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by Andrea Vaona

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1 Introduction

Building on Campbell (2006, 2008a and 2008b), Campbell (2010a) recently proposed an alternative derivation of the Phillips curve to the New-Keynesian and sticky information ones, by adopting an efficiency wages model with imperfect information. The present paper extends the efficiency wages Phillips curve from a closed economy context to an open economy one. As a consequence, it stays to Campbell (2010a) as Razin and Yuen (2002) stays to Woodford (2003). In order to accomplish this task we insert Campbell's model within an intertemporal optimization framework, by drawing theoretical insights also from Danthine and Kurmann (2004) and Obstfeld and Rogoff (1996). The rest of this paper is structured as follows. First the model is introduced. Afterwards, the trade account of the economy is opened, followed by the capital one. The last section summarizes our findings. The Appendix illustrates our solution procedure.

2 The model

2.1 The households' problem and the government budget constraint

We follow Danthine and Kurmann (2004), by supposing the economy to be populated by a continuum of households normalized to 1, each composed by a continuum of individuals normalized to 1. Households maximize their discounted utility

$$\max_{\left\{c_{t+i}(h),B_{t+i}(h),B^{*}_{t+i}(h),e_{t+i}(h),M_{t+i}(h)\right\}} \sum_{i=0}^{\infty} \beta^{t+i} E\left(U\left\{c_{t+i}\left(h\right), L_{t+i}\left(h\right) G\left[e_{t+i}(h)\right], \frac{M_{t+i}\left(h\right)}{P_{t+i}}\right\}\right) \tag{1}$$

subject to a series of income constraints

$$\begin{aligned} c_{t+i}\left(h\right) &= \frac{W_{t+i}\left(h\right)}{P_{t+i}}L_{t+i}(h)+\frac{T_{t+i}\left(h\right)}{P_{t+i}}-\frac{M_{t+i}\left(h\right)}{P_{t+i}}+\frac{M_{t+i-1}\left(h\right)}{P_{t+i}}- \\ & -\frac{B_{t+i}(h)}{P_{t+i}}+\frac{B_{t+i-1}(h)}{P_{t+i}}\left(1+i_{t+i-1}\right)-\frac{\epsilon_{t+i}B^{*}_{t+i}(h)}{P_{t+i}}+f_{t+i-1,t+i}\frac{B^{*}_{t+i-1}(h)}{P_{t+i}}\left(1+i^{*}_{t+i-1}\right) \end{aligned}$$

where β is the discount factor, E is the expectation operator, U is the utility function, $c_{t+i}\left(h\right)$ is consumption of household h at time $t+i$, $B_{t+i}(h)$ are the household's domestic bond holdings, i_{t+i} is the nominal domestic interest rate, $L_{t+i}\left(h\right)$ is the fraction of employed individuals within the household, $G\left[e_{t+i}(h)\right]$ is the disutility of effort - $e_{t+i}(h)$ - of the typical working family member, $M_{t+i}(h)$ is nominal money balances and P_{t+i} the price level. $W_{t+i}\left(h\right)$ and $T_{t+i}\left(h\right)$ are the household's nominal wage income and government transfers respectively. ϵ_t is the spot exchange rate and $f_{t+i-1,t+i}$ is the forward exchange rate for foreign currencies purchased/sold at time $t+i-1$ and delivered at time t. Finally, asterisks denote foreign variables.

In this framework, households, and not individuals, make all the decisions regarding consumption, domestic and foreign bond holdings, real money balances and effort. Individuals are identical ex-ante, but not ex-post, given that some of them are employed - being randomly and costlessly matched with firms independently from time - and some other are unemployed. The fraction of the unemployed is the same across all the families, and so their ex-post homogeneity is preserved.

Note that in our model no utility arises from leisure, therefore individual agents inelastically supply one unit of time for either work or unemployment related activities[1].

Building on Danthine and Kurmann (2004) and Campbell (2010a), we

[1] This implies that, using the symbology of Campbell (2010), $\psi=0$, where ψ is the steady state value of the short-run elasticity of labor supply. We also assume parameters to be chosen so that excess labour supply exists.

specify $G\left[e_{t+i}(h)\right]$ as follows

$$G\left[e_{t+i}(h)\right]=\left\{e_{t+i}(h)-\tilde{e}\left[\frac{W_{t+i}\left(h\right)}{P_{t+i}^{e}},u_{t+i}(h)\right]\right\}^{2}$$

where P_{t+i}^{e} are price expectations, $u_{t+i}(h)=1-L_{t+i}(h)$ is the unemployment rate and $\tilde{e}\left[\frac{W_{t+i}(h)}{P_{t+i}^{e}},u_{t+i}(h)\right]$ is an efficiency function with $\tilde{e}_{W}>0$, $\tilde{e}_{u}>0$, $\tilde{e}_{WW}<0,\tilde{e}_{Wu}<0$.

Note that, under the hypothesis of an additively separable utility function, utility maximization implies that

$$G'\left[e_{t+i}(h)\right]=0 \tag{2}$$

and, therefore,

$$e_{t+i}(h)=\tilde{e}\left[\frac{W_{t+i}\left(h\right)}{P_{t+i}^{e}},u_{t+i}(h)\right] \tag{3}$$

The government rebates its seigniorage proceeds to households by means of lump-sum transfers, $T_{t}\left(h\right)$:

$$\int_{0}^{1}\frac{T_{t}\left(h\right)}{P_{t}}dh=\int_{0}^{1}\frac{M_{t}\left(h\right)}{P_{t}}dh-\int_{0}^{1}\frac{M_{t-1}\left(h\right)}{P_{t}}dh$$

where $M_{t}\left(h\right)$ is money holdings of household h at time t.

Supposing that consumption and real money balances enter (1) in logs, utility maximization with respect to these two terms leads to a well-known money demand function (Walsh, 2003, p. 272):

$$\frac{M_{t+i}\left(h\right)}{P_{t+i}}=c_{t+i}\left(h\right)\left(\frac{1+i_{t+i}}{i_{t+i}}\right)b \tag{4}$$

where b is the weight of log real money holdings in the utility function. Note that, due to symmetry, the h index can be dropped.

2.2 The final and the intermediate product markets

As often in the New-Keynesian literature (see for instance Edge, 2002) we assume the existence of a continuum of monopolistically competitive firms hiring the homogeneous labour input to produce a horizontally differentiated output. We also assume that there exist perfectly competitive intermediaries combining all of the differentiated outputs to produce a homogeneous aggregate final output for the world economy thanks to a technology with constant elasticity of substitution (CES).

Similarly to Razin and Yuen (2002), solving the profit maximization problem of the representative intermediary leads to the product demand function for the j-th domestic firm

$$y_t^H(j) = Y_t^W \left[\frac{p_t^H(j)}{P_t} \right]^{-\gamma} \tag{5}$$

where $y_t^H(j)$ and $p_t^H(j)$ are respectively the output and the price of the j-th domestic firm, Y_t^W is world output, P_t is the aggregate domestic price index and γ is the elasticity of substitution of different product varieties in the CES production function. The demand function of the j-th foreign firm mirrors (5). Also note that the number of domestic firms is normalized to n and that of foreign firms to $1-n$. Finally $P_t = \left[\int_0^n p_t^H (j)^{1-\gamma} dj + \int_n^1 \epsilon_t p_t^F (j)^{1-\gamma} dj \right]^{\frac{1}{1-\gamma}}$ where $p_t^F(j)$ is the price of the j-th foreign firm. We hereafter drop the j index due to symmetry.

Similarly to Campbell (2010a), supposing that monopolistically competitive firms have the following production function

$$y_t = A_t^{\phi} L_t^{\phi} \left[\tilde{e} \left(\frac{W_{t+i}}{P_{t+i}^e}, u_{t+i} \right) \right]^{\phi} \tag{6}$$

- with A_t representing technology -, their profit maximization problem can be expressed as

$$\max_{\{L_t, W_t\}} \left(Y_t^W\right)^{\frac{1}{\gamma}} \left\{ A_t^{\phi} L_t^{\phi} \left[\tilde{e} \left(\frac{W_{t+i}}{P_{t+i}^e}, u_{t+i} \right) \right]^{\phi} \right\}^{\frac{\gamma-1}{\gamma}} P_t - W_t L_t$$

The first order condition with respect to L_t returns labour demand

$$\begin{aligned} L_t \quad = \quad & W_t^{\frac{\gamma}{\phi(\gamma-1)-\gamma}} \left[\frac{\phi(\gamma-1)}{\gamma} \right]^{-\frac{\gamma}{\phi(\gamma-1)-\gamma}} \left(Y_t^W\right)^{-\frac{1}{\phi(\gamma-1)-\gamma}} A_t^{-\frac{\phi(\gamma-1)}{\phi(\gamma-1)-\gamma}} \cdot \\ & \cdot \left[\tilde{e} \left(\frac{W_{t+i}}{P_{t+i}^e}, u_{t+i} \right) \right]^{-\frac{\phi(\gamma-1)}{\phi(\gamma-1)-\gamma}} P_t^{-\frac{\gamma}{\phi(\gamma-1)-\gamma}} \end{aligned} \tag{7}$$

Taking the first order condition with respect to W_t and substituting it into (7) one obtains the following condition

$$W_t \left[\tilde{e} \left(\frac{W_t}{P_t^e}, u_t \right) \right]^{-1} \tilde{e}_W \left(\frac{W_t}{P_t^e}, u_t \right) \frac{1}{P_t^e} = 1 \tag{8}$$

After Campbell (2010a), we are ready, at this stage, to linearize equations (4), (7) (8), $u_t = 1 - n_t$ and the production function of monopolistically competitive firms around the steady state so to obtain the price Phillips curve from the following system of equations

$$\begin{aligned} \left[\phi(\gamma-1)-\gamma\right] \hat{L}_t \quad &= \quad \gamma \hat{W}_t - \hat{Y}_t^W - \phi(\gamma-1)\hat{A}_t - \qquad (9) \\ & \quad -\phi(\gamma-1)\tilde{e}^{-1} \left[\begin{array}{c} \tilde{e}_w \frac{W_s}{P_s^e} \hat{W}_t \\ -\tilde{e}_w \frac{W_s}{P_s^e} \hat{P}_t^e + \tilde{e}_u du \end{array} \right] - \gamma \hat{P}_t \\ du_t \quad &= \quad -s_L \hat{L}_t \qquad (10) \\ \hat{W}_t \quad &= \quad \hat{P}_t^e + \frac{e_u - e_{Wu}}{e_{WW}} du_t \qquad (11) \\ \hat{P}_t \quad &= \quad \hat{M}_t - \hat{c}_t + \delta \hat{\imath}_t \qquad (12) \\ \hat{y}_t^H \quad &= \quad \phi \hat{A}_t + \phi \hat{L}_t + \phi \hat{W}_t - \phi \hat{P}_t^e - \phi e^{-1} e_u s_L \hat{L}_t \qquad (13) \end{aligned}$$

where variables with hats denote percentage deviations from steady state values, s_L is the steady state employment rate, du_t is the absolute change of the unemployment rate, the s subscript denotes steady state values and δ is the elasticity of money demand with respect to the nominal interest rate. Furthermore, in steady state one has $\tilde{e}\tilde{e}_w^{-1} = \frac{W_s}{P_s^e}$. Note that (10) is our counterpart of equation (17) in Campbell (2010a). They are different as we assume the short run elasticity of labour supply with respect to $\frac{W_t}{P_t^e}$ to be zero. Consider the case of a closed economy, where $\hat{c}_t = \hat{y}_t^H = \hat{Y}_t^W$ and call $\hat{\mathcal{M}}_t = \hat{M}_t + \delta\hat{\imath}_t$. Once imposing the short-run elasticity of labor supply to be zero, the system (9)-(13) is mathematically the same as the one used by Campbell (2010a, b) to derive the following price Phillips curve

$$\hat{P}_t = \hat{P}_t^e - \phi\hat{A}_t - \frac{(1-\phi)\left[\tilde{e}_{WW} - s_L\left(\tilde{e}_u - \tilde{e}_{Wu}\right)\right] + \phi\tilde{e}^{-1}\tilde{e}_u s_L \tilde{e}_{WW}}{s_L\tilde{e}_{WW}} du_t \quad (14)$$

We now move to open first the trade account of the economy and then the capital one.

3 Opening the trade account

Once opening the trade account only, $\hat{c}_t = (1-n)\left(\hat{p}_t^H - \hat{\epsilon}_t - \hat{p}_t^F\right) + \hat{y}_t^H$, due to the aggregate resource constraint and to $\hat{P}_t = n\left(\hat{p}_t^H\right) + (1-n)\left(\hat{\epsilon}_t + \hat{p}_t^F\right)$. Furthermore, as in Razin and Yuen (2002), $\hat{Y}_t^W = n\hat{y}_t^H + (1-n)\hat{y}_t^F$. On these grounds, the Appendix shows that one can take similar steps to those taken in Campbell (2010b) to obtain the following Phillips curve

$$\begin{aligned}\hat{P}_t &= \hat{P}_t^e - \left(\frac{1-n}{\gamma}\right)\left(\hat{y}_t^F - \hat{y}_t^H\right) - \phi\hat{A}_t - \\ &\quad - \frac{(1-\phi)\left[\tilde{e}_{WW} - s_L\left(\tilde{e}_u - \tilde{e}_{Wu}\right)\right] + \phi\tilde{e}^{-1}\tilde{e}_u s_L\tilde{e}_{WW}}{s_L\tilde{e}_{WW}} du_t\end{aligned} \quad (15)$$

Note that for $n = 1$, (15) coincides with (14). The difference between (15) and (14) is not in the slope of the Phillips curve, rather in the presence of an additional shifter represented by the variation differential in foreign and domestic outputs. An increase in foreign output moves the Phillips curve downward because it produces an increase in labour demand via (9) and therefore a decline in unemployment through (10). An increase in domestic output would tend to have a similar effect on unemployment, however, in order to satisfy (12) , it should also be matched by a decrease in the level of prices under the assumptions of no money growth, no change in the interest rate and no terms of trade effect. Such a decrease in the level of prices depresses profits and labour demand, boosting unemployment. This second channel prevails because labour demand is more elastic to price changes than to $\hat{Y}_t^W$ (as $\gamma > 1$ in equation 9).

4 Opening the capital account

Upon opening the capital account, we follow Razin and Yuen (2002, p. 6) by assuming that the product of the discount rate times 1 plus the real interest rate is equal to one. As a result, consumption smoothing can be achieved and $\hat{c}_t = 0$. Therefore, (12) turns out to be $\hat{P}_t = \hat{M}_t + \delta i_t$. Under these assumptions, following Campbell (2010b), it is possible to show that the efficiency wages Phillips curve is

$$\hat{P}_t = \hat{P}_t^e - \frac{\tilde{e}_{WW} - s_L\left(\tilde{e}_u - \tilde{e}_{Wu}\right)}{s_L \tilde{e}_{WW}} du_t - \left(\frac{1-n}{\gamma}\right)\left(\hat{y}_t^F - \hat{y}_t^H\right) - \hat{y}_t^H \qquad (16)$$

Opening the capital account of the economy changes both the slope and the position of the Phillips curve. Regarding the effect of $\hat{y}_t^H$ on the position of the Phillips curve, an increase in domestic output has not to be matched now by a decrease in prices because consumption does not vary. As a consequence, it shifts the Phillips curve downward, by decreasing unemployment via an increase in labour demand.

To understand the change in the slope of the Phillips curve consider that (15) can be rewritten as follows

$$\begin{aligned} \hat{P}_t &= \hat{P}_t^e - \frac{\tilde{e}_{WW} - s_L\left(\tilde{e}_u - \tilde{e}_{Wu}\right)}{s_L\tilde{e}_{WW}} du_t - \left(\frac{1-n}{\gamma}\right)\left(\hat{y}_t^F - \hat{y}_t^H\right) - \\ &\quad -\phi\hat{A}_t + \phi\left[\frac{\tilde{e}_{WW} - s_L\left(\tilde{e}_u - \tilde{e}_{Wu}\right)}{s_L\tilde{e}_{WW}} - \tilde{e}^{-1}\tilde{e}_u\right] du_t \\ &= \hat{M}_t + \delta\hat{\imath}_t - (1-n)(\hat{p}_t^H - \hat{\epsilon}_t - p_t^F) - \hat{y}_t^H \end{aligned} \tag{17}$$

The first three terms on the right hand side of equation (17) account for changes in money holdings gross of interest payments and net of a terms of trade effect, while the further two terms account for changes in domestic output. In other words, unemployment affects changes in the level of prices through two channels, the "money" and the "output" ones. After Campbell (2006, 2010) $\tilde{e}_W > 0$, $\tilde{e}_u > 0$, $\tilde{e}_{WW} < 0$, $\tilde{e}_{Wu} < 0$ and so $\frac{\tilde{e}_{WW} - s_L(\tilde{e}_u - \tilde{e}_{Wu})}{s_L\tilde{e}_{WW}} > 0$, while $\frac{\tilde{e}_{WW} - s_L(\tilde{e}_u - \tilde{e}_{Wu})}{s_L\tilde{e}_{WW}} - \tilde{e}^{-1}\tilde{e}_u \gtreqless 0$. The money channel is therefore clearly negative, while the output channel has an *a-priori* indeterminate sign. This implies that *a-priori* the output channel might either magnify or dampen the effect of unemployment on inflation. Opening the capital account shuts the output channel down, but, given the indeterminacy of its sign, this could make the Phillips curve either steeper or flatter.

5 Conclusions

The present paper extends the efficiency wages Phillips curve proposed by Campbell (2010a) from a closed economy setting to an open economy one, building on Obstfeld and Rogoff (1996), Razin and Yuen (2002) and Danthine and Kurmann (2004). We showed that opening the trade account of the economy introduces an additional shifter into the Phillips curve, but it does not change its slope. Opening the capital account, not only highlights factors that can change the position of the Phillips curve, but it also has an impact on its slope. The sign of this impact, however, is *a-priori* indeterminate.

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6 Appendix: Deriving the efficiency wages Phillips curve upon opening the trade account of the economy

The present appendix focuses on an economy with a closed capital account and an open trade account, given that a completely open economy is a special case of what follows. The procedure below is just a generalization of the one proposed by Campbell (2010b).

Consider equation (9) and substitute inside it (10), (12) and the condition $\tilde{e}\tilde{e}_w^{-1} = \frac{W_s}{P_s^e}$. Further add and subtract from the right hand side of the resulting equation $\hat{y}_t^H$ and substitute for $\hat{y}_t^H$ by using (13) to obtain

$$\hat{L}_t = \frac{\hat{y}_t^F - \hat{y}_t^H}{\gamma}(1-n) + \left[\hat{M}_t + \delta\hat{\imath}_t - (1-n)\left(\hat{p}_t^H - \hat{\epsilon}_t - \hat{p}_t^F\right)\right] - \hat{W}_t \tag{18}$$

One can further substitute (18) into (10) and the resulting equation into (11) to obtain

$$\hat{W}_t = z\hat{P}_t^e + (1-z)\left\{\frac{\hat{y}_t^F - \hat{y}_t^H}{\gamma}(1-n) + \left[\hat{M}_t + \delta\hat{\imath}_t - (1-n)\left(\hat{p}_t^H - \hat{\epsilon}_t - \hat{p}_t^F\right)\right]\right\} \tag{19}$$

where $z = \frac{e_{WW}}{e_{WW} - s_L(e_u - e_{Wu})}$. Contrasting (18) and (19) one can have a better understanding of the negative connection between money holdings and unemployment. Money growth increases prices and, to a smaller extent, wages ($z < 1$). Therefore, the real wage declines and unemployment decreases. Such a decrease in unemployment discourages effort and this is why the output channel differs from the money one (see equation 6).

Interacting (10) , (18) and (19) leads to

$$\left(\frac{1-n}{\gamma}\right)\left(\hat{y}_t^F-\hat{y}_t^H\right)+\left[\hat{M}_t+\delta\hat{\imath}_t-(1-n)\left(\hat{p}_t^H-\hat{\epsilon}_t-\hat{p}_t^F\right)\right]=\hat{P}_t^e-\frac{1}{s_L z}du_t \tag{20}$$

(18) can be also inserted into (13) and then into (12) thanks to the equation $\hat{c}_t=(1-n)\left(\hat{p}_t^H-\hat{\epsilon}_t-\hat{p}_t^F\right)+\hat{y}_t^H$. One can use the resulting equation and (20) together with the definition of z to get (15).