Real Business Cycles in a Small Open Economy with Non-Traded Goods*

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and

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1. Introduction

The Israeli economy business cycle properties are different from those of most OECD countries in four main dimensions (see, Table 1). First, aggregate consumption is twenty percent more volatile than output. Second, the trade balance is much more volatile than output and is procyclical. Third, investment is almost five times more volatile than output, and fourth, the auto-correlation in output is low.

The goal of this paper is to provide a simple extension of the real business cycle model of a small open economy that can fit these facts. In particular, extending the standard model for two sectors of traded and non-traded goods and using the Israeli data for the parameter specification, we can well fit the above exceptional business cycle observations. Following Tesar (1993), our main deviation from the standard model is the CES utility function for traded and non-traded goods, which allows for a wide range of volatility in consumption of traded goods.

The analysis starts with a small open economy with one traded good and endogenous labor supply as in Corria, Neves and Rebelo (1995) (CNR). We show that using this model with the Israeli economy moment estimators for the parameters, implies that consumption is extremely smooth when utility is Cobb-Douglas and is seventy five percent of output if the utility is as in Greenwood, Huffman and Hercowitz (1988) (GHH). [2]Moreover, whenever the model generates volatile consumption and investment paths, as observed in the data, the balance of trade becomes counter-cyclical, which is opposed to the Israeli stylized fact.

The one sector open economy model with free borrowing and lending and a fixed interest rate, strengthens the text book claim on consumption smoothness. That is, aggregate consumption volatility is lower than output volatility due to the agent's desire to smooth consumption in response to business fluctuations in output.[3] However, the fact that in countries such as Japan, United Kingdom and Austria consumption volatility is higher

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[2] For an explanation of the differences in consumption volatility due to utilities functions specifications in open small economies, see CNR (1995).

[3] Fridman's permanent income hypothesis, and Kydland and Prescott's (1982) classical paper provided the end qualitative and quantitative economic foundations for the observed facts that the U.S consumption volatility is about seventy five percent of production

than output volatility (see Table 1) is inconsistent with the textbook claim. We find that the Israeli data shows that consumption of traded goods is about three times more volatile than output while volatility of consumption of non-traded goods is about two thirds of the volatility of output. This fact is at odds with intuition based on the one sector model of a small open economy.

The puzzle that these observations imply is explained in this paper by the result that with the three parameters of the CES utility function and the share of non-traded goods in government expenditures, one can get almost any volatility in consumption, holding constant the production side parameters. The three utility function parameters are the level of complementarily between the traded goods and the non-traded goods, the level of risk aversion and the weight of aggregate traded goods relative to non-traded goods. The combination of these parameters drastically affects the consumer decision on shifting the traded goods consumption in response to shock in both sectors.

The main result is that the model fits all the main business cycle properties of the Israeli economy, described above.[4] This result is based on empirical properties of the Israeli economy. In particular, the data shows that the non-traded goods are a large fraction of aggregate consumption, traded and non-traded goods are relatively complement goods in consumer's preferences and the relative risk aversion parameter is low. The model's assumptions are that the production shocks to the two sectors are of standard first order auto correlation process with the same variance, that the investment cost of adjustments are fitted to the data (following Baxter and Crucini (1993)), and the government consumption of traded and non-traded goods are a constant share of output.

The remainder of the paper is written as follows. In the next section we present the main business cycle facts of the Israeli economy in comparison to other OECD countries and discuss the main facts on the Israeli aggregate time series. In section 3 we present a model of small open economy with traded and non-traded goods, and explain how it is solved and estimated. Then we show that using the one sector model for the Israeli economy we

[4] The main deviation of the predicted moments from the data is that the model predicts a high volatility in the balance of trade series relative to what is observed. Yet the direction of the over prediction is consistent with the deviation of the model from the existing standard models.

cannot fit the main observed business cycle facts. In section 5 we show how the estimated model fit the volatility moment of the Israeli economy.

2. Data

Table 1 below provides business cycle sample moments for the Israeli economy and for selected OECD countries. The samples range respectively, from 1970.1 through 1997.4 and from 1972.1 through 1992.2. The data sources for the Israeli economy are the Bank of Israel and the Central Bureau Statistic (CBS). Data for the OECD countries are from OECD`s Quarterly National Account and based on Backus, Kehoe and Kydland (1995). All series are in logarithms (with the exception of the balance of trade (TB)) and detrended with the Hodrick Prescott (H-P) filter.

Several observations can be made based on Table 1.

1. For most countries consumption is less volatile than output. For Israel it is most striking that consumption is more volatile than output. The stylized fact is that consumption variance is lower than output variance as it is for the average of OECD and European countries. Furthermore for all countries, including Israel, consumption is positively correlated with output.
2. Balance-of-trade is less volatile than output for all countries except Israel. Furthermore the balance-of-trade is negatively correlated with output for all countries except Israel.
3. For all countries investment is about two to three times more volatile than output, while for Israel investment it is almost five times more volatile than output. Investment is procyclical for all countries including Israel.[5]
4. For all economies the output is positively auto-correlated with a correlation coeficient that ranges between 0.6 to 0.9 for the OECD countries while for Israel it is much lower and is equal to 0.4.

[5] The differences in relative volatility between Israel and the OECD countries probably reflect differences in the covariance of the aggregate series within each economy.

Table 1

Moments of Macroeconomic Variables Detrended with the Hodrick-Prescott filter, OECD Economies and Israel

Country	*sd(x)/sd(y)*			*Autocorr*	*Corr with Y*		
	C	*TB*	*I*	*Y*	*C*	*TB*	*I*
Israel	1.20	1.87	4.88	.40	.30	.19	.38
Australia	.66	0.84	2.78	.60	.46	-.01	.67
Austria	1.14	0.89	2.92	.57	.65	-.46	.75
Canada	.85	0.52	2.80	.79	.83	-.26	.52
France	.99	0.91	2.96	.78	.61	-.30	.79
Germany	.90	0.52	2.93	.65	.66	-.11	.84
Italy	.78	0.78	1.95	.85	.82	-.68	.86
Japan	1.09	0.68	2.41	.80	.80	-.22	.90
Switzeland	.74	0.68	2.30	.90	.81	-.68	.82
U.K	1.15	0.73	2.29	.63	.74	-.19	.59
U.S	.75	0.27	3.27	.86	.82	-.37	.94
Europe	.83	0.49	2.09	.75	.81	-.25	.89

Notes: Data are quarterly from OECD`s Quarterly National Account 1972.1:1990.2 (based on Backus Kehoe and Kydland (1995)). The Israeli data are from Bank of Israel and CBS 1970.1:1997.4. All series are in logarithms (with the exception of the Net Export/GDP) and are detrended with the HP filter. Variables are defined as the following: Y, real output; C, real consumption (nondurable); I real investment; TB, ratio of net-export to output-both in current prices. The statistics for the Israel economy are based on GMM estimators as described in Christiano and Eichenbaum (1992) where the standard errors written in Table 6.

An explanation for these differences in volatility of consumption and investment series and the balance-of-trade cyclicality is the main subject of this paper. Our hypothesis is that the Israeli unique business cycle properties are due to the role of non-traded goods. In order to aggregate the data for traded and non-traded goods, we follow Stockman and Tesar's (1995) categorization of goods sectors (based on Kravis etc. (1982)). Their classification includes agriculture, manufacturing, retail and transportation in the traded sector, and electricity, construction, private and government services in the non-traded sector (full details on decomposition are provided in Balsam (1999)). It turns out that in Israel the non-traded sector is relatively large, and amounts to approximately *more than two thirds* of GDP, while under Stockman and Tesar (1995) decomposition the non-traded sector in Canada, France, Germany, Italy, Japan, United Kingdom, United State is on average *one half* of output[6]. Figure 1 in Appendix A depicts the traded and non-traded series for the Israeli economy.[7] Final private consumption is also constructed as in Stockman and Tesar, where the expenses on services are considered as non-traded goods. The share of the non-traded component in Israel's total consumption equals 0.6 while in the sampled OECD countries the average share is about 0.5.

Table A1 (Appendix A) summarizes the relative volatility of the sectoral moments for the Israeli economy from 1971.1 through 1997.4.[8] The striking feature of Table A1 is that the volatility of consumption of traded goods is as almost four times higher as that of the non-traded goods. Furthermore, the relative volatility of non-traded consumption to non-traded output is 0.59 where the counterpart volatility in the traded sector is 2.45. These facts show that for the Israeli economy the opportunity to trade across borders does not necessitate a smooth path for the traded consumption goods and probably other engines contribute to these consumption fluctuations, whereas in this paper we try to explain this mechanism by introducing non-traded goods.[9] In order to compare these facts to the OECD countries, we present in Table A1b the volatility of consumption of traded and non-traded goods as computed in Stockman and Tesar (1995). The statistics are based on averages of selected OECD countries. It is observed that the relative volatility in consumption of traded and non-traded goods are almost the same, whereas in both sectors the relative volatility of consumption to output is less than one. Furthermore, the consumption path of the traded goods relative to output of the traded goods seems to be smoother. These facts are different from the Israeli business cycle properties.

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[6] This grand value in Israel economy is mainly due to massive public and services sectors.

[7] The sectoral data on the Israeli ecnonmy is available on annual frequency. In order to derive quarterly series we assume that the quarterly weight is the same as the annual weight.

[8] The data start from 1971 due to availability, as for the classification of traded and non-traded goods.

[9] It should be noted that the trade deficit in Israel for the examined period is about 14 percent of output, where import consists of 39 percent of output.

Table A1 shows the cyclicle properties of three different measures of the real exchange rate, which is defined as the price ratio between traded to non-traded goods.[10] It turns out that the alternative definitions of the real exchange rate produce different relative volatility and contemporaneous correlations with output. In all cases the price ratio is more volatile than output.

In Table A2 (Appendix A) we display the contemporaneous correlations of the aggregate series. Most of the aggregate series exhibit positive contemporaneous correlations with the exception of the government expenditures, which are negatively correlated with most of the other variables.

3. The Model

The economy consists of two competitive firms that produce traded goods, Y_T and non-traded goods, Y_{NT}. Labor, L, is assumed to be constant. There is a representative consumer who maximizes her expected lifetime utility from consuming traded goods, C_T and non-traded goods, C_{NT} and a government who consumes non-traded goods, G_{NT} that is, financed by a lump sum transfer, τ.

Production

The traded goods and the non-traded goods are produced by Cobb-Douglas production functions that are given by,

$$(3.1) \qquad Y_{T_t} = \left(A_{T_t} \cdot L_{T_t}\right)^{\xi} K_{Tt}^{\;1-\xi} V_{T_t}, \qquad 0 < \xi < 1$$

$$(3.2) \qquad Y_{NT_t} = \left(A_{NT_t} L_{NT_t}\right)^{\alpha} K_{NT}^{1-\alpha} \cdot V_{NT_t} \qquad 0 < \alpha < 1$$

[10] Specifically we compare the model to three different measures of the price ratio. The first method, which is marked in the Table as A is taken from Helpman and Drazen (1987) where the ratio is extracted from a general price function which is consistent with the model definitions. The second method, which is marked in Table 7 as B is taken from Razin and Cuckerman (1976) where the price ratio is extracted based on CPI, according to the consumption's classification. The third method which is marked in Table 7 as C is taken from Meridor and Pesach (1994) where the ratio is calculated according to the ratio of import prices to output prices, C1, and the ratio of export prices to output prices, C2. The data availability for methods B and C are from 1981.1 to 1997.4, where the data availability for method A is from 1970.1 to 1997.4, which are marked as A1, where A2 represents the data from 1981.1 to 1997.4.

where L_{Tt} and L_{NTt} are the traded and non-traded labor inputs, respectively, such that $L_{Tt} + L_{NTt} = L$ and L is a constant. The capital stock in the two sectors is denoted by K_T, for traded goods production and K_{NT} for the non-traded goods production. The technology level is given by A_{NT}, A_T and is growing by a constant growth rate, γ such that,

$$(3.3) \qquad A_{NT\,t} = A_{T\,t} = \gamma^t .$$

The technology shocks are given by V_T and V_{NT} which follow a stochastic AR(1) process such that,

$$(3.4) \qquad V_{T\,t} = V_{T0}^{\,1-\rho_T} V_{T_{t-1}}^{\,\rho_T} \cdot e^{U_{Tt}}$$

$$(3.5) \qquad V_{NT\,t} = V_{NT\,0}^{\,1-\rho_{NT}} V_{NT_{t-1}}^{\,\rho_{NT}} \cdot e^{U_{NTt}}$$

where $0 < \rho_i < 1$ and U_i, $i = T, NT$, are i.i.d. shocks with zero mean and constant variance.

Investment

The laws of motion for investment, which are industry specific (Stockman and Tesar (1995)) are given by,

$$(3.6) \qquad K_{Tt+1} = \vartheta_T\left(I_{Tt} / K_{Tt}\right)K_{Tt} + (1-\delta)K_{Tt}$$

$$(3.7) \qquad K_{NTt+1} = \vartheta_{NT}\left(I_{NTt} / K_{NTt}\right)K_{NTt} + (1-\delta)K_{NTt} ,$$

where $0 < \delta < 1$ denotes the depreciation rate. $\vartheta_i\left(I_{it} / K_{it}\right)$, $i = T, NT$, are the adjustment cost functions following Hayashi (1982) and Baxter and Crucini (1993). Both functions are increasing, concave and twice continuously differentiable. In order to impose a condition that there are no adjustment costs at the steady state, it is assumed that $\vartheta(\gamma - 1 + \delta) = \gamma - 1 + \delta$ and $\vartheta'(\gamma - 1 + \delta) = 1$ where $\gamma - 1 + \delta$ is the steady state ratio of investment to capital.

Optimization

Firms choose $L_{i,t}$ and $K_{i,t+1}$, $i = T, NT$, to maximize their present value profits, where the price of traded goods and the real wage in terms of the traded goods, w, are taken as given stochastic processes and the real interest rate is a constant that is equal to r*. As such the optimization problem is,

$$(3.8) \qquad MAX \qquad E_0 \sum_{t=0}^{\infty} \left\{ \left(\frac{1}{1+r^*} \right)^t \begin{bmatrix} F_T(K_{Tt}, L_{Tt}, A_{Tt}) - w_t L_{Tt} - I_{Tt} \\ -q_{Tt}\left(K_{Tt+1} - K_{Tt}(1-\delta) - \vartheta_T\left(I_{T,t} / K_{T,t}\right) \cdot K_{Tt}\right) \end{bmatrix} \right\},$$

$$(3.9) \qquad MAX \qquad E_0 \sum_{t=0}^{\infty} \left\{ \left(\frac{1}{1+r^*} \right)^t \begin{bmatrix} P_t F_{NT}(K_{NTt}, L_{NTt}, A_{NTt}) - w_t L_{NTt} - I_{NTt} \\ -q_{NTt}\left(K_{NTt+1} - K_{NTt}(1-\delta) - \vartheta_{NT}\left(I_{NT,t} / K_{NT,t}\right) \cdot K_{NTt}\right) \end{bmatrix} \right\},$$

where $P_t \equiv P_{NTt} / P_{Tt}$ is the reciprocal of the real exchange rate. q_{NT} and q_T, are the Lagrange multipliers (Tobin's q).

The first order conditions for the optimization problems (3.8) and (3.9) are given by,

$$(3.10) \qquad -1 + \vartheta'\left(\frac{I_{Tt}}{K_{Tt}} \right) q_{Tt} = 0$$

$$(3.11) \qquad -1 + \vartheta'\left(\frac{I_{NTt}}{K_{NTt}} \right) q_{NTt} = 0$$

$$(3.12) \qquad q_{Tt}(1+r^*) = E_t\left[\frac{\partial F_{T,t+1}}{\partial K_{Tt+1}} + (1-\delta) q_{Tt+1} + q_{Tt+1}\left(\vartheta_T\left(\frac{I_{Tt+1}}{K_{Tt+1}} \right) - \vartheta_T'\left(\frac{I_{Tt+1}}{K_{Tt+1}} \right) \frac{I_{Tt+1}}{K_{Tt+1}} \right) \right]$$

$$(3.13) \qquad P_t q_{NTt}(1+r^*) = E_t\left[P_t \frac{\partial F_{NT,t+1}}{\partial K_{NTt+1}} + (1-\delta) q_{NTt+1} + q_{NTt+1}\left(\vartheta_{NT}\left(\frac{I_{NTt+1}}{K_{NTt+1}} \right) - \vartheta_{NT}'\left(\frac{I_{NTt+1}}{K_{NTt+1}} \right) \frac{I_{NTt+1}}{K_{NTt+1}} \right) \right]$$

$$(3.14) \qquad w_t = \frac{\partial F_{T,t}}{\partial L_{T,t}}$$

$$(3.15) \qquad w_t = P_t \frac{\partial F_{NT,t}}{\partial L_{NT,t}}$$

The Euler equations (3.10)-(3.11) specify the equality between the shadow price of capital and the marginal cost of investment. The equality between the shadow price of capital and its expected marginal gain is given by the Euler equations (3.12)-(3.13). The labor demand equations are given by (3.14)-(3.15).

Representative Consumer

The representative consumer chooses consumption, to maximize her expected lifetime present value of utility from consumption of traded and non-traded goods, which is,

$$(3.16) \qquad \text{MAX} \;\; E_0 \sum_{t=0}^{\infty} \beta^t U(C_{Tt}, C_{NTt}).$$

E_t denotes the expectations conditional on information at time period t, and β is the discount rate. The maximization in (3.16) is subject to the budget constraint, expressed in terms of the traded good,

$$(3.17) \qquad C_{Tt} + P_t C_{NTt} + B_{t+1} = P_t Y_{NTt} + Y_{Tt} - P_t I_{NTt} - I_{Tt} - \tau_t + B_t(1 + r^*),$$

where B_t is a financial asset that is traded in the international capital markets.

The consumer optimization problem above can be written as the following Lagrangian problem,

$$(3.18) \quad \text{MAX} \quad E_0 \sum_{t=0}^{\infty} \beta^t \left\{ U(C_{Tt}, C_{NTt}) - \Lambda_t \begin{pmatrix} C_{Tt} + P_t C_{NTt} + B_{t+1} - P_t \cdot Y_{NTt} - \\ Y_{Tt} + P_t I_{NTt} + I_{Tt} + \tau_t - B_t(1 + r^*) \end{pmatrix} \right\},$$

where Λ_t is the lagrangian multiplier. The first order Euler conditions of (3.18) are,

$$(3.19) \qquad U_{CT}(t) - \Lambda_t = 0$$

$$(3.20) \qquad U_{CNT}(t) - \Lambda_t P_t = 0$$

$$(3.21) \qquad -1 + \beta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} \cdot (1 + r^*) \right] = 0 \;.$$

It is assumed that the utility function has the following analytical specification,

$$(3.22) \qquad U(C_{T,} C_{NT}) = \frac{\left(v^{1/\mu} C_T^{(\mu-1)/\mu} + (1-v)^{1/\mu} C_{NT}^{(\mu-1)/\mu}\right)^{1-\theta} - 1}{1-\theta},$$

where v is the relative magnitude of the traded goods in total consumption, $1/\theta$ is the intertemporal rate of substitution and the constant relative risk aversion, and $1/\mu$ is the elasticity of intratemporal rate of substitution between the two goods, such that $\theta > 1, \ \mu > 0$, and if $\mu = 1$ then the utility function is Cobb-Douglas.

Government

We assume that the government consumes only non-traded goods. As such, each period the government budget constraint is given by,

$$(3.23) \qquad G_{NT\,t} \cdot P_t = \tau_t,$$

where G_{NT} is assumed to be deterministic.[11]

Equilibrium Conditions

The clearing markets equilibrium conditions are,

$$(3.24) \qquad C_{NTt} + G_{NT\,t} + P_t^{-1} I_{NTt} = Y_{NTt}$$

$$(3.25) \qquad C_{Tt} + I_{Tt} + TB_t = Y_{Tt}$$

$$(3.26) \qquad TB_t = B_{t+1} - B_t(1 + r^*),$$

where TB is the balance of trade, which is measured as net export.

Finally, we impose the "no-ponzi game condition", $\lim_{t \to \infty} \left(B_{t+1} / (1 + r^*)^{t+1}\right) = 0$, which rules out the possibility that the interest rate payments are financed with further borrowing, and therefore the initial amounts of debt is never paid back.

[11] In section 5 we relax this assumption and assume that the government also consumes traded goods.

Solution

The model is solved using a numerical approximation method following Kydland and Prescott (1982) and King, Plosser and Rebelo (1988). The solution for the stochastic equilibrium is based on a log-linearization of the model's equations around its non-stochastic steady state. Specifically, we log-linearize equations: (3.1),(3.2), (3.6), (3.7), (3.10-3.15), (3.17), and (3.19-3.21) where the equilibrium conditions (3.24-3.26) are substituted into the consumer budget constraint, (3.17). The solution consists of stochastic processes for the endogenous variables of the model conditional on the parameters and the stochastic specification of the technology shocks.[12]

Parameters

Table 2 presents the values for the parameters of the model. These values are found by estimating the parameters using the Israeli aggregate time series and estimations of parameters from other studies.

We assumed that the discount rate β is equaled to 0.997. The relative risk aversion θ is set to 1.4 based on the estimation by Bental and Eckstein (1997). This low value is consistent with results from Balsam, Kandel and Levy (1998) and Levy (1997). The utility parameter v is estimated as 0.4, using the sample mean value of the ratio of traded goods to non-traded goods of non-durable private consumption. The aggregate labor supply L, which is defined as the total working time divided by the total time available to the consumer, is set to be equaled to 0.16 as estimated by Bental and Eckstein (1997). The elasticity of intratemporal substitution $\mu = 0.54$ is estimated by using the Euler condition (3.22) at the steady state given the values of (θ, β, γ), and the investment output ratio which is estimated to be equaled to 0.25.[13]

The growth rate parameter $\gamma = 1.0055$ is estimated by equating the steady state growth rate of GDP per capita in the model to quarterly data of per capita GDP growth rate. The

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[12] We take $\vartheta\left(\frac{I_{NTt}}{K_{NTt}}\right)$ as a parameter.

[13] The relevant Euler equation in steady state is, $1 = \beta(1+r^*)\gamma^{(\mu-1)/\mu-\theta}$, where r*, which is set to be equal to 0.022, determines the investment output ratio

production functions labor elasticities parameters are estimated to equal $\alpha = 0.68$, and $\xi = 0.60$ using the ratio of nominal wage expenditure to nominal output in each sector (see, Balsam (2000)). The parameter V_T is normalized to be equal to one and V_{NT} is estimated by the ratio of consumption of non-traded goods to traded goods, following Rebelo and Vegh (1995).

The depreciation rate is set to $\delta = 0.02$ following Dahan and Hercowitz (1998). The government expenditure of non-traded goods, Gnt=0.24 is estimated by the ratio of the government expenditure on non-traded goods and output[14]. The parameter, b, which demonstrates the foreigner debt level in steady state, is estimated such that the ratio of consumption to output is 0.64 (see, Rebelo and Vegh'(1995)). As in Baxter and Crunici (1993) we set the parameter csi, (the elasticity of the adjustment cost function) to be equal to 1/15. Since the investment path generated by the model depends heavily on this value, In section 6 we examine different parameterization values for csi. We follow Kydland and Prescott (1982) and set the stochastic processes of shock to production, $\rho_{NT} = \rho_T = 0.55, \sigma_{NT}{}^2 = \sigma_T{}^2 = .0012$, such that the output persistence and its volatility is as observed in the data.

Table 2: Parameters

Parameters	Values
Relative risk aversion (θ)	1.4
Momentary utility (v)	.4
Labor supply $(\bar{L})$	0.16
Growth rate (γ)	1.0055
Labor share, non-traded sector (α)	0.68
Labor share, traded sector (ξ)	0.6
Level parameter, non-traded sector (V_{NT})	1.36
Level parameter, traded sector (V_{T})	1
Foreign debt (b)	9[15]
Depreciation (δ)	0.02
Government expenditure on non-traded goods (Gnt)	0.17[16]
Elasticity of intratemporal substitution (μ)	0.54
Time preference coefficient (β)	0.997
Adjustment cost elasticity (csi)	1/15
Shock's Persistence (ρ_{NT}, ρ_{T})	0.55
Shock's variance $(\sigma^2_{T}, \sigma^2_{NT})$	0.0012

[14] This ratio is computed after subtracting the traded government expenditures from output and net import. In section 6 we consider an elaborate environment in which the model includes government expenditure on traded goods.

[15] This value generates a long run ratio of foreign debt to output which equals to 12.4.

[16] This value generates a long run ration of government expenditure on non-traded goods to output which ד] equal to 0.24.

4. The One Sector Model

As explained in the introduction, the one sector neo-classical model of a small open economy cannot replicate the Israeli business cycle data. Corria, Neves and Rebelo (1995) (CNR) show that using a Coub-Douglas utility function implies a miniscule relative volatility in consumption path in conjunction with procyclicality in the balance of trade series. While adopting a GHH (Greenwood, Huffman and Hercowitz (1988)) utility function, which has the unique property that hours worked are determined solely by wage, can generate higher volatility in the consumption and counter-cyclicality in the balance-of-trade, as it is observed in most OECD contries. This utility function implies a different link between labor supply movements and consumption movements, which produces higher variance in consumption where the higher volatility in consumption has an impact on the balance of trade dynamics.

These properties of the neo-classical open economy model are not consistent with the business cycle properties of the Israel economy that we presented above. Specifically, for the Israel economy the variability in consumption has to be larger than output and the balance of trade has to be pro-cyclical rather than counter-cyclical.

In this section, we follow CNR model and try to find whether it is possible, using the Israeli estimated moments to specify a version of the model stochastic processes in order to fit the unique Israeli observed facts. As such, we modify the model presented in section 3, to be consistent with CNR. Both the utility and the production functions include only one traded good and we assume that the representative consumer derives utility from leisure such that the labor supply is endogenous. The model's parameters are estimated to fit the Israeli data (see, Appendix B for details), and Table 2 below summarizes our simulation results for this one sector model.

In case 1 we assume a Cobb-Douglas utility function, where the shocks to production stochastic process parameters are estimated using the Solow residual (see Appendix B). In this case consumption is extremely smooth, as a result of the borrowing and lending opportunities in the international market at a constant real interest rate. Therefore, the trade balance volatility becomes almost five times larger than the volatility of GDP and the correlation of the balance of trade with GDP is almost one. Obviously this result is inconsistent with the Israeli facts, but it is similar to the result reported by CNR.

In case 2 we assume a GHH utility function. Using this utility function with the relevant estimators of parameters (see Appendix B) we get that consumption is more volatile and the balance of trade is counter-cyclical as reported by CNR. Furthermore, we get low variability in the balance of trade.[17]

In case 3, we follow Kydland and Prescott (1982) and set the stochastic process of the shock to production $(\rho = .55 \text{ and } \sigma = 0.014)$, such that the output persistence and its volatility is as observed in the data. It is shown that pro-cyclicality of the balance of trade can be achieved under the GHH preference assumption. However, the investment path exhibits a counterfactual smoothness. This smoothness is a direct result of the low shock persistence, which follows the low auto-correlation observed in output data.

In case 4 we follow the shock's specification as assumed in case 3 and set the adjustment cost parameter (csi) in a way that guarantees a replication of the relative volatility in the investment dynamics.[18] As expected this high volatility in the investment path leads to a "pro-investment" dominance, which causes a counter cyclicality in the balance of trade and an excess volatility in its path. Furthermore, consumption volatility is lower than that of output.

To sum up, the above-mentioned examples show the failure of the standard small open economy model to replicate business cycle properties which exhibit high variance in consumption and investment series in conjunction with procyclicality in the balance of trade. In Balsam (2000) it is shown that this model performance cannot be improved by considering a more elaborate environment, which contains stochastic shocks to government expenditures or to foreign transfers[19]. These experiments provide the motivation for deviating from the standard one-sector framework.

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[17] CNR (pages 1097-1099) provide a very detailed explanation for the functions.

[18] Specifically, we choose values for the stochastic process and the elasticity of adjustment cost (csi) $(\rho = 0.485,\ \sigma = 0.014 \text{ and } csi = 1/200)$ that are consistent with both volatility in output and in investment as well as with the observed auto-correlation of output.

[19] As shown in CNR, in this framework government and foreign transfer shocks have the same influence on the decision rules through the income effect.

Table 3: Simulation Results, Basic Neo-Classic Model

Case	sd(x)/sd(y)			Corr with Y		
	C	TB	I	C,Y	TB,Y	I,Y
1	.067	4.77	.91	.97	.99	.97
	(0)	(.01)	(.005)	(.005)	(0)	(.007)
2	.75	.22	1.00	.99	-.71	.98
	(0(	).0075(	(.005(	)0(	).06)	)0.002)
3	.75	.31	.64	.99	.97	.99
	)0(	).005(	).002(	)0(	).004(	).001(
4	.74	5.24	4.78	1	-.84	.89
	(0(	).15(	).14(	)0(	).03(	).02(

Notes: C is defined as Consumption; TB is defined as the Balance of Trade measured as Net-Export; I is defined as Investment; Y is defined as Output. Case 1 shows the simulation results for the Coubb-Douglas utility function. Case 2 shows the simulation results for the GHH utility function. Case 3 shows the simulation results for the GHH utility function where $\rho = .55$ instead of $\rho = .67$ as in the previous case. This low value generates the persistence and volatility in the output series as observed in the data. In case 4 we pine down the adjustment cost parameter so that investment volatility is replicated. The percent relative standard deviations and correlation with output are sample means of statistics computed for each 1000 simulations. Each simulation is 112 periods which is the same number of periods computed in the data. The sample standard deviations of these statistics are in the parentheses. Each simulation is logged and detrended as done in the data.

5. The Two Sectors Model

In this section we present the results of simulating for the two sectors model of section 3, using the estimated parameters presented in section 4. It should be emphasized that here we use the CES preferences for traded and non-traded goods where labor supply is exogenous.

Table 4 presents the simulation results, where the role of the non-traded goods in generating consumption variance is emphasized. The main result from Table 4 is that for the benchmark parameters of a two-sector economy model implies that consumption volatility is higher than output volatility and trade balance is positively correlated with output. Hence, the main puzzle of the Israeli excess volatility in consumption can be easily explained by a two sectors model where labor supply is exogenous and the utility is standard.

Two parameters characterize the size of the non-traded sector in the model. One is v, which determines the relative importance of the traded goods in the utility function, and the second is Gnt, which is the level of government expenditures on non-traded goods. It can be seen from Table 4 that the smaller is v and the bigger is Gnt the consumption path becomes more volatile. Furthermore, under all parameterizations the balance of trade is positively correlated with output.[20] Note that the utility function becomes the same as the one-sector model when v is equal to 1. As v converges to 1 (case 4 in Table 4), the business cycle moments become the same as in the one sector neo-classical model.[21]

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[20]In Table 6 we show that this procyclicality property shows sensitivity to the stochastic process specifications and to the adjustment cost parameters.

[21] That is also a test for the correctness of the model's solution.

Table 4: Basic Business Cycle Properties

Case	Relative volatility Std (C)/Std(Y)	Corr (Y,TB)
1. V=.4, Gnt=.177 Bench	1.36	.94
	(.11)	(.01)
2. V=.3	1.52	.92
	(.07)	(.01)
3. V=.5	1.12	.98
	(.12)	(.003)
4. V=.99	.03	.88
	(.003)	(.02)
5. Gnt=0	.83	.73
	(.07)	(.05)
6. Gnt=.1	1.03	.85
	(.09)	(.03)
7. Gnt=.2	1.52	.96
	(.13)	(.008)

Notes: C is defined as consumption; TB is defined as the balance-of- trade measured as net-export; Cases 1 -4 show the simulation results for the role of the relative magnitude of traded goods in the utility function. Cases 5-7 show the simulation results for the role of the non-traded in the public sector. The relative standard deviations and correlation with output are sample means of statistics computed for each 1000 simulations. Each simulation is 112 periods which is the same number of periods computed in the data. The sample standard deviations of these statistics are in parentheses. Each simulation is logged and detrended as done in the data.

The preference parameters are known to have an important role in generating the consumption path. In Table 5 we examine the effects of these parameters on consumption and balance-of-trade co-movements with output. As presented in Tesar (1993) the bigger the elasticity of intratemporal substitution between the two goods (measured by μ) relative to elasticity of intertemporal substitution (measured by $1/\theta$), the consumer becomes more sensitive to changes in the timing of consumption.

As such, the consumer is willing to change the composite of the consumption bundle in order to spread the marginal utility of consumption. In other words, the consumption path becomes smoother. It turns out that these parameters do have a role in shaping the dynamics, where the lower is the elasticity of intratemporal (intertemporal) substitution the bigger (smaller) is the volatility consumption. However, in all the experiments under any conventional parameter specifications set, the relative volatility in consumption remains relatively high.[22]

Table 5: Sensitive Analysis on the Preferences Parameters

Case	Relative volatility Std(C)/Sts(Y)	Corr (Y,TB)
1. $\mu = .50, \theta = 1.5$	1.30	.94
	(.10)	(.01)
2. $\mu = .50, \theta = 2$	1.01	.99
	(.09)	(.001)
3. $\mu = .50, \theta = 5$	.53	.97
	(.04)	(.006)
4. $\theta = 1.5, \mu = .44$	1.34	.94
	(.10)	(.01)
5. $\theta = 1.5, \mu = 1$	1.08	.97
	(.08)	(.006)
6. $\theta = 1.5, \mu = 2$	.81	.98
	(.05)	(.002)

Notes: C is defined as Consumption; TB is defined as the Balance-of-Trade measured as Net-Export; θ, is the constant relative risk averse (CRRA) while $(1/\theta)$ is elasticity of intertemporal substitution; μ, is elasticity of intratemporal substitution. The relative standard deviations and correlation with output are sample means of statistics computed for each 1000 simulations. Each simulation is 112 periods which is the same number of periods computed in the data. The sample standard deviations of these statistics are in the parentheses. Each simulation is logged and detrended as done in the data.

In Table 6 (Appendix C) we study the model performance and sensitivity for additional moments including the relative volatility of investment and balance-of-trade, as well as the co-movements between output and consumption, output and investment. We focus here on the sensitivity of the moments changing the parameters for stochastic processes and the adjustment costs.

Case 1 considers the benchmark parameterization and shows that the co-movements between the different aggregate variables and output have the same signs and relative level as that of the data. However, there are two outstanding caveats. First, the contemporaneous correlations are higher than the data. Second, the relative volatility of

[22] That is the case where all other parameters are as in benchmark. In general it is possible to find μ and θ as well as other parameters to get low variability in consumption.

investment (balance-of-trade) is relatively low (high) than the data. Two parameters influence the investment dynamic, the shock's persistence, ρ, and the adjustment cost parameters, csi. In cases 2 to 5 and 6 to 8 we explore, respectively, the sensitivity of the results to these two parameters. We find that the smaller (bigger) the adjustment cost parameter (shock persistence) the more volatile the investment path. As a result, the lower is the covariance of the balance-of-trade and income (due to "pro investment effect" dominance). Furthermore, we find a positive monotonic impact of the shock's persistence on the consumption dynamics, and that the volatility in the balance of trade path remains high in all cases. In case 5 we explore the effect of a positive diffusion between the two shocks, which turns out to preserve the basic characteristics of the benchmark case.

In case 8 we adapt the adjustment cost parameter and the shock's persistence in a way that guarantees that volatility of investment and output as well as output persistence predicted by the model matches the moments observed in the data[23]. It turns out that this specification increases the volatility of consumption and of the balance of trade, but improves the correlation of these variables with output as well as the correlation of investment with output. However, the co-movements of investment and consumption with output are still too high, and moreover, the volatility in the balance of trade is exaggerated.[24]

In cases 9, and 10, we use the value of the adjustment cost parameter as in case 8 and explore the sensitivity of the model to the variance of the shock to production. We find that the bigger the variance of the shock in the non-traded (traded), the larger (smaller) the volatility of consumption and the larger (smaller) is the procyclicality of the balance of trade, while the opposite occurs to the investment volatility. In case 11 we assume that the two shocks are positively correlated. This leads to a lower volatility in consumption, and a lower level of procyclicality in the balance of trade.

The above cases show that the consumption path is more volatile than what is observed in the data. This over volatility is due to our benchmark parameterization in which we

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[23] In particularly, $\rho_i = .475, \sigma_i^2 = .00131$.

[24] It should be noted that these properties also exist in the one sector model.

assume that government expenditures consist of only non-traded goods. In case 12 we add the level of government expenditure on traded goods and fit the moments of the model.[25] It turns out that this case improves the closeness of the second moments predicted by the model to the data second moments.

In Table 7 we extend the analysis to the dynamics of each sector separately as well as the dynamic of real exchange rate extracted from the price ratio between traded and non-traded goods. We compare the moments of these variables to the moment from the Israeli data, using the parameters of case 12 in Table 6 (Appendix C) as a benchmark. In general, we find that the model is consistent with the observations that traded goods output and consumption are more volatile than non-traded output and consumption. However, the relative volatility of traded to non-traded output is exaggerated.

We also find consistency with most signs of the contemporaneous correlations with two exceptions, the correlation of traded output to non-traded output, and output correlation with the price ratio.[26] It is well known that the standard business cycle model fails to track the cyclicalities of the real wage and the interest rate. This property exists as well in a model of non-traded goods of Stockman and Tesar (1995) and also in a two sector model in Baxter (1992). Chari, Kehoe and McGrattan (1998) have shown that a model that includes sticky prices with certain assumptions on preferences and monetary shocks can account for the persistence, volatility and the co-movement of the real exchange rate and output. However their "preferred" model parameterization fails to track the other aggregate moments such as the contemporaneous co-movements between the balance of trade and output.

[25] In this case $\mu = 0.35$, such that the investment output ratio is replicated.

Table 7: Statistical Moments, Traded and Non-Traded Sectors

Variable	Israel Data	Model
Std(P)/Std(Y)	5.25 (4.83, 5.67)	2.89 (2.60,3.18)
Std(CT)/Std(Y)	2.77 (2.44, 3.10)	2.36 (2.12,2.60)
Std(CNT)/Std(Y)	0.68(.61, .74)	0.48 (.44,..52)
Std(CT)/Std(CNT)	3.95 (3.57, 4.33)	4.88 (4.88,4.88)
Std(YT)/Std(YNT)	1.14 (1.06, 1.21)	6.23 (6.13, 6.33)
Corr (P,Y)	0.11 (.01, .21)	-0.47 (-.39, -.55)
Corr(CNT,Y)	0.18 (.10, .27)	0.55 (.48,.62)
Corr(CT,Y)	0.30 (.23, .37)	0.49 (.41,.57)
Corr(CNT,CT)	0.59 (.53, .65)	0.99 (.99,.99)
Corr(YNT,YT)	0.57 (.51, .63)	-0.18 (-.08,-28)
AR(P)	0.75 (.71, .79)	0.25 (.16,.34)

Notes: CNT and CT are defined as Consumption of Non- Traded and Traded good respectively; P is defined as price ratio between non-traded and traded good (reciprocal of real exchange rate) which is calculated in accordance to Drazen and Helpman (1987); YNT and YT are defined as Output of Non-traded and Traded good respectively; Y is defined as Output. Numbers in data's parentheses are GMM standard errors, calculated as described in Christiano and Eichenbaum (1992). The relative standard deviations and correlations derived from the model are sample means of statistics computed for each 1000 simulations. Each simulation is 112 periods which is the same number of periods computed in the data. Each simulation is logged and detrended as done in the data.

6. Concluding Remarks

The main result of this paper is that the observed phenomenon that volatility of consumption is twenty percent higher than the volatility of output is compatible with a simple specification of a two-sector model of a small open economy. Furthermore, using parameters that fit the steady state first moments of the Israeli data, the main second moments from the data are close to the corresponding moments predicted by the model. We also show that the predicted second moments are very sensitive to changes in several parameters that are within the range used in the literature.

The higher volatility of aggregate consumption relative to aggregate output is due to the volatility of traded consumption but not that of the non-traded consumption. This

[26] The price ratio is computed according to Drazen and Helpman (1987).

phenomenon exists both in the data and in the model (Table 7). This result might be at odds with intuition based on a one sector model version of a small open economy and hence can be viewed as surprising. Since for that model the traded consumption has a very low volatility relative to output. We show that when the two-sectors economy converges to the one sector economy the volatility in consumption become a small fraction of output volatility whereas other parameters stay the same. The puzzle that this observation implied is explained by the result that with the three parameters of the CES utility function and the share of non-traded goods in government expenditures, one can get almost any volatility in consumption holding constant the production side parameters. The openness of the economy enables the representative consumer to react in different ways to shocks in traded and non-traded goods, depending on her preferences. By lending and borrowing, consumers can change drastically or moderately their consumption of traded goods while non-traded goods consumption can at most be smoothed in response to shock in non-traded output. We show that there exists a configuration of parameters of the model that is compatible with certain facts of the Israeli economy and generate the result that the optimal path for traded consumption is almost two and half times more volatile than aggregate output as also observed in the data.[27] Interestingly, most of the other implications of the model with the same parameters are also consistent with the observed second moments of the economy.

7. References

[27] The main deviation of the predicted moments from the data is that the model predict a high volatility in the balance of trade series relative to what observed. Yet the direction of the over prediction is consistent with the deviation of the model from the existing standard models.

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Appendix A

Figure 1: The Ratio of Non-Traded Output to Traded Output, Israel 1971:1997.

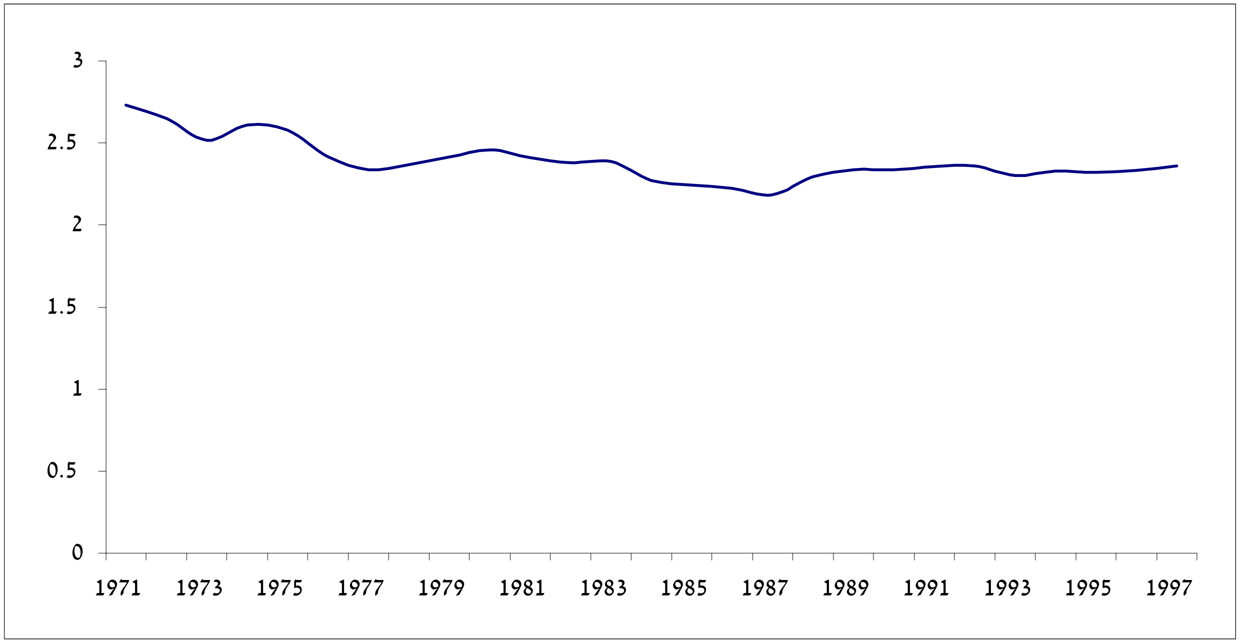

Table A1: Relative Volatility Israeli Data 1971.1-1997.4

Variable	Israel Data
Std(CT)/Std(YT)	2.45 (2.24,2.66)
Std(CT)/Std(Y)	2.77 (2.44, 3.10)
Std(CNT)/Std(YNT)	0.59 (.53,0.65)
Std(CNT)/Std(Y)	0.68 (.61, .74)
Std(CT)/Std(CNT)	3.95 (3.57, 4.33)
Std(YT)/Std(YNT)	1.14 (1.07, 1.21)
Std(P)/Std(Y) . A1	5.25 (4.83, 5.67)
Std(P)/Std(Y) . A2	3.94 (3.53, 4.35)
Std(P)/Std(Y) . B	1.79 (1.56, 2.02)
Std(P)/Std(Y) . C1	4.70 (4.16, 5.24)
Std(P)/Std(Y) . C2	3.10 (2.68,3.52)
Corr (P,Y) . A1	0.11 (.01, .21)
Corr (P,Y) . A2	0.44 (.36,.52)
Corr (P,Y) . B	-0.008 (-.098,.082)
Corr (P,Y) . C1	-0.19 (-.31,-.05)
Corr (P,Y) . C2	-0.21 (-.34,.08)

Notes: CNT and CT are defined as Consumption of Non- Traded and Traded good respectively; P is defined as price ratio between non-traded and traded good (reciprocal of real exchange rate) which is calculated in three different ways (see note 7 in section 2); YNT and YT are defined as Output of Non-traded and Traded good respectively; Y is defined as Output. Numbers in data's parentheses are GMM standard errors, calculated as described in Christiano and Eichenbaum (1992).

Table A1b: Volatility in Selected OECD Countries

Based on Stockman and Tesar (1995)

Variable	Data
Std(CT)	1.77 (0.99, 2.54)
Std(YT)	3.45 (2.38, 4.52)
Std(CNT)	1.78 (0.85, 2.71)
Std(YNT)	2.02 (1.48, 2.56)
Std(Y)	2.53 (2.00, 3.06)

The numbers are taken from Stockman and Tesar (1995), where the figures in the "Data" column are cross-country averages of the moments. The figures in parentheses are the two standard deviations range around the cross country average; output standard deviation by sector are five countries averages (Canada, Germany, Italy, Japan, United State), where the sample range from 1970 to the last available observation, which varies from 1984 to 1986 depending on the country and the sector; consumption standard deviation by sector are six countries averages which contains France to all the five mentioned above.

Table A2: Contemporaneous Correlations for the Israeli Economy 1971.1-1997.4

	CNT	CT	C	Y	G	I	YNT	YT	TB
CNT	1	0.552279	0.771843	0.22833	-0.33874	0.054592	0.20081	0.241271	0.241632
CT		1	0.951691	0.248974	-0.13306	0.205695	0.287677	0.152323	-0.00534
C			1	0.277139	-0.22328	0.174465	0.292116	0.203471	0.085587
Y				1	0.016299	0.347045	0.914443	0.807596	0.145265
G					1	-0.28771	0.100511	-0.01691	-0.81563
I						1	0.342078	0.185184	0.023884
YNT							1	0.638034	0.020687
YT								1	0.185184
TB									1

Notes: CNT and CT are defined as Consumption of Non- Traded and Traded good respectively where C defined as total consumption; YNT and YT are defined as Output of Non-traded and Traded good respectively; Y is defined as Output; G is defined as government expenditures ; I is defined as investment; TB is defined as balance of trade measure as net-export. The data are from 1971.1-1997.4, due to data availability as for the traded and non-traded output series (note that the data shown in section 1 are from 1970.1-1997.4). All series are in logarithms (with the exception of the Net Export/GDP) and are detrended with the HP filter.

Appendix B

This appendix summarizes the assumptions that we impose on the two sectors model of section 3 in order to be consistent with the one sector framework of CNR (1995). The economy is assumed to consist of a representative firm that produces traded goods, Y_T. There is a representative consumer who maximizes her expected lifetime utility from consuming traded goods, C_T and leisure L. There is a government who consumes traded goods, G_T that is financed by a lump sum transfer, τ.

Production

The traded goods is produced by a Cob-Douglas production function that is given by,

$$(A1) \qquad Y_{T_t} = \left(A_{T_t} \cdot N_{T_t}\right)^{\xi} K_{Tt}^{1-\xi} V_t \qquad 0 < \xi < 1$$

where N_T is labor input, and K_T is capital stock. The technology level is given by A_T and is growing by a constant growth rate, γ such that,

$$(A\,2) \qquad A_{T\,t} = \gamma^{t}.$$

The technology shock is given by V_T which follows a stochastic AR(1) process such that,

$$(A3) \qquad V_t = V_0^{\,1-\rho} \;\; V_{t-1}^{\;\;\rho} \;\; \cdot e^{U_t}$$

where $0 < \rho < 1 <$, and U is i.i.d. with zero mean and constant variance.

Investment

The laws of motion for investment, is given by,

$$(A4) \qquad K_{Tt+1} = \vartheta_T \left(I_{Tt} / K_{Tt}\right) K_{Tt} + (1-\delta) K_{Tt}$$

where the definitions for the parameters are as in section 3.

Optimization

The firm chooses N_T and K_T, that maximize its present value profit, where the optimization problem is,

$$(A5) \qquad MAX \qquad E_0 \sum_{t=0}^{\infty} \left\{ \left(\frac{1}{1+r^*} \right)^t \begin{bmatrix} F_T(K_{Tt}, L_{Tt}, A_{Tt}) - w_t N_{Tt} - I_{Tt} \\ -q_{Tt}(K_{Tt+1} - K_{Tt}(1-\delta) - \vartheta_T(I_{T,t}/K_{T,t}) \cdot K_{Tt}) \end{bmatrix} \right\}$$

Representative Consumer

The representative consumer chooses consumption, and leisure which maximize her expected life time present value of utility which is,

$$(A6) \qquad MAX \ E_0 \sum_{t=0}^{\infty} \beta^t U(C_{Tt}, L_t).$$

E_t denotes the expectations conditional on information at time period t, and β is the discount rate. The maximization in A6 is subject to the budget constraint,

$$(A7) \qquad C_{Tt} + B_{t+1} = Y_{Tt} - I_{Tt} - \tau_t + B_t(1+r^*),$$

where B_t is a financial asset that traded in the international capital markets.

As in CNR we assume that the utility function has two of the following analytical specifications,

$$(A8) \qquad \text{Coub Douglas}: \qquad U(C_t, 1 - N_{Tt}) = \frac{\left[C_t^v (1 - N_{Tt})^{1-v}\right]^{1-\theta}}{1-\theta} \quad 0 < v < 1$$

where $1 - N_{Tt} = L_t$, and v describes the relative magnitude of the consumption goods in utility, and θ expresses the relative risk aversion.

$$(A9) \qquad GHH: \quad U(C_t, 1 - N_t) = \left[C_t - \psi A_t N_t^v\right]^{1-\theta} \qquad v > 1, \psi > 0$$

where A expresses the growth rate, which is added in order to guarantee a stable steady state. Here, the parameter v defines the elasticity of labor supply.

Government

At each period the government budget constraint is given by,

$$(A10) \qquad G_{T_t} = \tau_t \, ,$$

where G_T is assumed to be deterministic.[28]

Equilibrium Conditions

The clearing markets equilibrium conditions are,

$$(A11) \qquad C_{Tt} + I_{Tt} + G_{Tt} + TB_t = Y_{Tt}$$

$$(A12) \qquad TB_t = B_{t+1} - B_t(1 + r^*) \, ,$$

where TB is the balance of trade, which is measured as net export.

Solution

The model is solved using a numerical approximation method following Kydland and Prescott (1982) and King, Plosser and Rebelo (1988) as explained in section 3.

Parameterization

The values of the following parameters, relative risk aversion, (θ), growth rate (γ), depreciation (δ), level parameter (V_T) adjustment cost elasticity (csi), are calculated as in section 4. The labor share (ξ) is computed, as presented in section 4, though its value in a one-sector production function equals to 0.65. All other parameters are estimated according to the model's steady state solution and the decision rules coefficients. As such, the aggregate macroeconomic basic ratios are estimated. Namely, we set S_c, which is the ratio of consumption to output, to be equal to 0.55 as observed in the data, and set S_g, which is the ratio of government expenditure to output to equal to be 0.4. Since the ratio of investment to output is determined by the model parameters, we set the discount factor

[28] We have made the necessary adaptations to the government expenditure specifications according to the utility functions as explained in CNR.

$\beta = 0.986$, such that the ratio of investment to output is 0.21 as observed in the data. The Coub-Douglas utility moment v=0.14 is estimated such that the total working time divided by the total time available to the consumer equals to 0.16, as estimated by Bental and Eckstein (1997). The GHH utility moment v=1.7 is borrowed from GHH (1988) and followed by CNR, where $\psi = 2.52$ is estimated according to the ratio of total working time to the total time available to the consumer.

In section 5 in table 3, the simulation results in cases 1 and 2 are based on a direct estimation of the solow residual that derived from the following equations,

$$(A13) \qquad SR_t = \log(Y_{Tt}) - \xi \log(N_{Tt}) - (1-\xi)\log(K_{Tt}),$$

where SR defines the solow residual that follows a stochastic process,

$$(A14) \qquad \log(V_{Tt}) = \ln V_0 (1-\rho) + \rho \log(V_{Tt-1}) + u_{Tt}$$

where the estimated parameter values are $\rho = 0.67$ and $\sigma = 0.0282$.

Appendix C

Case	Parameter Varied Relative to Benchmark	Relative Volatility			Contemporaneous Correlation			Auto-Correlation	Std
		C	TB	I	TB,Y	C,Y	I,Y	Y	Y
Israeli Data									
	_	1.20 (.11)	1.87 (.21)	4.88 (.43)	.19 (.09)	.30 (.08)	.38 (.07)	.40 (.08)	1.94 (.001)
Benchmark Parameterization $\rho_i = .55, \sigma_i^2 = .001215, i = NT, T$									
1	_	1.36 (.11)	5.10 (.21)	1.53 (.07)	.94 (.01)	.72 (.06)	.91 (.02)	.40 (.08)	1.94 (.001)
Sensitivity Analysis, Technology Shocks, Persistence Parameter - ρ									
2	.7	1.44 (.14)	4.62 (.13)	1.53 (.04)	.98 (.005)	.69 (.07)	.98 (.006)	.53 (.07)	2.05 (.002)
3	.9	1.77 (.24)	3.64 (.46)	2.86 (.28)	.66 (.09)	.55 (.11)	.82 (.05)	.68 (.07)	2.26 (.002)
4	.95	1.87 (.28)	4.80 (.80)	4.33 (.45)	-.05 (.16)	.41 (.13)	.79 (.06)	.70 (.06)	2.38 (.003)
5	$\rho_{NT,T} = .25$	1.22 (.09)	3.99 (.18)	2.03 (.08)	.90 (.02)	.79 (.04)	.94 (.01)	.58 (.07)	2.17 (.002)
Sensitivity Analysis, Adjustment Cost Parameter - csi									
6	1/30	1.43 (.12)	4.57 (.11)	1.58 (.04)	.98 (.005)	.69 (.06)	.98 (.005)	.44 (.08)	1.92 (.001)
7	1/100	1.54 (.14)	3.92 (.34)	3.09 (.21)	.66 (.06)	.61 (.07)	.81 (.03)	.45 (.08)	1.90 (.001)
8	1/230	1.53 (.13)	5.80 (.60)	4.66 (.36)	.16 (.11)	.59 (.07)	.72 (.05)	.40 (.08)	1.94 (.001)

Case	Parameter Varied Relative to Benchmark	Relative Volatility			Contemporaneous Correlation			Auto-Correlation	Std
		C	TB	I	TB,Y	C,Y	I,Y	Y	Y
Sensitivity Analysis, Shock Variance - σ^2									
9	$\sigma^2_{NT} * 1.25$	1.57 (.12)	5.56 (.60)	4.35 (.34)	.24 (.10)	.64 (.06)	.72 (.05)	.40 (.08)	2.10 (.001)
10	$\sigma^2_{T} * 1.25$	1.48 (.14)	6.03 (.65)	4.96 (.37)	.08 (.11)	.51 (.07)	.73 (.05)	.40 (.08)	2.02 (.001)
11	$\sigma_{T,NT} = .25 * \sigma^2_i, i = NT, T$	1.25 (.11)	4.87 (.51)	4.53 (.30)	.096 (.11)	.61 (.07)	.80 (.03)	.39 (.08)	2.13 (.001)
Adding Government Traded Goods									
12	$csi_i = 1/170, \rho_i = .52, \sigma_i^2 = .0008$	1.23 (.12)	3.94 (.41)	4.78 (.38)	.30 (.09)	.50 (.08)	.68 (.05)	.40 (.06)	1.94 (.001)

Notes: Variables are defined as follows: C, consumption; Y, output; I, investment; TB, balanced of trade (net-export). Numbers in data's parentheses are GMM standard errors, calculated as described in Christiano and Eichenbaum (1992). The percent relative standard deviations and correlation with output are sample means of statistics computed for each 1000 simulations. Each simulation is 112 periods which is the same number of periods computed in the data. The sample standard deviations of these statistics are in the parentheses. Each simulation has been logged and detrended as has been done in the data.