = \bar{\lambda}$ is constant; see Turnovsky (2002). The interpretation of the other optimality conditions is standard and can be found elsewhere; see, e.g., Turnovsky (2000, Ch. 11).

By combining equations (2a) and (2b) and defining the agent's consumption expenditure as $E \equiv C + pM$, the two consumption rates can be expressed as functions of expenditure:

$$C = \nu E, \tag{3a}$$

$$M = \frac{1-\nu}{p} E. \tag{3b}$$

Dividing (2c) by (2a) and using (3a) shows that the expenditure–output ratio depends both on the leisure–labor ratio and on the output–labor ratio; i.e.,

$$\frac{E}{Y} = \frac{\alpha_1}{\theta A^\rho} \left(\frac{l}{1-l}\right) \left(\frac{Y}{1-l}\right)^\rho. \tag{3c}$$

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The conditional factor demand for oil, given production, can be derived from (2d) and reads

$$Z = \left(\frac{pA^{\rho}}{\alpha_2}\right)^{-\frac{1}{1+\rho}} Y. \tag{3d}$$

It follows that the higher the relative price of oil, the lower its usage in the production of a given quantity of output.

3. MACROECONOMIC EQUILIBRIUM

In macroeconomic equilibrium, all static and dynamic optimality conditions (2) must hold continuously for all agents. In the steady state equilibrium of this economy, all aggregate quantities as well as the market price of capital, q, and the labor allocation, l, remain constant. It is convenient to express the dynamics in per capita (or average) magnitudes. Note that because all agents are identical, average and per capita values coincide; e. g., $\bar{C} = C$ and $\bar{M} = M$. The equation of motion for the capital stock follows from (1e), using (2e), as

$$\frac{\dot{K}}{K} = \frac{q-1}{h} - \delta. \tag{4}$$

The equation of motion (2g) for q can be written as

$$\frac{A\alpha_3\left[1-\alpha_2\left(\frac{p}{\alpha_2 A}\right)^{\frac{\rho}{1+\rho}}\right]^{(1+\rho)/\rho}\left[\alpha_1(1-l)^{-\rho}K^{\rho}+\alpha_3\right]^{-(1+\rho)/\rho}}{q} + \frac{\dot{q}}{q} + \frac{(q-1)^2}{2hq} - \delta = r. \tag{5}$$

The dynamic equation for leisure can be obtained as

$$\dot{l} = A_1(l,K)\epsilon\gamma\frac{\dot{H}}{H} - A_1(l,K)A_2(l,K)\frac{\dot{K}}{K}, \tag{6}$$

where $A_1(l, K)$, $A_2(l, K)$ are defined as

$$A_1(l,K) \equiv \frac{l}{\epsilon(1+\theta) - 1 + \frac{(\epsilon-1)(1+\rho)\alpha_3 K^{-\rho}}{[\alpha_1(1-l)^{-\rho}+\alpha_3 K^{-\rho}]}\left(\frac{l}{1-l}\right)},$$

$$A_2(l,K) \equiv \frac{(\epsilon-1)(1+\rho)\alpha_3 K^{-\rho}}{[\alpha_1(1-l)^{-\rho}+\alpha_3 K^{-\rho}]}.$$

Equation (6) reveals that l is a function of H and K. The differential equation for the reference stock can be derived to be

$$\dot{H} = \zeta \left[\left(\frac{1-\nu}{p\nu}\right)^{1-\nu} \frac{\nu\alpha_1 A}{\theta} \left(\frac{l}{1-l}\right)\left(\frac{1}{1-l}\right)^{\rho} \times \frac{\left[\alpha_1(1-l)^{-\rho} + \alpha_3 K^{-\rho}\right]^{-(1+\rho)/\rho}}{\left[1-\alpha_2\left(\frac{p}{\alpha_2 A}\right)^{\frac{\rho}{1+\rho}}\right]^{-(1+\rho)/\rho}} - H \right]. \tag{7}$$

Equations (4)–(7) describe the economy's internal dynamics in terms of K, H, l, and q.[7] Finally, the external dynamics of net foreign assets, B, are governed by equation (1f), which can be expressed in terms of B, K, l, and q as

$$\dot{B} = rB + \left(1 - p\left(\frac{pA^{\rho}}{\alpha_2}\right)^{-\frac{1}{1+\rho}}\right) \frac{A\left[\alpha_1(1-l)^{-\rho} + \alpha_3 K^{-\rho}\right]^{-1/\rho}}{\left[1-\alpha_2\left(\frac{p}{\alpha_2 A}\right)^{\frac{\rho}{1+\rho}}\right]^{-1/\rho}} - \frac{\alpha_1}{\theta A^{\rho}}\left(\frac{l}{1-l}\right)\left(\frac{1}{1-l}\right)^{\rho}\left(\frac{A\left[\alpha_1(1-l)^{-\rho} + \alpha_3 K^{-\rho}\right]^{-1/\rho}}{\left[1-\alpha_2\left(\frac{p}{\alpha_2 A}\right)^{\frac{\rho}{1+\rho}}\right]^{-1/\rho}}\right)^{1+\rho} - \frac{q^2-1}{2h}K. \tag{8}$$

For the linearized dynamic system for $\dot{K}$, $\dot{H}$, and $\dot{q}$ to be saddlepoint stable, there must be one unstable root to match the "jump variable" q and two stable roots, related to the two "sluggish variables" K and H.[8] It is straightforward to show that the eigenvalues satisfy $\mu_1 < \mu_2 < 0 < \mu_3$, provided $\epsilon < 0$, what empirical evidence overwhelmingly suggests. Finally, to satisfy the transversality condition (2h), the economy's intertemporal budget constraint has to be met, implying in turn that the stock of net foreign assets converges to its steady state.

4. NUMERICAL ANALYSIS OF AN OIL PRICE SHOCK

4.1. Benchmark Calibration

Because the model is too complex to be solved analytically, we resort to numerical simulations. We calibrate the model to reproduce some key features of a set of oil-importing OECD countries being hit by an oil price shock, such as the Euro area countries, Australia, Denmark, Japan, Sweden, and Switzerland.[9] Table 1

TABLE 1. Benchmark parameters

Production parameters	$A = 1$, $\rho = 1/3$, $\alpha_1 = 0.596$, $\alpha_2 = 0.004$, $\alpha_3 = 0.4$, $\delta = 0.05$, $h = 15$
Preference parameters	$\beta = 0.04$, $\epsilon = -1.5$, $\theta = 1.75$, $\nu = 0.992$, $\gamma = 0.6$, $\zeta = 0.2$
Exogenous parameters	$r = 0.04$, $p_0 = 1$
Initial stock of bonds	$B(0) = 0.125$

summarizes the parameters upon which our simulations are based. Empirical evidence on the elasticity of substitution in production (σ) in the presence of energy inputs is not unique. Whereas Edenhofer et al. (2005) work with $\sigma = 0.4$, van der Werf (2008) estimates σ for different countries in the range between 0.2 and 0.6, and Kemfert (1998) reports elasticities in the range between zero and one for Germany. In general, there is evidence that σ is well below unity; see, e. g., Papageorgiou (2008), who found that $\sigma \approx 0.7$. Therefore, we chose an intermediate value and set $\rho = 1/3$, which gives $\sigma = 0.75$. The parameter on capital in the production function $\alpha_3 = 0.4$ is noncontroversial, whereas the weight of oil α_2 is a crucial parameter for the magnitude of adverse supply-side effects of an oil price hike. $\alpha_2 = 0.004$ is chosen in such a way that, together with the oil share in the consumption bundle, $1 - \nu = 0.008$, the ratio of oil imports to output equals 0.0227, and the ratio of oil consumption to oil input equals 0.429.[10] The world interest rate, r, and the rate of time preference, β, are set equal to 0.04, a value that is noncontroversial. The rate of depreciation equals 0.05 and is noncontroversial as well. The initial stock of bonds is chosen to yield a net foreign asset–GDP ratio of approximately 0.25.[11]

The elasticity of leisure, θ, is the key determinant of the equilibrium labor-leisure allocation and has been set to ensure that this is empirically plausible. A value of 1.75 accords with the standard value in the business cycle literature and yields an equilibrium fraction of time devoted to leisure of around 0.7, consistent with the empirical evidence. The choice of adjustment costs is less obvious and $h = 15$ lies in the consensus range of 10 to 16.[12] The initial relative price of oil is normalized to unity.

The critical parameters pertain to the relative importance of the reference stock, γ, and the speed at which it is adjusted, ζ. Carroll et al. (2000) set the adjustment speed of habits equal to 0.2, an assumption we shall adopt. This corresponds to a half-time of the reference stock's adjustment of 3.47 years or, equivalently, to a weight of the consumption bundle over the last 10 years of 0.865. Many studies estimate γ to be in the range of 0.6 to 0.8 [see, e.g., Gruber (2004), Sommer (2007), or Carroll et al. (2011)]. We choose $\gamma = 0.6$ as the benchmark, and we shall conduct some sensitivity analysis with respect to γ.[13]

Using the AMECO database of the European Commission, containing data for OECD countries, for the year 2006 the consumption expenditure-to-GDP ratio can be calculated to be between 0.7 and 0.9, with the lowest value for Switzerland

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Table 2. Base equilibrium

Y	K	l	Z	q	E	C	M	Stable eigenvalues
0.4614	1.0208	0.6854	0.0073	1.75	0.3889	0.3858	0.0031	–0.1507 –0.0638
qK/Y	E/Y	B/Y	Oil share in Y	M/Z	GTB	OTB	TB	
3.87	0.84	0.27	0.0226	0.4239	0.00545	0.01045	–0.005	

Note: GTB, OTB, and TB denote the goods trade balance, (exclusive of oil), the oil trade balance, and the overall trade balance, respectively.

and the highest for Greece, and the share of investment in GDP to be roughly 0.2, whereas the capital–output ratio ranges between 1.9 and 3.4.

Calibrating the model with the parameters summarized in Table 1 gives the initial base equilibrium shown in Table 2. The critical equilibrium ratios are all in their respective ranges. The steady state consumption expenditure–output ratio is 0.84, the investment–output ratio is 0.15 (note that in the steady state, net investment is zero), the capital–output ratio is 2.2, and the capital value–output ratio is 3.87. About 69% (31%) of time is allocated to leisure (labor). Note that the baseline equilibrium is independent of the particular values of the preference parameters γ and ζ.

4.2. Time-Separable Preferences

Before we discuss the adjustments in the model with time-nonseparable preferences, it is useful to simulate the model for the case of TSP. This is achieved by setting $\gamma = 0$. The base equilibrium remains the same, only the two stable eigenvalues change, the dynamics of the reference stock decouples from the dynamics of the capital stock and its market price, and the evolution of the reference stock becomes irrelevant. The reference stock adjusts with a speed of 20%, whereas the capital stock, q, and the stock of traded bonds monotonically converge to the steady state with an adjustment speed of 5.9%.

Assume now that the oil price p rises unexpectedly and permanently about 100% from 1 to 2. The short-run (impact) and long-run (steady-state) changes of key economic variables are reported in the first column of Table 3.

On impact, the increase in the oil price induces producers to cut back their oil usage by around 41%. This in turn lowers the marginal product of labor and hence, given the real wage, labor demand. The shock's negative wealth effect induces consumers to reduce expenditures by about 1.37%. Consumption of the domestically produced good, C, falls by 1.37%, too, and consumption of imported oil, M, drops by 50.7%.[14] The consumption expenditure drop is larger than the reduction in income (that is, the expenditure–output ratio falls); thus net savings,

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TABLE 3. Increase of p from 1 to 2: sensitivity analysis

	Oil share = 0.0226, $\alpha_2 = 0.004$, $\nu = 0.992$				Oil share = 0.03505, $\alpha_2 = 0.007$, $\nu = 0.987$	Oil share = 0.05047, $\alpha_2 = 0.011$, $\nu = 0.98$
	$\gamma = 0$	$\gamma = 0.6$	$\gamma = 0.7$	$\gamma = 0.8$	$\gamma = 0.6$	$\gamma = 0.6$
$\Delta Y(0)\%$	–0.796	**–1.105**	–1.156	–1.207	–1.695	–2.406
$\Delta\tilde{Y}\%$	–1.656	**–1.452**	–1.408	–1.360	–2.236	–3.176
$\Delta\tilde{K}\%$	–1.656	**–1.452**	–1.408	–1.360	–2.236	– 3.176
$\Delta(1-l(0))\%$	0.175	**–0.279**	– 0.353	– 0.428	–0.435	– 0.633
$\Delta(1-\tilde{l})\%$	–0.333	**–0.126**	–0.081	– 0.033	–0.198	–0.287
$\Delta Z(0)\%$	–41.013	**–41.197**	–41.227	–41.257	–41.548	–41.971
$\Delta\tilde{Z}\%$	–41.524	**–41.403**	–41.377	–41.349	–41.868	–42.428
$\Delta E(0)\%$	–1.368	**–0.977**	– 0.912	–0.847	–1.489	–2.091
$\Delta\tilde{E}\%$	–1.616	**–1.709**	– 1.729	– 1.751	–2.622	–3.718
$\Delta C(0)\%$	–1.368	**–0.977**	–0.912	–0.847	–1.489	–2.091
$\Delta\tilde{C}\%$	–1.616	**–1.709**	–1.729	–1.751	–2.622	–3.718
$\Delta M(0)\%$	–50,68	**–50.49**	–50.46	–50.42	–50.74	–51.05
$\Delta\tilde{M}\%$	–50.81	**–50.85**	–50.86	–50.88	–51.31	–51.86
Δ GTB(0) %	61.545	**10.952**	2.694	–5.503	7.129	4.827
$\Delta\widetilde{\text{GTB}}\%$	–4.497	**16.787**	21.348	26.294	11.139	8.046
Δ OTB(0) %	12.216	**12.075**	12.051	12.028	11.210	10.124
$\Delta\widetilde{\text{OTB}}\%$	11.424	**11.567**	11.597	11.630	10.417	8.976
ΔTB(0)%	–41.548	**13.298**	22.250	31.135	20.021	28.298
$\Delta\widetilde{\text{TB}}\%$	28.776	**5.877**	0.970	–4.351	8.859	12.166
$\Delta\tilde{B}\%$	28.776	**5.877**	0.970	–4.351	8.859	12.166
$\Delta W(0)\%$	–2.051	**–3.227**	–3.879	–5.170	–5.003	–7.212
$\Delta\tilde{W}\%$	–1.959	**–2.346**	–2.567	–3.009	–3.642	–5.261
Long-run oil share	0.025660	**0.025640**	0.025636	0.025631	0.039589	0.056807
Half-time K	11.69	**9.71**	9.23	8.71	9.74	9.77
Time zero CA	—	**4.88**	9.33	15.93	4.96	5.13
Stable eigenvalues	–0.2	**–0.1507**	–0.1419	–0.1329	–0.1506	–0.1505
	–0.0593	**–0.0638**	–0.0651	–0.0668	–0.0636	–0.0632

$\text{NS} = Y - pZ + rB - \delta K - E - \Psi$, which are zero in the steady state, become positive. The reduction in consumption increases the marginal rate of substitution between consumption and leisure. Given the real wage rate, households increase their labor supply. In sum, the increase in labor supply exceeds the reduction in labor demand, and employment (labor) increases by 0.175%, whereas the real wage falls. Given the initial capital stock, output drops about 0.8%. Initial welfare of the representative agent falls by 2.05%.[15]

The cutback in oil input reduces the marginal product of capital, and q drops, as the capital stock cannot be instantaneously adjusted, because of Hayashi-type adjustment and installation costs. In turn, this reduces investment expenditures. Hence, net investment $\text{NI} = I - \delta K$, which is zero in the steady state, falls and becomes negative. Because net savings NS increase whereas net investment NI falls, the current account CA = NS – NI turns into a surplus. Looking at the trade

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balance, the reductions in consumption of the domestically produced good and investment expenditure outweigh the reduction in output by far; hence the goods trade balance $[Y - \Phi(I, K) - C]$ sharply improves. On the other hand, the oil balance $-p[Z + M]$ deteriorates, because the value of oil imports increases. The improvement of the goods trade balance overweighs the deteriorated oil balance by far, and the overall trade balance (which was negative in the initial steady state) improves by 41.55%. Because NS is falling and NI is rising, the current account surplus becomes smaller, and the accumulation of net foreign assets slows down. Because NI is negative, the economy decumulates its capital stock. As is usual in the standard model of a small open economy, the transitional dynamics is monotonic.

Compared to the base equilibrium, in the new steady state, output and the capital stock have fallen by 1.66%, and employment (labor) drops by 0.33%. Oil input is reduced by 41.52%, from which it follows that almost all adjustment in oil usage happens on impact. Long-run consumption expenditures and consumption of the domestically produced good are reduced by 1.62%, and consumption of imported oil falls by 50.81%. The goods trade balance (positive) deteriorates by more than 4.5%, which, together with a more negative oil balance (11.42%), increases the trade balance deficit by 28.55%. The trade balance deficit is completely financed by increased interest earnings, as the stock of traded bonds rises by 28.55%, too. The steady-state current account equals zero (i. e., $\text{NS} = \text{NI}$). The overall welfare effect of the oil shock is quite small, as intertemporal welfare falls by 1.96%.

It is interesting to note that with respect to output, oil input, and consumption expenditures, most of the adjustment happens right on impact, whereas the short-run and long-run reactions of the goods trade balance and the trade balance go in opposite directions. Of course, the current account dynamics and the impact response of employment are at odds with empirical evidence.

4.3. The Benchmark Economy

We now turn to the effects of a 100% oil price shock in the benchmark economy with time-nonseparable (habit-forming) preferences. The parameter values are given by the benchmark calibration (Table 1). The dynamics of key economic variables and the reference stock are now interdependent. The two stable eigenvalues are -0.1507 and -0.0638, respectively. Thus, the speed of convergence of any variable at any point in time is a weighted average of the two stable eigenvalues. Over time, the weight of the smaller eigenvalue (-0.1507) declines, and the larger eigenvalue (-0.0638) describes the asymptotic speed of adjustment. The flexibility provided by the additional eigenvalue allows the model to match some features of the data, in particular with respect to the current account.

Impact effects. The impact and long-run effects of an unanticipated permanent 100% increase in the oil price are reported in the second column of Table 3, where the benchmark economy is set in bold. Starting from the base equilibrium, the 100% rise in the oil price leads producers to reduce oil input instantaneously by roughly 41%. The marginal product of labor is reduced, and given the real wage, labor demand falls. As in the case of TSP, on the production side the lower marginal productivity of capital induces investment expenditure cutbacks, and net investment becomes negative, because adjustment costs prevent the capital stock from adjusting instantaneously. Net investment is not sensitive to the type of preferences, as preferences affect the economy's production side only indirectly via households' labor supply.

However, the reaction of households differs dramatically. The presence of a reference consumption stock dampens the utility associated with a change in initial consumption relative to the reference stock and makes agents more reluctant to change their consumption pattern. This is the "status effect" described by Alvarez-Cuadrado et al. (2004). The negative wealth effect of the oil price shock has an impact on consumption expenditures, E, and on C with a 0.98% reduction only. Because of the status effect, the expenditure–output ratio increases. The increase in the expenditure–output ratio is financed by negative net savings; i.e., $\mathrm{NS} < 0$. The marginal rate of substitution between consumption and leisure increases, and at the going real wage, agents increase their labor supply, but by a smaller amount than in the case of TSP, because the status effect dampens the change in the marginal rate of substitution. On the labor market, the reduction in labor demand overweighs the increase in labor supply, the real wage drops, and employment falls by 0.28%, which is in line with empirical evidence. Given the capital stock, output drops by 1.11%. Compared to the case of TSP, output drops by a larger amount, because labor is now reduced, whereas in the case of TSP labor input increases. In Figures 1a, 1c and 1d the drops in output and labor and the increase in the expenditure–output ratio are illustrated by the difference between the dashed and solid lines.[16] Instantaneous welfare of the representative agent falls by 3.23%.

Oil input and oil consumption both fall (41.2% and 50.49%, respectively), but valued at the higher oil price, the value of oil imports increases, and the (negative) oil trade balance (OTB) deteriorates by roughly 12%, as shown in Figure 1e.[17] The reductions in consumption of the domestically produced good and investment expenditure are larger than the output drop; hence the (positive) goods trade balance (GTB) improves by 10.95% (see also Figure 1f), which is much smaller than in the case of TSP, because the status effect dampens the consumption response and magnifies the output reaction via lower employment. The improvement in the goods trade balance is not sufficient to outweigh the deteriorated oil balance. The overall trade balance deteriorates by about 13.30%, as illustrated in Figure 1g.[18] As the overall trade deficit increases, net foreign assets start to decumulate, as the initially downward-sloping time path of bonds in Figure 1j confirms.

Dynamic adjustments. The reduction in investment expenditures initiates a decumulation of the capital stock. The dynamic evolution of the capital stock is monotonic and is illustrated in Figure 1b. The half-time of the capital stock adjustment is roughly 9.7 years. Compared to the conventional case, this means

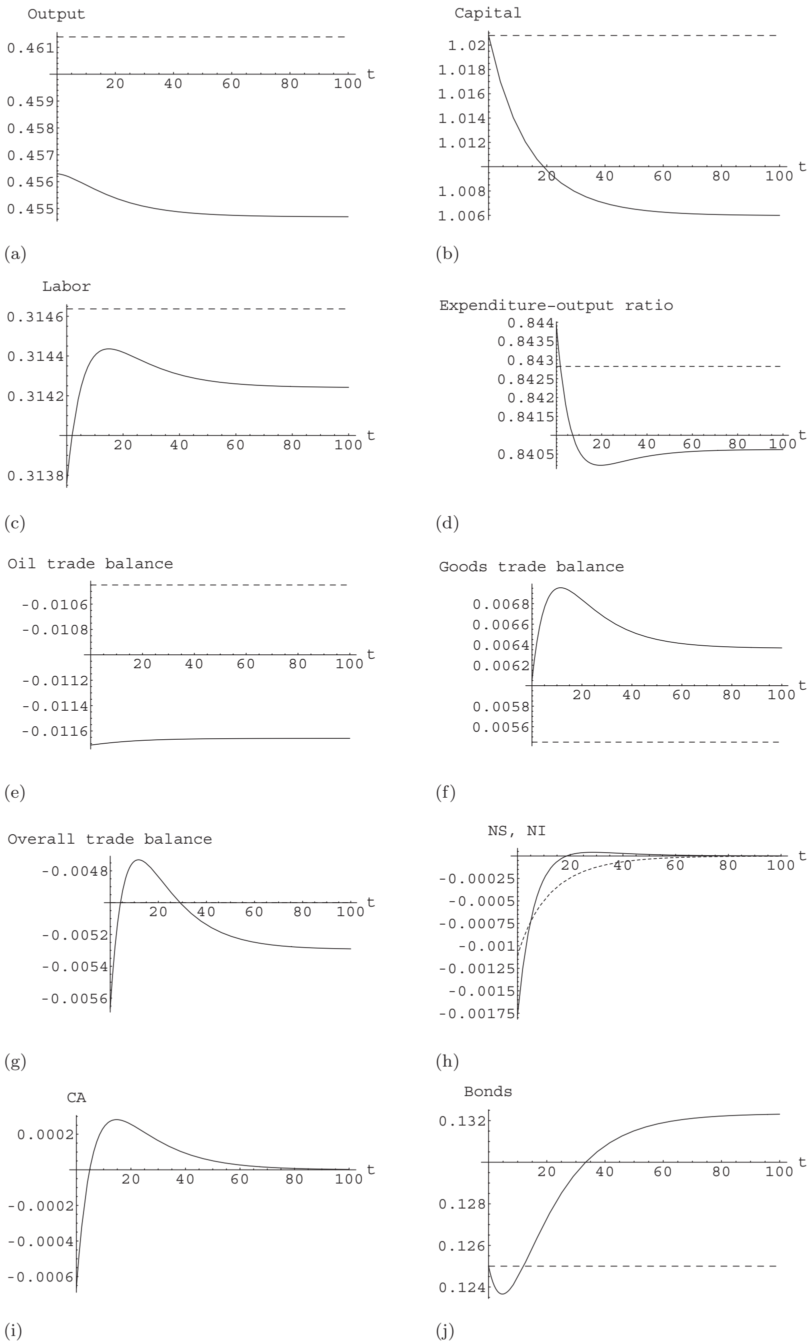

FIGURE 1. Dynamic effects of 100% increase in p: benchmark economy.

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that the adjustment in the capital stock is speeded up. Thus, the introduction of a reference consumption stock counterintuitively speeds up the dynamics. The reason is that the interaction of the capital stock dynamics with the more rapid consumption reference stock dynamics increases the speed of convergence.[19]

As time proceeds, lower consumption expenditures leads to a gradually declining reference stock. This in turn makes agents less reluctant to reduce their consumption expenditures over time. The falling capital stock and reduced labor (which is always below the base level) induce an ongoing output reduction. After its impact increase, the expenditure–output ratio starts to fall, quickly achieving levels below the baseline and partially recovering in the latter stage of transition (see Figure 1d). As can be seen from Table 3, the difference between the impact and steady state change of oil input is extremely small (0.206 percentage points), implying that almost all of the oil input adjustment happens instantaneously after the shock hits the economy. Also, most of the output reaction occurs on impact (see Figure 1a).

The dynamics of the overall trade balance and the current account merits further comment. Qualitatively, the impact reactions of the goods trade balance and the oil balance are the same as in the case of TSP. In fact, the initial response of the oil balance is barely different, as Table 3 reveals. However, the quantitative impact effects on the goods trade balance and the current account differ sharply from those in the case of TSP. The status effect induces households to draw down their wealth by negative net savings. In fact, in the benchmark economy the status effect is so strong that net savings fall by more than net investments, and the current account, CA, turns into a deficit; i.e., $CA = NS - NI < 0$ (see Figures 1h and 1i, where the solid line represents NS and the dashed line NI). As time passes by, the consumption reference stock falls, which makes households less reluctant to cut consumption expenditures further, implying increases in net savings (however, NS remains negative for roughly the first 18 years). The gradually falling capital stock increases its value and induces higher net investment (albeit NI remains negative during the transition). As NS increases faster than NI, the current account deficit reduces. After 4.88 years, $NS = NI$, the current account becomes zero, and the decumulation of net foreign assets stops. From there on, $NS > NI$, and the current account is in surplus, as Figures 1h and 1i illustrate. The evolution of the current account thus shows the J-curve property and a nonmonotonic adjustment.

The emergence of a J-curve after a deterioration of the terms of trade when habit formation is present is described in detail by Mansoorian (1998) and Cardi (2007), although their models are different in several key aspects.[20]

The current-account adjustment of the J-curve type in the benchmark economy with habit-forming preferences also differs sharply from its adjustment in the economy discussed in Matsuyama (1987), who applies a finite-time horizon model of the Blanchard (1985) type. In Matsuyama's paper, an oil price increase produces either a current account deficit that remains until the steady state is reached, or an initial current account surplus, followed by a current account deficit in the later stage of transition, depending on the relative magnitudes of portfolio substitution and wealth effects.

It is important to note that the reaction of net savings depends on the oil share in consumption. If, e.g., households do not consume oil (that is, $\nu = 1$), the higher oil price affects households only indirectly via income (output). Hence, smaller expenditures are necessary to maintain a certain consumption level. In that case, in the benchmark economy ($\gamma = 0.6$, but $\nu = 1$), net savings fall by less than net investment, turning the current account into a surplus right on impact. Sensitivity analysis reveals that without oil in consumption, the J-curve effect appears only for higher weights of habits, γ, in utility, and becomes shorter-lived.

Steady state effects. As the second column of Table 3 reveals, in the long run output and the capital stock fall by 1.45% (with respect to the base equilibrium), and labor is reduced by 0.13%. Oil input usage is cut back by 41.40%, and consumers reduce their expenditures by 1.71% (according to the second column of Table 3, C falls by 1.71%, and M drops by 50.85%). The (positive) goods trade balance improves by 16.79%, whereas the oil balance deteriorates by 11.57%, resulting in an overall deterioration of the (negative) trade balance by 5.88%. Accordingly, the steady state net foreign asset position (positive) has to rise by 5.88%. The long-run oil share (OTB/Y) increases by 13.21% and is still fairly low at 0.02564. The 100% oil price hike lowers the agent's overall welfare by 2.35%.

Compared to the case of TSP, the model with a reference consumption stock matches data much better, predicting that after an oil price shock, the economy will suffer a slump, as output drops, employment falls, and the current account worsens. A large part of the total steady state output change occurs right on impact, a feature that is stressed by many empirical studies; see, e.g., Jiménez-Rodríguez and Sánchez (2005), Kilian (2008), and Blanchard and Galí (2010). The dynamic evolution of the current account confirms the early findings of Agmon and Laffer (1978), and more recently of Rebucci and Spatafora (2006) and Kilian et al. (2009). Moreover, compared to the model with TSP, the long-run change in the overall trade balance is strongly reduced. With respect to the output loss, the model fits actual findings that this loss is quite low. The long-run output loss (−1.45%) is in accordance with what, e.g., the OECD (2004), Jiménez-Rodríguez and Sánchez (2005), Nordhaus (2007), and Blanchard and Galí (2010) found.

5. SENSITIVITY ANALYSIS

Having discussed the dynamics and the steady state changes, we briefly perform some sensitivity analysis with respect to the weight γ of the reference consumption stock in preferences, and the oil share in output.[21] Results are reported in Table 3.

5.1. Weight of Habits in Preferences

Starting from the benchmark calibration, we vary the weight γ from 0.6 to 0.8, as recent empirical evidence suggests values of γ up to 0.9. An increase in the weight of habits strengthens the status effect and makes agents more reluctant to reduce their expenditures and to supply more labor. This increases the output loss and the reduction in net savings, resulting in a larger current account deficit. In turn, the period of bonds decumulation becomes longer, and the changes in the net foreign asset position will be more pronounced. Because agents are forward-looking, an increasing reluctance to reduce consumption expenditures on impact requires a larger long-run expenditure cut to maintain intertemporal solvency. On the other hand, a larger long-run consumption reduction increase agents' willingness to supply labor, thus reducing the steady state drops in employment, output, and the capital stock. The case of $\gamma = 0.8$ is of particular interest, as some empirical work suggests this value. In that case, the economy faces a lower steady state stock of traded bonds.

5.2. Oil Share in Output

According to empirical evidence, we calibrated the oil share in output to be 0.0226, reflecting the low energy cost share in GDP in the last 20 years. However, it cannot be precluded that this share will not increase in the future. Also, countries may differ with respect to oil shares. Finally, from a historical point of view, it is interesting to apply the model to the oil price shocks of the 1970s and early 1980s, a period in which the oil share was much higher than in our days.[22] Sensitivity analysis with respect to the oil share (see the last two columns in Table 3) yields three important results. First, the dynamics but not the magnitude of changes is insensitive with respect to the oil share. Second, the model shows that the observed small effects of oil price shocks in modern economies can be explained by low oil shares. Third, the model calibrated to a relatively large oil share (5%) adequately describes the effects of the oil crises of the 1970s and 1980s,[23] where oil prices more than doubled.

6. CONCLUSIONS

Recent empirical evidence showed that the macroeconomic effects of oil price shocks are quite small. Previous research has focused almost entirely on the reaction of output, employment, and inflation, and little attention was paid to an economy's external dynamics. This paper has examined the effects of oil price shocks in a small open-economy framework, paying particular attention to the current account.

Empirical evidence strongly suggests the introduction of time-nonseparable preferences. Because this increases the complexity of the model substantially, most of our work has proceeded numerically by calibrating a plausible small open-economy model. Our analysis shows the importance of introducing a status effect by comparing the results with that of the model with TSP. Whereas the TSP model predicts an impact increase in employment, a current account surplus, and a monotonic adjustment of a country's net foreign asset position, which is at odds with empirical evidence, the presence of the status effect enriches the dynamics substantially, predicting that an oil price hike lowers employment and turns the current account into a deficit, as consumers are reluctant to reduce their consumption expenditures sufficiently, and thus net savings fall by more than net investment. Moreover, the adjustments in the current account are almost entirely driven by the goods (nonoil) trade balance. Over time, net savings recover faster than net investment, and the current account deficit is reduced and eventually turns into a surplus, giving rise to a J-curve. Depending on the weight of the consumption reference stock and thus on the strength of the status effect, the economy ultimately ends up with a larger or smaller stock of net foreign assets. The model thus provides a sound theoretical underpinning of empirical evidence described by Agmon and Laffer (1978) and others, who found that current account dynamics of oil price shocks is nonmonotonic, and yields a plausible pattern of the current account. Because of a small oil share in GDP, our model also predicts quite small responses of output and employment to an oil price shock, as recent empirical research suggests. Larger oil shares result in larger output and employment reductions and greater welfare losses, as experienced in the 1970s, were oil shares were roughly twice as high as today, but do not change the dynamics qualitatively.

Finally, we conclude with two remarks. First, one issue that has received attention and we have not addressed concerns possible asymmetric responses to oil price shocks [see Mork (1989), Hamilton (1996, 2011), and Serletis and Elder (2011)]. Reasons for the asymmetry include policy responses and adjustment costs associated with changes in oil usage [see Atkeson and Kehoe (1999) and Wei (2003)] and oil price uncertainty [see Elder and Serletis (2010) and Rahman and Serletis (2011)]. These asymmetries may also explain nonmonotonic current account dynamics. Although this nonlinearity is important if one deals with short-run oil price fluctuations where both price increases and decreases occur with regularity, it is less relevant for our analysis, where our concern has been with a long-run change (increase) in the oil price, which is not reversed. In fact, the evidence in favor of asymmetries has recently been questioned [see Kilian and Vigfusson (2011)].

Second, our analysis has focused on a small open economy, facing unlimited access to the world financial market and taking the oil price as exogenously given. Our contribution thus complements the work done by Balke et al. (2008) and Bodenstein et al. (2011), which concentrates on large, interdependent economies and on temporary shocks.

NOTES

1. One can also think in terms of imported energy, as oil price movements and price movements of other fossil sources of energy are strongly correlated; see Asche et al. (2003).

2. For the sake of notational simplicity, we abstract from indexing individual variables with a subscript i.

3. This restriction keeps the model more tractable. Moreover, the difference between assuming that the reference stock is formed by looking outward or inward (i.e., by basing the reference stock on

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the agent's own past consumption) is relatively small, although it does depend upon the specific shock that hits the economy; see Alvarez-Cuadrado et al. (2004).

4. The half-time of the reference stock's adjustment to a change in the average consumption bundle is $\grave{t} = -(1/\zeta)\ln 0.5$; see Carroll et al. (2000). Values for ζ between 0.1 and 0.3 seem to span a plausible range, implying half-times of 6.93 and 2.31 years. Following Carroll et al. (2000), as a benchmark we set $\zeta = 0.2$, implying a half-time of 3.47 years.

5. In the case $B < 0$, the agent is a net debtor.

6. Note that (1c) does not appear in the maximization problem of the outward-looking agent, because the reference stock is treated as given and thus represents an externality.

7. An Appendix, containing the derivation of the differential equation system and the linearization procedure in detail, is available from the author upon request.

8. The differential equation for l can be eliminated, as l is a function of H and K, reducing the internal dynamics to a third-order system.

9. The model is not calibrated to a particular country. Rather, the calibration is a "plausible" one [on the issue of calibration, see Turnovsky (2011)]. Note also that the model does not properly fit oil-exporting countries such as Norway or the United Kingdom. In fact, changing some country-specific relations such as B/Y does not lead to very different outcomes. Thus, the calibrated model can be applied to a broad set of oil-importing countries.

10. Empirical evidence shows that the share of oil expenditure in GDP is very low. Parry and Darmstadter (2004) state that for the United States, this share has fallen from 4% to 6% in the mid-1970s to the mid-1980s to below 2% now. Nordhaus (2007) writes that between 1970 and 1995 the oil share in U.S. GDP was around 3% on the average. For Germany, in 2006 the share of the value of oil imports in GDP was about 2.2%. In other European countries (e. g. France, Italy, Austria), in 2006 this share was approximately 2.2% as well (calculations from the author, based on data from Eurostat). Following Bodenstein et al. (2011), we shall assume that the ratio of oil consumption to oil input in production is roughly 1/2.

11. E.g., in 2006, the ratio was 0.28 for Germany, 0.06 for France, -0.21 for Austria, -0.06 for Italy, -0.80 for Portugal, and -0.83 for Greece. (Calculations from the author, based on data from the IMF.) However, the economic effects of oil price shocks in the calibrated model are quite insensitive to changes in the initial stock of bonds.

12. Ortigueira and Santos (1997) show that the speed of convergence is sensitive to h, and choose $h = 16$ on the grounds that it generates a speed of convergence of around 2% per annum, consistent with much empirical evidence. Auerbach and Kotlikoff (1987) assume $h = 10$, and recognize that this is at the low value of estimates, whereas Barro and Sala-i-Martin (2003) propose a somewhat higher value.

13. There is some difficulty in translating empirical estimates of γ, which are based on discrete-time models, to our continuous-time model.

14. As can be seen from equations (3a) and (3b), C and the value of imported oil consumption, pM, always change by the same percentage as expenditures E.

15. The effects on welfare reported are equivalent variation measures, calculated as the percentage change in the permanent flow of consumptions C and M necessary to equate the initial level of welfare to what it would be following the shock. We apply the method shown in the appendix of Alvarez-Cuadrado et al. (2004).

16. The dashed lines refer to the base equilibrium.

17. We have not drawn the time paths for C, M, and Z. Their time paths are similar to those of expenditure E and output Y. This is because C, M and E move proportionally according to equations (3a) and (3b), and Z is proportional to Y, as equation (3d) states.

18. In the figure, the dashed line, illustrating the base equilibrium, and the horizontal axis coincide.

19. On this issue, see Alvarez-Cuadrado et al. (2004, p. 61).

20. In Mansoorian's model, there is no capital accumulation and no labor, as output is exogenously fixed. In Cardi's model, (i) agents are "inward-looking," (ii) labor is fixed, (iii) there are no imported inputs, and (iv) there is a valuation effect, as bonds are denoted in terms of the imported good. A

terms-of-trade change thus exercises a direct wealth effect in terms of the domestic good. In our model, however, there is no valuation effect on the agent's asset position and thus no such wealth effect. Besides net foreign assets, in the models of Mansoorian and Cardi the adjustments of all other economic key variables are one-dimensional, whereas in our model they are two-dimensional, thus enriching the dynamics. Moreover, in contrast to our work, both papers focus on the current account and do not investigate the evolution of other key economic variables.

21. Because of space limitations, a more detailed sensitivity analysis is available upon request.
22. See, e.g., OECD (2004) and Parry and Darmstadter (2004).
23. See, e.g., Nordhaus (2007).

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