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THE "NEW KEYNESIAN" PHILLIPS CURVE: CLOSED ECONOMY VS. OPEN ECONOMY

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ABSTRACT

The paper extends Woodford’s (2000) analysis of the closed economy Phillips curve to an open economy with both commodity trade and capital mobility. We show that consumption smoothing, which comes with the opening of the capital market, raises the degree of strategic complementarity among monopolistically competitive suppliers, thus rendering prices more sticky and magnifying output responses to nominal GDP shocks.

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1 Introduction

In this paper, we examine how open capital market policies would interact with the degree of price rigidity in the domestic economy to affect the output-inflation tradeoffs and, similarly, the volatilities of output and inflation in response to nominal shocks. The analysis will be conducted in an optimization-based "New Keynesian" framework *a la* Blanchard and Kiyotaki (1987). In the discussion, we extend to an open-trade and open-capital economy the succinct exposition of Woodford (2000), which is conducted in the context of a closed economy.

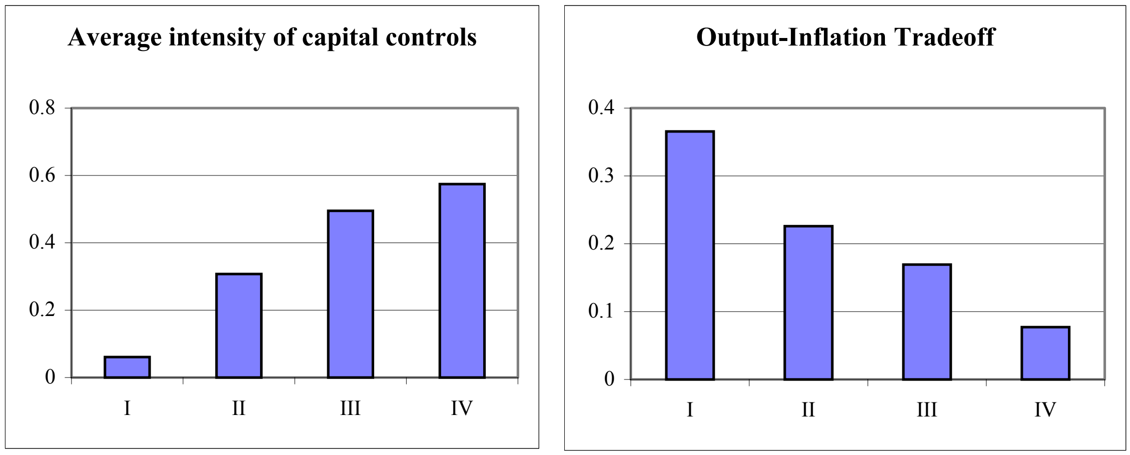
Why is such extension potentially useful? Evidently, the degree of price stickiness is related to the organization of markets—for instance, whether the labor market is common or segmented. Similarly, the degree of price stickiness can be affected by the openness of the economy both in commodity trade and capital mobility.

As an illustration, consider the evidence in Figure 1 below. The left panel measures the extent to which 4 groups of countries restrict capital movements based on the IMF's Annual Report on Exchange Rate Arrangements and Exchange Restrictions. The right panel provides their corresponding average output-inflation tradeoff parameters as estimated by Ball, Mankiw, and Romer (1988). The figure shows clearly that countries with greater restrictions on capital mobility tend to have steeper Phillips curves. This finding has been recently substantiated by econometric estimations (see, Loungani, Razin, and Yuen (2001)).

2 The analytical framework

Consider a small open economy with a representative household that is endowed with a continuum of goods-specific skills—uniformly distributed on the unit interval $[0, n]$—to be supplied to a differentiated product industry. As a consumer, the representative household has access to consumption of both domestic (distributed on $[0, n]$) and foreign goods (dis-

Figure 1: Capital controls and the output-inflation tradeoff
The greater the intensity of capital controls, the steeper is the Phillips curve



tributed on $(n, 1]$). The household seeks to maximize a discounted sum of expected utilities:

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(C_t, M_t/P_t; \xi_t) - \int_0^n v(h_t(j); \xi_t) dj],$$

where β is the subjective discount factor, C is the Dixit-Stiglitz index of household consumption, P the Dixit-Stiglitz price index, M/P the demand for real balances, ξ a preference shock, and $h(j)$ the supply of type-j labor to the production of good of variety j. Like Obstfeld and Rogoff (1996), we define the consumption index and its corresponding price index respectively as

$$C_t = \left[\int_0^n c_t(j)^{\frac{\theta-1}{\theta}} dj + \int_n^1 c_t^*(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}},$$

and

$$P_t = \left\{ \int_0^n p_t(j)^{1-\theta} dj + \int_n^1 [\varepsilon_t p_t^*(j)]^{1-\theta} dj \right\}^{\frac{1}{1-\theta}}, \tag{1}$$

where $c(j)$ represents domestic consumption of the j^{th} domestically produced good, $c^*(j)$ domestic consumption of the j^{th} foreign-produced good, $p(j)$ the domestic-currency price of $c(j)$, $p^*(j)$ the foreign-currency price of $c^*(j)$, ε the nominal exchange rate (domestic-currency price of foreign currency), $\theta > 1$ the elasticity of substitution among the different goods, and n the fraction of goods that are produced domestically.

The budget constraint facing the household is given by:

$$\begin{aligned} & \int_0^n p_t(j) c_t(j) dj + \varepsilon_t \int_n^1 p_t^*(j) c_t^*(j) dj + \left(\frac{i_t}{1+i_t} \right) M_t + B_t + \varepsilon_t B_t^* \\ = \quad & M_{t-1} + (1+i_{t-1}) B_{t-1} + f_{t-1,t}(1+i_{t-1}^*) B_{t-1}^* + \int_0^n w_t(j) h_t(j) dj + \int_0^n \Pi_t(j) dj, \end{aligned}$$

where B is the domestic-currency value of domestic borrowing, B^* the foreign-currency value of foreign borrowing, $f_{t-1,t}$ the forward exchange rate for foreign currencies purchased/sold at time $t-1$ for delivery at time t, i and i^* the domestic and foreign interest rates, $w(j)$ the wage rate per unit labor of type j, and $\Pi(j)$ profit income from firms of type j. With perfect capital mobility, covered interest parity prevails:

$$1 + i_t = (1 + i_t^*) \left(\frac{f_{t,t+1}}{\varepsilon_t} \right).$$

>From now on, we shall focus on the relation between aggregate supply of goods and consumption smoothing made possible by international capital mobility. For this purpose, we would not be concerned about the details of aggregate demand (including the demand for money), international commodity trade, and the determination of the exchange rate. For simplicity, separability between consumption and real money balances is assumed for the utility function.

The relevant utility-maximizing conditions for our purpose include an intratemporal condition for the choice of labor supply of type j:

$$\frac{v_h(h_t(j);\xi_t)}{u_c(C_t;\xi_t)} = \frac{w_t(j)}{P_t} \tag{2}$$

and an intertemporal condition for the consumption-saving choice:

$$\frac{u_c(C_t;\xi_t)}{u_c(C_{t+1};\xi_{t+1})} = \beta(1+r^*), \tag{3}$$

where r^* is the world real rate of interest, assumed for simplicity to be time-invariant. This latter equality is a consequence of the covered interest parity and the Fisher equation.

As in the Dixit-Stiglitz model, demand for good j satisfies

$$c_t(j) = C_t \left(\frac{p_t(j)}{P_t}\right)^{-\theta}. \tag{4}$$

The production function assumes the form

$$y_t(j) = A_t f(h_t(j)),$$

where A is a random productivity shock. The variable cost of supplying $y_t(j)$ is $w_t(j)f^{-1}(y_t(j)/A_t)$, which implies a (real) marginal cost of

$$s_t(j) = \frac{w_t(j)}{P_t A_t f'(f^{-1}(y_t(j)/A_t))}.$$

Using (2), we can replace the real wage above by the marginal rate of substitution. Imposing symmetry across firms (so that we can drop the index j), the above equation can be rewritten as

$$s(y,C;\xi,A)=\frac{v_h(f^{-1}(y/A);\xi)}{u_c(C;\xi)Af'(f^{-1}(y/A))}. \tag{5}$$

Trade-wise, price-making firms face world demand for its products so that equation (4) implies

$$y_t(j)=Y_t^W\left(\frac{p_t(j)}{P_t}\right)^{-\theta}. \tag{4'}$$

where $y_t(j)$ is the quantity of good j supplied by the firm to meet the world demand and $Y_t^W=Y_t^H+Y_t^F$ the index for all goods produced around the world, with $Y_t^H=\int_0^n \frac{p_t(j)y_t(j)}{P_t}dj$ and $Y_t^F=\int_0^n \frac{\varepsilon_t p_t^*(j)y_t(j)}{P_t}dj$ as corresponding production indices for home goods and foreign goods.

The goods markets are monopolistically competitive. A fraction γ of the firms sets their prices flexibly at p_{1t}, supplying y_{1t} whereas the remaining $1-\gamma$ of firms sets their prices one period in advance (in period $t-1$) at p_{2t}, supplying y_{2t}. In the former case, the price is marked up above the marginal cost by a factor of $\mu(=\frac{\theta}{\theta-1}>1)$ so that

$$\frac{p_{1t}}{P_t}-\mu s(y_{1t},C_t;\xi_t,A_t)=0. \tag{6a}$$

In the latter case, p_{2t} will be chosen to maximize expected discounted profit

$$E_{t-1}\left[\left(\frac{1}{1+i_{t-1}}\right)(p_{2t}y_{2t}-w_th_t)\right]=E_{t-1}\left\{\left(\frac{1}{1+i_{t-1}}\right)\left[Y_t^WP_t^\theta p_{2t}^{1-\theta}-w_tf^{-1}(Y_t^WP_t^\theta p_{2t}^{-\theta}/A_t)\right]\right\},$$

where we have used the inverse demand function from (4) for y_{2t} and the inverse production function for h_t. One can show that p_{2t} satisfies

$$E_{t-1}\left\{\left(\frac{1}{1+i_{t-1}}\right)Y_t^WP_t^{\theta-1}\left[\frac{p_{2t}}{P_t}-\mu s(y_{2t},C_t;\xi_t,A_t)\right]\right\}=0. \tag{6b}$$

Given p_{1t} and p_{2t}, the aggregate price index (1) can be rewritten as:

$$P_t=\left\{n[\gamma p_{1t}^{1-\theta}+(1-\gamma)p_{2t}^{1-\theta}]+(1-n)\varepsilon_tp_t^{*1-\theta}\right\}^{\frac{1}{1-\theta}}. \tag{1'}$$

In the extreme case where all prices are fully flexible (i.e., $\gamma = 1$), output will attain its *natural* level Y_t^n implicitly defined by

$$\frac{p_t}{\left[np_t^{1-\theta} + (1-n)\varepsilon_t p_t^{*1-\theta}\right]^{\frac{1}{1-\theta}}} = \mu s(Y_t^n, C_t^n; \xi_t, A_t). \tag{6a$'$}$$

Among other things, Y_t^n depends on the level of home consumption under flexible prices (C_t^n), domestic and foreign prices (p_t and p_t^*), as well as the exchange rate (ε_t). For later purpose, we can denote $s(Y_t^n, C_t^n; \xi_t, A_t)$ as s_t^n.

In the absence of capital flows, $C_t^n = Y_t^n$ so that the natural output level is defined by

$$\frac{p_t}{\left[np_t^{1-\theta} + (1-n)\varepsilon_t p_t^{*1-\theta}\right]^{\frac{1}{1-\theta}}} = \mu s(Y_t^n, Y_t^n; \xi_t, A_t). \tag{7}$$

When the economy is completely closed in terms of both commodity trade and capital flows ($n = 1$ and $C_t^n = Y_t^n$), (6a$''$) further simplifies to

$$1 = \mu s(Y_t^n, Y_t^n; \xi_t, A_t). \tag{8}$$

In this last case, equilibrium output is completely independent of monetary policy.

3 The Phillips curve

This section derives the expectations-augmented Phillips curve of the kind hypothesized by Friedman (1968) and Phelps (1970) for both open and closed economies.

In order to obtain a tractable solution, we log-linearize the equilibrium conditions around the steady state. We assume that $\beta(1+r^*) = 1$, which is necessary for the existence of a steady state. In particular, we consider a *deterministic* steady state where $\xi_t = 0$ and $A_t = \overline{A}$ with $\varepsilon_t = \overline{\varepsilon}$, $p_t^* = \overline{p}^*$, and $C_t = \overline{C}$. Define $\widehat{x}_t = \log(\frac{x_t}{\overline{x}}) \simeq \frac{x_t - \overline{x}}{\overline{x}}$ as the proportional deviation of any variable x_t from its deterministic steady state value $\overline{x}$. We can then log-linearize equation (5) around the deterministic steady state equilibrium to get

$$\widehat{s}_t - \widehat{s}_t^n = \omega(\widehat{y}_t - \widehat{Y}_t^n) + \sigma^{-1}(\widehat{C}_t - \widehat{C}_t^n), \tag{5}$$

where $\omega = \omega_w + \omega_p$, $\omega_w = \frac{v_{hh}(\overline{y}/\overline{A})}{v_h f'}$, $\omega_p = -\frac{f''(f^{-1}(.))(\overline{y}/\overline{A})}{f'(f^{-1}(.))f'(.)}$, and $\sigma = -\frac{u_{cc}\overline{y}}{u_c}$. Log-linearizing the two price-setting equations (6a) and (6b) using (5′), we obtain

$$\log(p_{1t}) = \log(P_t) + \omega(\widehat{y}_{1t} - \widehat{Y}_t^n) + \sigma^{-1}(\widehat{C}_t - \widehat{C}_t^n), \tag{6a'}$$

and

$$\log(p_{2t}) = E_{t-1}\left[\log(P_t) + \omega(\widehat{y}_{2t} - \widehat{Y}_t^n) + \sigma^{-1}(\widehat{C}_t - \widehat{C}_t^n)\right], \tag{6b'}$$

>From the definition of the aggregate price index (1′), we can derive the following approximation

$$\log(P_t) = n[\gamma\log(p_{1t}) + (1-\gamma)\log(p_{2t})] + (1-n)\log(\varepsilon_t p_t^*). \tag{1''}$$

Define the inflation rate $\pi_t = \ln(P_t/P_{t-1})$ so that $\pi_t - E_{t-1}(\pi_t) = \log(P_t) - E_{t-1}\log(P_t)$, and the real exchange rate as $e_t \equiv \varepsilon_t P_t^*/P_t$. We show in the Appendix how these price relations can be combined to obtain the open-economy Phillips curve as follows:

$$\begin{aligned}\pi_t - E_{t-1}(\pi_t) \;=\; & \left(\frac{\gamma}{1-\gamma}\right)\left\{\left(\frac{n\omega}{1+\theta\omega}\right)(\widehat{Y}_t^H - \widehat{Y}_t^n) + \left[\frac{(1-n)\omega}{1+\theta\omega}\right](\widehat{Y}_t^F - \widehat{Y}_t^n)\; 9 \right. \\ & \left. + \left(\frac{\sigma^{-1}}{1+\theta\omega}\right)(\widehat{C}_t - \widehat{C}_t^n)\right\} + \left(\frac{1-n}{n}\right)\left\{\left(\frac{1}{1-\gamma}\right)\log(e_t) - E_{t-1}[\log(e_t)]\right\}.\end{aligned} \tag{1}$$

3.1 Perfect capital mobility

When capital is perfectly mobile, consumption smoothing can be achieved and it will be trendless given the assumption that $\beta(1+r^*) = 1$. As a result, $\widehat{C}_t = 0 = \widehat{C}_t^n$. The Phillips curve therefore simplifies to

$$\pi_t - E_{t-1}(\pi_t) \;=\; \left(\frac{\gamma}{1-\gamma}\right)\left\{\left(\frac{n\omega}{1+\theta\omega}\right)(\widehat{Y}_t^H - \widehat{Y}_t^n) + \left[\frac{(1-n)\omega}{1+\theta\omega}\right](\widehat{Y}_t^F - \widehat{Y}_t^n)\right\} 9'$$

(2)

$$+\left(\frac{1-n}{n}\right)\left\{\left(\frac{1}{1-\gamma}\right)\log(e_t) - E_{t-1}[\log(e_t)]\right\}.$$

3.2 Closing the capital account

In the absence of capital flows, consumption smoothing can no longer be achieved and consumption will fluctuate with domestic output (i.e., $\widehat{C}_t = \widehat{Y}_t^H$ and $\widehat{C}_t^n = \widehat{Y}_t^n$). As a result, the Phillips curve assumes the form

$$\pi_t - E_{t-1}(\pi_t) = \left(\frac{\gamma}{1-\gamma}\right)\left\{\left(\frac{n\omega+\sigma^{-1}}{1+\theta\omega}\right)(\widehat{Y}_t^H - \widehat{Y}_t^n) + \left[\frac{(1-n)\sigma^{-1}}{1+\theta\omega}\right](\widehat{Y}_t^F - \widehat{Y}_t^n)\right\} \quad 9''$$

(3)

$$+\left(\tfrac{1-n}{n}\right)\left\{\left(\tfrac{1}{1-\gamma}\right)\log(e_t) - E_{t-1}[\log(e_t)]\right\}.$$

3.3 Closed economy

If we further close the trade account, the economy will be self-sufficient and $n = 1$. In this case, the Phillips curve will take an even simpler form

$$\pi_t - E_{t-1}(\pi_t) = \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega+\sigma^{-1}}{1+\theta\omega}\right)(\widehat{Y}_t^H - \widehat{Y}_t^n), \qquad (9''')$$

which is exactly identical to equation (1.23) in Woodford (2000).

3.4 A comparison

The difference in the output-inflation tradeoff coefficients between (9′) and (9″) lies in $\gamma\sigma^{-1}/(1-\gamma)(1+\theta\omega)$, which captures the sensitivity of inflation to consumption spending. This term will disappear in the presence of consumption smoothing as will be achieved under perfect capital mobility. The difference in the same coefficients between (9″) and (9‴) is $\gamma(n-1)\omega/(1-\gamma)(1+\theta\omega)$, where n represents the fraction of world consumption that is produced domestically in the case of trade openness whereas 1 stands for the same fraction (which is 100%) in the case of a closed economy. Therefore, successive opening of the economy will flatten the Phillips curve.

4 Short-run aggregate supply

This section examines how exogenous shocks to nominal GDP defined as $n[\gamma p_{1_t} y_{1t} + (1-\gamma) p_{2t} y_{2t}] = P_t^H Y_t^H \equiv Q_t$ would affect the relative responses of domestic output and producer prices. From the Phillips curve equation (9), we can show that the sensitivity of $\log(Y_t^H) - \log(Y_t^n)$ with respect to innovations in the exogenous process, viz., $\log(Q_t) - E_{t-1}[\log(Q_t)]$, in the case of perfect capital mobility is

$$\textit{output-elasticity}^{open} = \frac{1}{1 + \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega}{1+\theta\omega}\right)},$$

while the sensitivity of $\log(P_t^H) - E_{t-1}\log(P_t^H)$ is

$$\textit{price-elasticity}^{open} = \frac{\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega}{1+\theta\omega}\right)}{1 + \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega}{1+\theta\omega}\right)}.$$

Similarly, the sensitivity parameters in the case of a closed economy are given by

$$\textit{output-elasticity}^{closed} = \frac{1}{1 + \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega+\sigma^{-1}}{1+\theta\omega}\right)},$$

and

$$\textit{price-elasticity}^{closed} = \frac{\left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega+\sigma^{-1}}{1+\theta\omega}\right)}{1 + \left(\frac{\gamma}{1-\gamma}\right)\left(\frac{\omega+\sigma^{-1}}{1+\theta\omega}\right)}.$$

As discussed in Woodford (2000), these sensitivity parameters are related to the degree of strategic complementarity among price setters. In turn, the latter depends on the organization of markets. For instance, strategic substitutability (complementarity) will prevail if all factor prices are (cannot be) instantaneously equalized across suppliers of different goods, the case of common (segmented) factor markets. In our case, we show another example where the organization of the world capital market matters—in particular, the integration or not of the domestic capital market into the world market. Consumption smoothing, which comes with the opening of the capital market, will increase the degree of strategic complementarity, thus rendering prices more sticky and magnifying output responses.

5 Appendix

Let us start with the two price-setting equations:

$$\log(p_{1t}) = \log(P_t) + \omega(\widehat{y}_{1t} - \widehat{Y}_t^n) + \sigma^{-1}(\widehat{C}_t - \widehat{C}_t^n), \tag{A.1a}$$

and

$$\log(p_{2t}) = E_{t-1}\left[\log(P_t) + \omega(\widehat{y}_{2t} - \widehat{Y}_t^n) + \sigma^{-1}(\widehat{C}_t - \widehat{C}_t^n)\right]. \tag{A.1b}$$

Log-linearizing the demand functions facing the firm (4) (where we can replace c_t and C_t^W by y_t and Y_t^W respectively), we get

$$\widehat{y}_{jt} = \widehat{Y}_t^w - \theta[\log(p_{jt}) - \log(P_t)], \; j = 1, 2, \tag{A.2}$$

where $\widehat{Y}_t^w = n\widehat{Y}_t^H + (1-n)\widehat{Y}_t^F$. Substituting (A.2) into (A.1a) and rearranging terms, we have

$$\log(p_{1t}) = \log(P_t) + \left(\frac{\omega}{1+\theta\omega}\right)(\widehat{Y}_t^W - \widehat{Y}_t^n) + \sigma^{-1}\left(\frac{1}{1+\theta\omega}\right)(\widehat{C}_t - \widehat{C}_t^n), \tag{A.1a$'$}$$

and

$$\log(p_{2t}) = E_{t-1}\left[\log(P_t) + \left(\frac{\omega}{1+\theta\omega}\right)(\widehat{Y}_t^W - \widehat{Y}_t^n) + \sigma^{-1}\left(\frac{1}{1+\theta\omega}\right)(\widehat{C}_t - \widehat{C}_t^n)\right], \tag{A.1b$'$}$$

Together, (A.1a$'$) and (A.1b$'$) imply that

$$\log(p_{2t}) = E_{t-1}\log(p_{1t}). \tag{A.3}$$

>From the aggregate price index equation (1$'$), we have an approximate relation of the following kind

$$\log(P_t) = n[\gamma\log(p_{1t}) + (1-\gamma)\log(p_{2t})] + (1-n)\log(\varepsilon_t p_t^*). \tag{A.4}$$

From this, the unanticipated rate of inflation is given by

$$\begin{aligned} \log(P_t) - E_{t-1}[\log(P_t)] &= n\gamma\{\log(p_{1t}) - E_{t-1}[\log(p_{1t})]\} + (1-n)\{\log(\varepsilon_t p_t^*) - E_{t-1}[\log(\varepsilon_t p_t^*)]\} \\ &= n\gamma[\log(p_{1t}) - \log(p_{2t})] + (1-n)\{\log(\varepsilon_t p_t^*) - E_{t-1}[\log(\varepsilon_t p_t^*)]\}, \end{aligned}$$

where we have used (A.3) to get the second equality. (A.4) also implies $\log(p_{2t}) = \left[\frac{1}{n(1-\gamma)}\right][\log(P_t) - n\gamma\log(p_{1t}) - (1-n)\log(\varepsilon_t p_t^*)]$ so that

$$\begin{aligned}\log(P_t) - E_{t-1}\log(P_t) &= \left(\frac{\gamma}{1-\gamma}\right)[\log(p_{1t}) - \log(P_t)] \\ &+ \left(\frac{1-n}{n}\right)\left\{\left(\frac{1}{1-\gamma}\right)\log(e_t) - E_{t-1}[\log(e_t)]\right\},\end{aligned}$$

where $e_t \equiv \varepsilon_t P_t^*/P_t$ is the real exchange rate. Substituting (A.1a$'$) into the above expression yields an open-economy Phillips curve of the form

$$\begin{aligned}\log(P_t) - E_{t-1}\log(P_t) &= \left(\frac{\gamma}{1-\gamma}\right)\left[\left(\frac{\omega}{1+\theta\omega}\right)(\widehat{Y}_t^W - \widehat{Y}_t^n) + \left(\frac{\sigma^{-1}}{1+\theta\omega}\right)(\widehat{C}_t - \widehat{C}_t^n)\right] \\ &+ \left(\frac{1-n}{n}\right)\left\{\left(\frac{1}{1-\gamma}\right)\log(e_t) - E_{t-1}[\log(e_t)]\right\}.\end{aligned}$$

Equation (9) in the text can be obtained by noting that $\widehat{Y}_t^W = n\widehat{Y}_t^H + (1-n)\widehat{Y}_t^F$.

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