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12 June 2008

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June 12, 2008

Abstract

We explore the equivalence between the factor income taxes (in Schmitt-Grohe and Uribe 1997) in the closed economy and the tariff in the open economy, in the sense that they share similar propagation mechanism of sunspot and fundamental shocks under a balanced-budget rule.

Key Words: Sunspots, Endogenous Tariff Rate, Comovement

JEL Classification Number: F41, Q43

*We wish to thank Jess Benhabib, Jushan Bai, Kim Jinill and Paul Dower for their support. *Correspondence*: Y. Zhang; Email: laurencezhang@yahoo.com; Tel: 1-212-992-9777

1. Introduction

It has been known that indeterminacy may arise as a consequence of complicated government policies that allow for feedback from the private sector to future values of fiscal policy variables. A class of models of fiscal increasing returns includes Blanchard and Summers (1987) and Schmitt-Grohe and Uribe (1997, in short SGU). The key to generate indeterminacy in those models is that keeping the government expenditure constant, an increase in the capital stock can expand the tax base and reduce the tax rate. The after tax return of the capital *may* increase as the capital stock increases, therefore the original rise in the shadow price of capital needs to be reversed and the system moves back towards the steady state, generating another equilibrium path.

Tariff as a source of fiscal increasing returns may share a similar channel with the factor income taxes to generate indeterminacy, see Zhang (2008). In Zhang, we find that if the government needs to finance its pre-set level expenditure through imposing a tariff on imported oil, it will make the endogenous rate to be countercyclical with respect to the output, thus a similar mechanism occurs.

In this paper, we introduce intrinsic uncertainty in the form of exogenous productivity and government purchases shocks and investigate the propagation mechanism of sunspot and fundamental shocks under a balanced-budget rule in the tariff model. SGU conduct a calibration of their model and observe the comovements of the variables under the fundamental and sunspot shocks. Following their method, we find many similar results, thus validating the notion that tariffs and factor income taxes are equivalent.

2. The One-Sector Open Economy With Tariff Revenue

This is the one-sector oil-in the production RBC model studied by Zhang (2008). A representative agent maximizes the intertemporal utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t (\log c_t - bn_t) \tag{1}$$

where c_t is consumption of a single good which is the numeraire and tradeable, n_t labor supply and $\beta \in (0,1)$ is the subjective discount rate in the discrete time model. Assume that the economy is open to importing oil so that the agent can use the tradeable good to buy oil. The oil price is assumed to be exogenous and its supply from the rest of the world is assumed to be perfectly elastic.

On the production side, there is a single good produced with a Cobb-Douglas production technology with three inputs–capital (k_t), labor (n_t) and non-reproducible natural resources (o_t)[1] :

$$y_t = z_t k_t^{a_k} n_t^{a_n} o_t^{a_0} \tag{2}$$

where the third factor in the production, non-reproducible natural resources, say oil (o_t),

[1] z_t is the exogenous process for productivity.

is imported, and the technology displays the constant returns to scale ($a_k+a_n+a_0=1$).

Assuming the firms are price takers in the factor markets, the profits of the firms are given by

$$\pi = y - (r+\delta)k - wn - p^o(1+\tau)o \tag{3}$$

where $(r+\delta)$ denotes the user cost of renting capital[2], w denotes the real wage, and p^o denotes the real price of oil (the imported goods). τ is the (endogenous) tariff rate imposed on the imported oil, which is uniform to all firms. Perfect competition in factor and product markets implies that factor demands are given by:

$$w_t = a_n \frac{y_t}{n_t}$$

$$r_t + \delta = a_k \frac{y_t}{k_t}$$

$$p^o(1+\tau_t) = a_0 \frac{y_t}{o_t}$$

Since we assume that the foreign input is perfectly elastically supplied, the factor price, p^o, is independent of the factor demand for o, we can obtain the reduced form

[2] $\delta \in (0,1)$ denotes the depreciation rate of capital, r_t is the rental rate of capital.

production function as we substitute out $o_t = a_0 \frac{y_t}{p^o(1+\tau_t)}$ in the equation (2),

$$y_t = z_t A k_t^{\frac{a_k}{1-a_0}} n_t^{\frac{a_n}{1-a_0}\,3}. \tag{4}$$

The government collects the tariff revenue to finance its **pre-set** level expenditure as in SGU.

$$p^o \tau_t o_t = G$$

The agent budget constraint is

$$c_t + s_{t+1} = (1 + r_t)s_t + w_t n_t + \pi_t$$

where s_t is aggregate saving[4]. Here the aggregate factor payment, $p^o(1 + \tau_t)o_t$ goes to the foreigners ($p^o o_t$) and the government ($p^o \tau_t o_t$). The first order conditions with respect to labor supply and savings are given by

$$\begin{aligned} b &= \frac{w_t}{c_t} \\ \frac{1}{c_t} &= \beta E_t \left[\frac{1}{c_{t+1}} (1 + r_{t+1}) \right] \end{aligned}$$

[4] We assume that the government consumes the tariff revenue from the importing oil. $G = p^o \tau_t o_t = \frac{\tau_t a_0 y_t}{(1+\tau_t)}$ is exogenously given.

In equilibrium, $s_t = k_t$, and factor prices equal marginal products[5].

As we see in Zhang (2008), the number of the tariff rates that generate enough revenue to finance a given level of government revenue can be 0, 1 or 2. As the steady state tariff rate is in an open interval, the indeterminacy appears.[6]

We analyze the solution to a log-linear approximation of the equilibrium conditions of the model, which, in addition to sunspot shocks, is also subject to technology and government purchases shocks. When the equilibrium is indeterminate, the equilibrium conditions can be reduced to the following first-order stochastic linear difference equation:

$$\begin{bmatrix} \widehat{\tau}_{t+1} \\ \widehat{k}_{t+1} \\ \widehat{z}_{t+1} \\ g_{t+1} \end{bmatrix} = \begin{bmatrix} \mathbf{M} & \widetilde{\mathbf{M}} \\ 0 & \mathbf{\Lambda} \end{bmatrix} \begin{bmatrix} \widehat{\tau}_{t} \\ \widehat{k}_{t} \\ \widehat{z}_{t} \\ g_{t} \end{bmatrix} + \begin{bmatrix} \varepsilon^{s}_{t+1} \\ 0 \\ \varepsilon^{z}_{t+1} \\ \varepsilon^{g}_{t+1} \end{bmatrix} \tag{5}$$

where $\mathbf{\Lambda}$ is a 2×2 diagonal matrix and $\mathbf{M}$ is a 2×2 matrix with both eigenvalues inside the unit circle.[7]The diagonal (λ_z, λ_g) in $\mathbf{\Lambda}$ denotes the serial correlation of the

[5] The first order conditions, budget constraint of the household and the government balanced budget requirement become: $bn_t = \frac{1}{c_t} a_n y_t$, $\frac{1}{c_t} = \beta E_t \frac{(1-\delta + a_k \frac{y_{t+1}}{k_{t+1}})}{c_{t+1}}$, $c_t + k_{t+1} = (1-\delta)k_t + (1-a_0)y_t$, and $p^o \tau_t o_t = G$.

[6] The upper and lower bounds of the interval are determined by the system parameters.

[7] The matrix $[\mathbf{M}]$, $[\widetilde{\mathbf{M}}]$ and $[\mathbf{\Lambda}]$ can be found in the technical appendix. The appendix is available upon request.

exogenous processes for productivity, z_t, and government expenditures, g_t, respectively. We assume that the productivity and the government expenditures innovations, ε_t^z and ε_t^g, have mean zeros and are serially uncorrelated and orthogonal to each other. The sunspot innovation ε_t^s is assumed to have zero mean and be serially uncorrelated but potentially contemporaneously correlated with either of the fundamental innovations.[8] All variables in (5) are expressed as percentage deviations from the steady state.

For the calibration of our model, we assume that the time unit is a quarter, the steady state tariff rate of oil in this country is 60 percent, and the serial correlation of both fundamental shocks is 0.9 ($\lambda_z = \lambda_g$).[9] The remaining parameters take the values as in Wen and Aguiar-Conraria (2005)[10]. Given the above values of those parameters, the rational expectation equilibrium is indeterminate.

Figure 1 displays the impulse responses of the tariff rate, output, hours, and consumption to sunspot ($\varepsilon_0^s = 1$), technology ($\varepsilon_0^z = 1$), and government expenditures shocks ($\varepsilon_0^g = 1$). Panel a of figure 1 shows the impulse responses to one unit innovation ($\varepsilon_0^s = 1$) in the tariff rate under the assumption that ε_t^s is uncorrelated with any fundamental shock. The initial increase in the tariff rate triggers a highly persistent, hump-shaped response in aggregate economy variables and tariff rate. When the equilibrium is indeterminate, the initial responses of endogenous variables to fundamental shocks is

[8] In our numerical exercise, $\varepsilon_{t+1}^s = \widehat{\tau}_{t+1} - E_t[\widehat{\tau}_{t+1}]$ can be viewed as the forecast error of $\widehat{\tau}_{t+1}$

[9] The steady state tariff rate is the optimal rate calculated by Newbery (2005), which is consistent with the one in EU (2002). See Zhang (2008).

[10] $\delta = 0.025$, $\beta = 0.99$, $a_k = 0.09$, $a_o = 0.21$ and $a_n = 0.7$ are of the country, Netherland.

not necessarily magnified. Panels b and c of figure 1 show, respectively, the impulse responses to technology and government expenditure shocks under three alternative assumptions about the initial percentage deviations in the tariff rate: -10, 0, and 10. As shown in panel b, for example, a positive innovation in the technology shock can lead to a contraction in output if the initial response of the tariff rate is sufficiently above the steady state. Under indeterminacy, the impulse responses of aggregate economy variables are highly persistent, hump-shaped regardless of the the initial value of the tariff rate.

When the economy is subject to fundamental and sunspot shocks, the comovements of tariffs, output, hours, and consumption depend in principle on our assumed correlation of the sunspot shock with the fundamental shock and on the relative importance of each source of uncertainty. Figure 2 summarizes this relationship when the only sources of uncertainty are sunspot shocks and persistent productivity shock ($\lambda_a = 0.9$). It shows the serial correlation (panel a), the contemporaneous correlation with output (panel b), and the standard deviation relative to output (panel c) of the tariff rate, output, hours, and consumption as a function of the variance of sunspot shock, $\sigma^2_{\varepsilon^s}$. For three different values of the correlation between the sunspot and the technology shocks: -1, 0, and 1, the variance of the sunspot shock, $\sigma^2_{\varepsilon^s}$, is shown on the horizontal axis; it takes values between zero and one. The variance of innovation in the technology shock, $\sigma^2_{\varepsilon^z}$, is set so that the sum of the variance of the innovations in the technology and sunspot shocks is equal to one, $\sigma^2_{\varepsilon^s} + \sigma^2_{\varepsilon^z} = 1$. The figure 2 encompasses two extreme cases: one in which the economy is hit only by sunspot shocks ($\sigma^2_{\varepsilon^s} = 1$, $\sigma^2_{\varepsilon^z} = 0$) and another in which the economy is hit only by technology shock($\sigma^2_{\varepsilon^s} = 0$, $\sigma^2_{\varepsilon^z} = 1$). Each plot displays three lines: the solid line corresponds to the case in which the sunspot and the technology innovations are uncorrelated ($corr(\varepsilon^s_t, \varepsilon^z_t) = 0$), a dotted line corresponds to the case in which the correlation between the sunspot and the technology innovations is equal to -1 ($corr(\varepsilon^s_t, \varepsilon^z_t) = -1$), and a chain-dotted line corresponds to the case in which the correlation between the sunspot and the technology innovations is equal to 1 ($corr(\varepsilon^s_t, \varepsilon^z_t) = 1$). Panel a, b, and c show, respectively, the first-order correlation, the contemporaneous correlation with output, and the standard deviation relative to output of the tariff rate, output, hours, and consumption as a function of the variance of the sunspot shock ($\sigma^2_{\varepsilon^s}$).

The main implication of figure 2 is that neither the first-order serial correlations, the contemporaneous correlations with output, nor the standard deviation relative to output of tariff rates, hours, and consumption is affected by the relative volatility of the sunspot shock or its correlation with the technology shock. This can be seen in the fact that in most cases the three lines are perfectly flat and indistinguishable from each other. This shows that rational expectations equilibrium under the indeterminacy case does not necessarily imply that any arbitrary pattern of comovement in endogeneous variables can be supported as an equlibirium outcome by an appropriate choice for the joint distribution of sunspot and fundamental shocks[11].

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[11] When the economy is subject to persistent government expenditure and sunspot shocks, a similar result can arise.

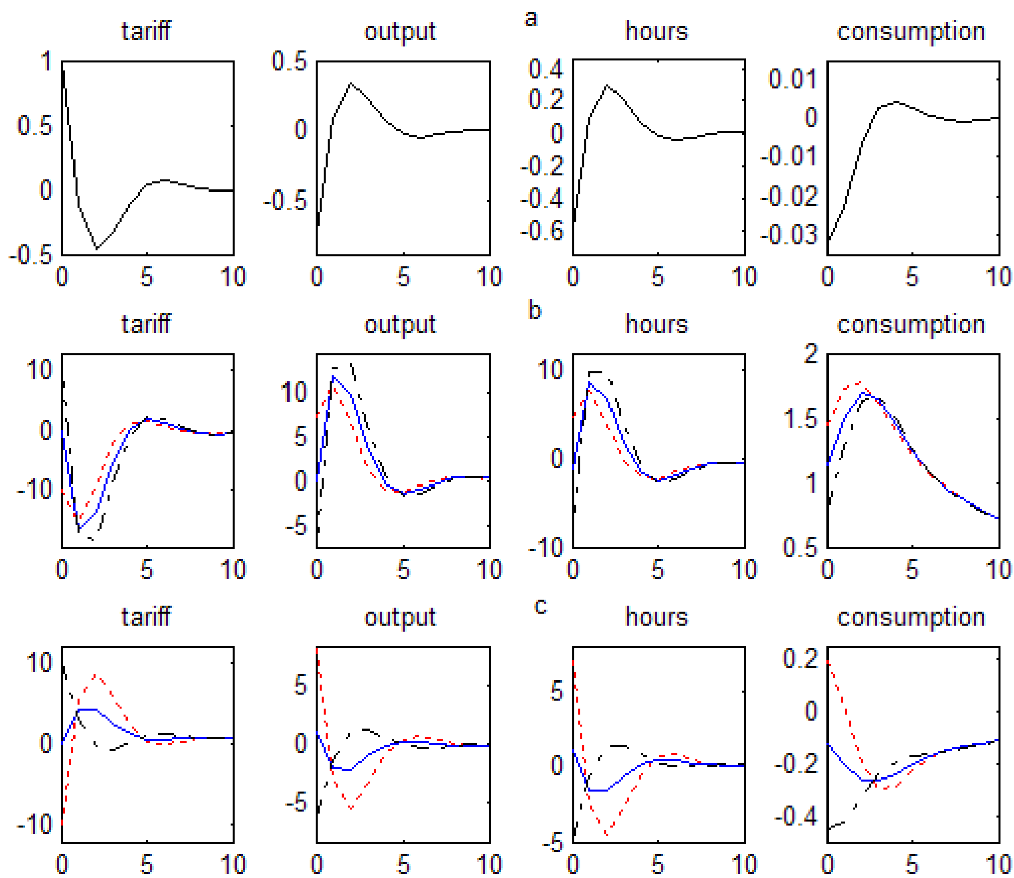

Figure 2.1: —Impulse responses. a, Sunspot shock, $\varepsilon_0^s = 1$. b, Technology shock, $\varepsilon_0^z = 1$. c, Government expenditures shock, $\varepsilon_0^g = 1$. The technology and government expenditures shocks are assumed to follow univariate $AR(1)$ processes with a high serial correlation of 0.9. The steady-state tariff rate is $\tau = 0.6$, which implies that the rational expectation equlibrium is indeterminate. All variables are expressed in percentage deviations from the steady state.— $\widehat{\tau}_0 = 0$, $\cdots$ $\widehat{\tau}_0 = -10$, -·- $\widehat{\tau}_0 = 10$

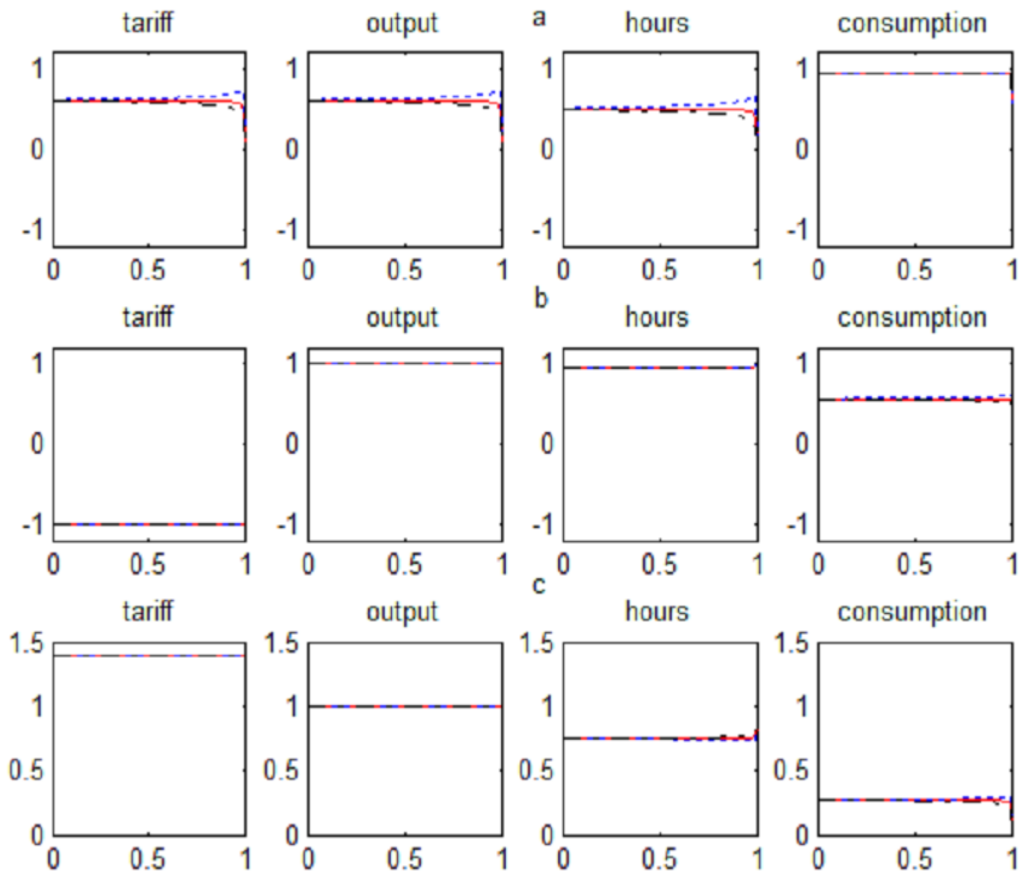

Figure 2.2: ——Comovements. Each plot shows either the serial correlation (panel a), the contemporaneous correlation with output (panel b), or the standard deviation relative to output (panel c) as a function of the variance of sunspot shock, $\sigma^2_{\varepsilon^s}$, for three different values of the correlation between the sunspot and the technology shocks: -1, 0, and 1. The variance of the sunspot shock, $\sigma^2_{\varepsilon^s}$, is shown on the horizontal axis; it takes values between zero and one. The variance of innovation in the technology shock, $\sigma^2_{\varepsilon^z}$, is set so that the sum of the variance of the innovations in the technology and sunspot shocks is equal to one, $\sigma^2_{\varepsilon^s} + \sigma^2_{\varepsilon^z} = 1$. — $corr(\varepsilon^s_t, \varepsilon^z_t) = 0$, ...$corr(\varepsilon^s_t, \varepsilon^z_t) = -1$, -.-$corr(\varepsilon^s_t, \varepsilon^z_t) = 1$