Accepted Manuscript

Title: Business Cycle Accounting of Trade Barriers in a Small Open Economy

Authors: Seyed Ali Madanizadeh, Ali Karimirad, Mohammad H. Rahmati

Please cite this article as: Madanizadeh SA, Karimirad A, Rahmati MH, Business Cycle Accounting of Trade Barriers in a Small Open Economy, *Quarterly Review of Economics and Finance* (2018), https://doi.org/10.1016/j.qref.2018.06.003

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Business Cycle Accounting of Trade Barriers in a Small Open Economy[1]

Seyed Ali Madanizadeh
Sharif University of Technology, Graduate School of Management and Economics

Ali Karimirad
University of British Columbia, Vancouver School of Economics

Mohammad H. Rahmati
Sharif University of Technology, Graduate School of Management and Economics

May, 2018

Abstract

To what extent can a short-term decline in the output of a small open economy be explained by trade barriers? To answer this, we extend the Business Cycle Accounting method of Chari et al. (2007) to a small open economy model. We include an additional time-varying wedge to model financial trade frictions caused by barriers on imports. International sanctions on Iran provide an empirical opportunity to apply this method to data on Iran's recession in 2012-13. The results indicate that efficiency and investment wedges account for most of the fluctuations in aggregate variables during the sanctions, and trade barriers had little contemporaneous explanatory power. The effect of oil boycotts remains unknown.

Keywords: business cycle accounting; financial trade barriers; sanction; Iran economy

I. Introduction

International shocks can catalyze business cycles in small open economies. Fluctuation in trade barriers is an important example of international shocks. We know that barriers are determinants of aggregate fluctuations, but the magnitude of aggregate output that is caused by these barriers remains unknown. Chari, Kehoe and McGrattan (2007) –CKM from now on- deal with the challenge of evaluating the quantitative importance of competing mechanisms of business cycles in the framework of a closed economy. They introduce a simple method of business cycle accounting to determine which theories play a primary role in generating business

1

cycles -especially the Great Depression[1]. We extend their framework to small open economies in the presence of international trade barriers.

We show that the standard CKM framework, which has only efficiency, investment, labor and government wedges, cannot be applied to a small open economy. Therefore, we introduce a fifth wedge for trade which we call the trade wedge. The motivation behind adding the trade wedge rests on the insight that trade barriers vary over time in small countries and consequently, cause deviations from equilibrium. As a result, they cause fluctuations in terms-of-trade and other international variables.[2] That is, trade barriers distort the foreign prices relative to domestic prices, which can be seen as distortions due to other wedges.[3] Noticeably, both efficiency and trade wedge cause movements in total aggregate production, so the exclusion of trade wedge shall obscure the interpretation of efficiency wedge[4]. Therefore, it is crucial to separate the trade wedge in equilibrium from other wedges because each wedge represents a different group of frictions and shocks. Thus, the interpretation of each wedge is different, and the optimal policy for addressing each wedge would be different too.

Our benchmark prototype economy consists of five wedges: efficiency wedge, labor wedge, investment wedge, government wedge, and the trade wedge. The efficiency wedge appears in the form of productivity, and the other wedges act like time-varying taxes. We show that in the CKM framework, international restraints like trade barriers and boycotts unreasonably map into the efficiency wedge. In contrast, our benchmark model with five wedges map trade barriers into the trade wedge, so in the accounting outcome they are separated from the efficiency.

To demonstrate how the accounting procedure with the trade wedge works, we apply it to the recent 2012-2013 recession in Iran's economy and measure how significant the trade sanctions were in generating this recession. The case of Iran is a good example because its economy experienced a deep recession during the last phase of international nuclear program sanctions. Specifically, using our method one can ask if international sanctions had any impact on Iran's economy and if that impact came from financial trade barriers or other channels. To the best of our knowledge, earlier studies attempt to examine the economic impact of international sanctions, using aggregate statistics, without any econometric structural approaches. The results of our paper indicate that efficiency and investment are the key wedges that led to 2012-2013 recession. It is important to note that trade wedges have little power to explain the magnitude of a recession.

The organization of the paper is as follows. Section II reviews literature. Section III explains the model and wedges in our benchmark prototype economy. The detailed economy of international sanctions is discussed and the equivalence results are provided in section IV. This section provides a basis for how we separate efficiency from trade wedge. Section V describes the recession of 2012-2013 in Iran, and the calibration of deep parameters follows in section VI.

---

[1] In section II we review this literature.

[2] Mendoza (1995) shows term-of-trade shocks account nearly half of GDP variability. Broda (2004) shows term-of trade shocks explain almost 30% of GDP fluctuations in fixed regime, and almost 40% real exchange fluctuations in countries with flexible regimes.

[3] Loosely speaking, in CKM framework labor wedge distorts the labor market and investment wedge distorts intertemporal capital decision.

[4] Rahmati et al. (2015) studied the 2012-2013 recession in Iran using the Chari et al. (2007) benchmark model and found that the drop in output is mainly attributable to productivity shocks. In that paper we could not identify whether productivity wedges dropped because of sanctions or poor domestic policies.

2

The accounting procedures and steps are discussed in section VII. Results and findings are reported in section VIII. The final section is the conclusion.

II. Literature Review

Chari et al. (2007) developed a simple method to quantitatively study economic fluctuations, and they applied it to the analysis of the U.S. Great Depression. They examine a benchmark prototype economy with time-varying wedges for efficiency, labor, investment, and government that distort the equilibrium conditions. They show that each wedge can map into detailed economy models and called this mapping the equivalent results. Table 1 shows the mapping of their wedges to models with various frictions. For instance, the efficiency wedge is equivalent to frictions in prices of raw materials.

The next step is an accounting procedure, which can assess how much of the observed movements in aggregate variables can be attributed to each wedge in the benchmark prototype economy. Noticeably, the impact of each wedge, measured at the accounting step, translates into its equivalent detailed economy. Its advantage is a way to compare the performance of competing explanations in a simple framework.

Their benchmark prototype economy is constructed for the U.S.. Their only source of foreign shocks is a movement in net export that in their setup is analogous to government spending. In contrast, firms in a small open economy mostly import their intermediate goods; thus, any extra costs to their flow of inputs create substantial GDP losses. To quantify the dynamic short-term effects of a large change in trade costs, we need a new wedge to capture this effect.

Uribe and Schmitt-Grohé (2017) study business cycles in poor, emerging and rich countries. They show that these classifications behave differently as demonstrated in Table 2. They conclude that business cycles in emerging and poor countries are twice as volatile as rich countries. Moreover, they observe less consumption smoothing in less developed countries. Table 2 also shows that U.S. government expenditure is counter-cyclical, while government expenditures are cyclical in emerging economies. Finally, trade-balance-to-output ratio and current-account-to-output ratio are countercyclical, but the correlation with output is much higher for the U.S. Therefore, international trade acts as a shock absorber for the U.S. economy (trade balance decreases in recession and increases in booms). Also, the intensity of trade (sum of export and import to GDP) is much higher in emerging markets, which make them more susceptible to international shocks.

The method of BCA in CKM (2007) has been extended in two ways by others. The first approach uses the standard four-wedge benchmark prototype economy to investigate the source of fluctuations and to provide evidence in support of competing theories. For example, Kersting (2008) shows that the labor wedge plays a vital role in the recession and the following recovery of UK economy in 1980s. He concludes that reforms in labor market were crucial for the improvement of labor wedge and the economy's performance. Similar papers like Cho and Doblas-Madrid (2013), Orsi and Turino (2014), Chakraborty and Otsu (2013) use the same standard approach for other countries.

3

The second group extends the Business Cycle Accounting method to study their own questions, which require some amendments to the original four-wedge benchmark model. Ohanian, Restrepo-Echavarria, and Wright (2009) introduce a new wedge— international wedge—to explain why capital flowed to Latin America instead of East Asia, despite that the latter experienced much faster growth rates than the former. They show that domestic distortions in labor and capital markets can explain why capital did not flow into countries with higher productivity. Sustek (2011) includes two additional wedges—for financial markets frictions and monetary policies—to study the relationship between GDP and inflation in the U.S. economy. Rahmati and Rothert (2011) introduce other wedges— trend shock and country risk—to account for the fluctuations in Mexico during the Tequila Crises, especially in trade balance and current accounts[5]. Our paper is the first that shows the Chari et al. (2007) benchmark model is not appropriate to study international trade barriers in a small open economy, so we must develop a new benchmark model.

A related Literature on Sanctions: The long history of economic sanctions begins near the start of the World War I. Elliott, Clyde, and Hufbauer (1999) record 170 sanctions in the 20th century. Out of 50 cases in the 1990's, the U.S. initiated 36 sanctions, which were against 30 countries. There has been a widespread public debate over the effectiveness of international economic sanctions. Elliott et al. (1999) study almost one quarter of sanctions in 1970s, 80s, and 90s and found that moderate sanctions reduce bilateral trade by 27%, while severe sanctions decreased it by 91%. In a similar study, Caruso (2003) uses a gravity model and shows severe multilateral sanctions reduce trade by 81%. Following the recent international sanctions against Russia, Dreger et al. (2016) study a similar question to that of ours: how much of Ruble deprecation in 2014 stems from the sanctions after the crisis in Ukraine versus the sharp decline in oil price. They examine this question using VAR models and high frequency observations, and they find that the depreciation can be attributed to the decline of oil prices rather than the sanctions.

III. The Model

In this section, we present our benchmark model and introduce the wedges as in that of Chari et al. (2007) which consists of three sectors: household, firm, and government.

Households

The benchmark model is a stochastic neoclassical growth model. In period t, the economy experiences a vector of shocks (s_t) from a finite set of events, where the history of shocks is denoted by $s^t = (s_0, s_1, \cdots, s_t)$, which is referred to as the exogenous state. The initial state s_0 is given, and the probability of history s^t is $\pi_t(s^t)$. The representative household maximizes its expected utility over per capita consumption (c_t) and per capita labor (l_t):

---

[5] Otsu (2010) and Otsu (2008) also define a new wedge to answer questions that cannot be answered in the framework of the standard four-wedge model.

$$Max \sum_{t=0}^{\infty} \sum_{s^t} \beta^t . \pi_t(s^t) . u(c_t(s^t), l_t(s^t)) \tag{1}$$

The utility function is:

$$u(c_t, l_t) = \frac{(c_t(1-l_t)^x)^{1-\sigma}-1}{1-\sigma} \tag{2}$$

where β is discount factor, and $1/\sigma$ is intertemporal elasticity of substitution[6].

Households solve the maximization problem for the optimal amount of consumption, saving, and working hours in each period knowing the wedges' paths and the initial amount of capital $K(s_0)$. All are subject to the budget constraint:

$$c_t(s^t) + \left(1 + \tau_{x,t}(s^t)\right) . x_t(s^t)$$
$$= (1 - \tau_{l,t}(s^t)) . w_t(s^t) . l_t(s^t) + r_t(s^t) . k_{t-1}(s^t) + T_t(s^t) \tag{3}$$

where $T_t(s^t)$ is the lump sum transfer to households, $g_t(s^t)$ is the government wedge which is exogenous and equals to the sum of government expenditures and net exports similar to Chari et al. (2007). $k_t(s^{t-1})$ denotes the per capita stock of capital, $x_t(s^t)$ is the investment per capita, $w_t(s^t)$ is the real wage rate, and $r_t(s^t)$ is the rental rate on capital.

The economy has five stochastic exogenous state variables:

$$s_t = (A_t, 1 - \tau_{l,t}, {}^1\!/_{(1 + \tau_{x,t})}, g_t, 1 + \tau_{m,t})$$

where A_t is the efficiency (productivity) wedge, $1 - \tau_{l,t}$ is the labor wedge, $1/(1 + \tau_{x,t})$ is the investment wedge, g_t is the government wedge, and $1 + \tau_{m,t}$ is the trade wedge.

Firms

Firms maximize their profit in each period:

$$Max \ y_t(s^t) - w_t(s^t) . l_t(s^t) - r_t(s^t) . k_t(s^t) - (1 + \tau_{m,t}(s^t)) . m_t(s^t)$$

---

[6] As shown in Ebrahimian and Madanizadeh (2017), this preference function is consistent with long run facts of the Iran's macroeconomic variables.

Firms solve their optimization problems for the optimal amount of labor $l_t(s^t)$, capital $k_t(s^t)$, and intermediate good $m_t(s^t)$ given the factor prices $w_t(s^t)$, $r_t(s^t)$, and wedges $(1 + \tau_{m,t}(s^t))$. The production function is

$$y_t(s^t) = A_t(s^t)(k_t(s^t)^\alpha \, l_t(s^t)^{1-\alpha})^{1-\gamma} \, m_t(s^t)^\gamma \tag{4}$$

where $y_t(s^t)$ is the firm's revenue (not value added). Firms sell their product in a competitive market, and their price is normalized to one.

The feasibility constraint in our model follows:

$$c_t(s^t) + k_{t+1}(s^t) + g_t(s^t) = y_t(s^t) + (1 - \delta)k_t(s^t) - e_t m_t(s^t) \tag{5}$$

Denote the real exchange rate as e_t, then the domestic factor share of final production is $y_t(s^t) - e_t m_t(s^t)$, which is equivalent to the gross domestic production. Finally, the depreciation rate of capital is δ. From now on, s^t is omitted from equations for the sake of brevity.

The equilibrium of this benchmark prototype economy is summarized by equation (4), (5), and F.O.C's of the household and firm are given by.

$$\frac{u_{l,t}}{u_{c,t}} = -(1 - \tau_{l,t}) \, w_t \tag{6}$$

$$\beta E_{t+1}(u_{c,t+1}(1 + \tau_{x,t+1})[r_{t+1} + (1 - \delta)]) = u_{c,t}(1 + \tau_{x,t}) \tag{7}$$

$$r_t = A_t F_k(k_t(s^t), l_t(s^t)) \tag{8}$$

$$w_t = A_t F_l(k_t(s^t), l_t(s^t)) \tag{9}$$

$$\tau_m = \gamma \frac{y_t(s^t)}{m_t(s^t)} \tag{10}$$

IV. Equivalence Results of Trade Barrier Wedges

In this section, we show that in the four-wedge benchmark model of Chari et al. (2007), the effect of trade barriers on the economy is manifested by the efficiency wedge. Next, we show that introducing a new trade wedge into the benchmark model can isolate the effects of trade barriers from the efficiency wedge. Therefore, in the five-wedge benchmark prototype economy of section III, the efficiency wedge should mostly represent domestic shocks with the same interpretation as the efficiency wedge in Chari et al. (2007) and the trade wedge will capture the effects of trade barriers.

Consider the following economy with financial trade barriers, financial sanctions, and boycotts[7]. The aggregate final output producer combines composite value-added goods z_t and imports m_t accordingly to produce q_t as:

---

[7] We only introduce this detailed model to demonstrate the mapping between trade barriers and boycotts in detailed model and wedges in the four-wedge and five-wedge benchmark economies. For estimation, we use the five-wedge benchmark economy that we introduced in the last section. It is a standard procedure in the business cycle accounting (BCA) literature to set up a detailed model with one specific shock in which we are interested. We only

$$q_t = z_t^{1-\gamma} m_t^\gamma \tag{11}$$

where $0 < \gamma < 1$. It chooses z_t and m_t to solve:

$$Max\ q_t - v_t z_t - e_t m_t - \theta_t r_t e_t m_t \tag{12}$$

subject to (6), where v_t is the price of composite value-added, r_t is the interest rate, and θ_t ($0 < \theta_t < 1$) is the fraction of imports that firms have to pay in advance for input bills,. The financial frictions are θ_t and are similar to the working capital in Neumeyer and Perri (2005). One difference is that in their model θ_t is constant over time. For firms to use m_t during the period, they must pay a fraction of importing goods at the beginning of the period, so they need the working capital.

The composite value-added goods are produced from capital k_t and labor l_t according to

$$z_t = F(k_t, l_t) \tag{13}$$

The representative producer of the composite good z_t chooses k_t and l_t to solve this problem

$$Max\ v_t z_t - w_t l_t - r_t k_t \tag{14}$$

subject to (13), where w_t is the wage rate.

Households maximize expected utility over per capita consumption, per capita labor, and per capita capital,

$$Max \sum_{t=0}^{\infty} \beta^t . u(c_t, l_t) \tag{15}$$

subject to the budget constraint

$$c_t + \left(k_{t+1} - k_t(1 - \delta)\right) = w_t l_t + r_t k_t + T_t \tag{16}$$

where T_t is lump sum transfer to households, which is equal to $\theta_t r_t e_t m_t$. We describe export as

$$x_t = \xi_t \times (e_t)^\eta \tag{17}$$

where ξ_t is an exogenous shock, and η is the price elasticity of foreigners' demand for domestic final goods. A boycott reduces the level of ξ_t. This results in a decrease in exports and ultimately depreciates both nominal and real exchange rates. Trade balance implies that[8]

$$x_t = m_t \tag{18}$$

---

need to show the equivalence result for this particular shock. Otherwise, we can expand the detailed model and introduce many shocks.

[8] Does zero trade balance seem strong assumption during international sanctions? In experience of Iran and other countries like Iraq in 1990s, sanctions halt international financial transactions and prohibit bond issuance. Hence, Iran forced to barter goods for goods with India and China. Obviously, foreign direct investment also stopped. So, balance of payment stands as a reasonable assumption in the detailed model.

PROPOSITION 1: Consider the four-wedge benchmark prototype economy that has constraint (5) and consumer budget constraint (16) which has the efficiency wedge $A_t = (1 - \gamma)(\frac{\gamma}{(1+r_t\theta_t)e_t})^{\frac{\gamma}{1-\gamma}}$, the labor and investment wedge given by

$$\left(1 - \tau_{l,t}\right) = \left(1/1 + \tau_{x,t}\right) = 1 \qquad (19)$$

where $e_t = \phi(\theta_t, \xi_t)$. Then the equilibrium allocations for aggregate variables in the detailed economy and this benchmark prototype economy are the same[9].

Proposition 1 shows that the effects of sanctions (financial trade barriers) are captured by the efficiency wedge. However, we know from Chari et al. (2007) that many other frictions map into the efficiency wedge; thus, we cannot isolate the effect of sanctions from other frictions.

PROPOSITION 2: Consider the five-wedge benchmark prototype economy that has resource constraint (5) and consumer budget constraint (16) with the efficiency wedge $A_t = 1$, the labor and investment wedge given by

$$\left(1 - \tau_{l,t}\right) = \left(1/1 + \tau_{x,t}\right) = 1 \qquad (20)$$

and the trade wedge $1 + \tau_{m,t} = (1 + r_t\theta_t)e_t$. Then the equilibrium allocations for aggregate variables in the detailed economy and this benchmark prototype economy are the same[10].

Proposition 2 suggests that the international boycotts and financial sanctions manifest themselves only in the trade wedge and not the efficiency wedge in our five-wedge model of Section III, providing a basis for why we use the benchmark prototype economy with five wedges as described in Section III.

V. Iran Case Study: Trade Barriers, International Sanction, and Recession

Iran has been subjected to various international sanctions over the past four decades. In 1979, right after the revolution, the United States imposed the first round of economic sanctions against Iran. Consequently, bilateral trades between Iran and the U.S. dropped from 6.6 B\$ in 1978 to less than 400 M\$ in 1981 (Torbat (2005)). Noticeably, the recent waves of U.N. sanctions after 2006 culminated in severe economic recession during 2012-2013. These sanctions are composed of several agreements enacted by developed countries. They impose economic restrictions on Iran to force the country to halt its nuclear activities. However, no economic study has yet examined the how effective these U.N. policies were at causing economic damage to Iran. Is there a causal link between these sanctions and severe recession? To study these questions and evaluate the policy impact of sanctions, it is crucial to understand the background of the Iranian economy.

---

[9] See appendix A for the proof of the proposition.
[10] See appendix A for the proof of the proposition.

In 2012-13, Iran's economy experienced a deep recession. The real GDP dropped around 6.8% in 2012 and 1.9% in 2013 (18% deviations from trend in two years). Iran's currency, the Rial, depreciated by a factor of three in 18 months and inflation surged to around 40%. Real private and government investments declined by 17% and 60% respectively. Total import plunged by 18%, trade balance plummeted by 4% of GDP in 2012 and oil revenues[11] were reduced by 7.4% of GDP in 2012. All these falls are indicative of a great recession that took place during the era of some poor domestic policies and international sanctions. We elaborate the details of these sanctions and poor governance in this section.

The international trade sanctions restrain exports of Iranian oil and imports of goods by imposing extra financial costs and boycotts on Iran's exports. After a report by the International Atomic Energy Agency in 2006, the U.N. Security Council passed eight resolutions[12] concerning Iran's nuclear programs that resulted in severe sanctions on Iran.[13] The most severe sanctions started in 2012. They included a boycott of Iran's oil export[14] and restrictions on foreign banks that prevented them from providing financial services to Iranian clients. As a result, credit and legal risk progressively increased such that the necessary gross margin for a letter of credit tripled between 2012 and 2013. Moreover, the European Union also imposed restrictions on trade with Iran and prohibited any technology transfers. These trades restrictions were focused on the energy sector. It also banned the provision of insurance and reinsurance by insurers in the member states to Iranian-owned companies. On January 23rd, 2012, the EU also agreed to an oil embargo on Iran and proposed to freeze the assets of Iran's Central Bank in the member states. These sanctions put Iran in an unprecedented situation. Trade with the EU countries dropped from 27.8 B€ in 2011 to 13.03 B€ in 2012 and 6.2 B€ in 2013[15]. As shown in Fig. 2, the oil exports dropped substantially after the oil sanctions.

Moreover, these strict sanctions coincide with poor domestic policies. The government had started an energy reform in 2010. During that time, the government increased the gasoline price from 1000 Rial to 4000 Rial and the diesel price from 165 Rial to 1500 Rial over a night.[16] Moreover, the government committed to pay annually 25 B$ lump sum unconditional cash transfer to the households, without any determined sources to fund the payment[17]. The government started the plan by borrowing from the Central Bank and commercial banks to finance it. Furthermore, the government initiated a housing project for low income households to

---

[11] Oil revenues were 83% of Iran's total export in 2011.

[12] United Nations Security Council Resolutions: 1696 (31 July 2006), 1737 (23 December 2006), 1747 (24 March 2007), 1803 (3 March 2008), 1835 (27 September 2008), 1929 (9 June 2010), 1984 (9 June 2011), 2049 (7 June 2012)

[13] In March 1995, the United States prohibited the U.S trade in Iran's oil industry, and in May of the same year all U.S trade with Iran was prohibited. The U.S. has also forbidden all companies to invest more than $20 million in Iran's oil industry[13]. These sanctions imposed restrictions on specific industries such as military and oil industry and deprived Iran from trade with U.S companies. After ILSA and before next wave of sanctions, Iran experienced a mild growth of 3.2% and extensive trades with foreign countries other than U.S.

[14] Oil export sanction reduced oil exports from 2.2 million barrels to less than a million barrels a day.

[15] http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_113392.pdf

[16] The price of gasoline in all stations is set centrally by the government and often remains constant for months. For further information see Rahmati et al. (2018)

[17] This subsidy decreases to 8 B$ after devaluation of Rial.

build about 1.8 Million low-cost houses. To finance this project, the government borrowed from the Central Bank. More importantly, the money base grew annually at a rate of 31% between 2005 and 2010, while the Rial was pegged to the U.S. dollar in this period. All these policies combined with the international sanctions caused a high inflation in 2011 and 2012, as discussed before.

VI. Data and Calibration

We use public quarterly data of the Central Bank of Islamic Republic of Iran (CBI), Islamic Republic of Iran Customs, and Statistics Center of Iran (SCI) to calibrate and estimate the model. Data contains aggregate macroeconomic variables for 82 quarters, starting from the 1993 to 2013.[18] Table 3 summarizes the calibration of parameters for the annual and the quarterly data.

To calibrate the leisure elasticity, ψ, we use the following F.O.C.s

$$\frac{-u_l}{u_c} = w_t \qquad (21)$$

Using equation 2, we have

$$[l_t/(1 - l_t)]H_t w_t = x C_t \qquad (22)$$

where H_t is total working hours, number of employees × average working hours, C_t is total consumption, and w_t is the wage per hour, so we can estimate x equal to 2.4 as the slope of C_t and $[l_t/(1 - l_t)]H_t w_t$.

The share of labor cost in value-added, $1 - \alpha$, is 0.34 (the average of the share of labor cost in GDP in the 22-year period). The model suggests that the share of imported intermediate goods in final output is constant and is equal to γ.[19].

We use national data on capital stock and its depreciation from 1993 to 2012 to calibrate the depreciation rate. The rate of labor-augmenting technical progress (g_z), capital trend, and long run GDP growth rate are almost constant and in the range of 4% to 4.2%. Employment rate has no trend while population growth rate is 1.75%. Therefore, based on our calibration, we get α=0.66, and $g_z = 2.4\%$.

The elasticity of substitution between the two consecutive periods, $1/\sigma$, is the only parameter that cannot be calibrated with long-run data. We calibrate $1/\sigma$ based on the moments produced

---

[18] A full description of data and how we detrended the data, convert it to real dollars as described in the data appendix of the paper and which is available online at http://gsme.sharif.edu/~rahmati

[19] We use 20 year average to calibrate this parameter. We cannot reject the null hypothesis of no trend in the share of importing intermediate goods in final output. The t-statistics of trend is 1.2. Also, for the robustness check, we also tried the benchmark model that importing intermediate goods are complementary to a value-added representative producer and the results do not change.

by the model and compared them with data. The model with $\sigma = 1$ generates comparable moments to real data.[20]

VII. Accounting Procedure

Similar to Chari et al. (2007), the accounting procedure is carried out in three steps, as follows:

- First step: estimating the parameters of the Markov Process

We estimate the stochastic process of $\pi_t(s^t)$, assuming that wedges follow a first-order Markovian process[21].

$$s_t = P_0 + P s_{t-1} + \epsilon_t \quad \epsilon_t \sim N(0, \Sigma) \tag{18}$$

where s_t is $(ln(A_t), \tau_{l,t}, \tau_{x,t}, \ln(g_t), \tau_{m,t})$.

P_0, P, and Σ should be estimated in this model. We have five wedges in the model, so s_t is a 5×1 vector, P and Σ are 5×5 matrices, and P_0 is a 5×1 vector representing the optimal number of wedges. The number of parameters that should be estimated depends on the number of constraints imposed on P and Σ. For instance, since Σ is a symmetric and negative semidefinite matrix, it suffices to calculate the upper triangular matrix Q so that: $\Sigma = Q.Q^{\prime}$ In this case we have to estimate 5 parameters for P_0, 25 paraments for P, and 15 parameters for Σ. We assume that P is a diagonal matrix and each wedge have a first order auto-correlation so that we should estimate only 15 parameters[22].

To estimate these parameters, we first need to state the problem in the state-space.

$$X_{t+1} = AX_t + B\epsilon_{t+1} \tag{19}$$

$$D_t = CX_t + \eta_t \tag{20}$$

$$X_t = (k_t, ln(A_t), \tau_{l,t}, \tau_{x,t}, \ln(g_t), \tau_{m,t}, 1) \tag{21}$$

$$D_t = (ln(y_t), ln(l_t), \ln(x_t), ln(g_t), ln(m_t)) \tag{22}$$

where D_t is the real data for Iran at time t. X_t is the set of state variables which k_t is the only endogenous state variable. Households know their capital level, wedges, and $\pi_t(s^t)$ – the process of evolution of wedges— before making their decisions. P and P_0 are sub-matrix of A, and Σ is a sub-matrix of B.

To find C, we need to solve seven equations which consist of two first-order conditions for the household equations (6), (7); first-order conditions for the firm's equations (8), (9), (10), the

---

[20] We discuss our calibration method and data in more detail in the online appendix.

[21] Kengo and Inaba (2011) shows that assuming wedges evolve according to VAR(1) is a proper assumption, even though the wedges have no VAR(1) representation in the dynamic stochastic general equilibrium economy. This is an important finding indicating that in this structural model higher order lag effects are captured by our benchmark model.

[22] Because we have only 82 quarters, using 45 parameters makes the estimation inaccurate.

production function equation (4), and the resource constraint equation (5). We can substitute w_t and r_t from equation (8) and (9) into (6) and (7) to get five required equations. We log-linearize these five essential equations (i.e. (4), (5), (6), (7), and (10)) and write D_t as a linear function of X_t. The coefficient of this linear function is C.

Then, we use data of GDP, labor, investment, government expenditure, net exports, and imported intermediate goods to obtain D_t. We use the Maximum Likelihood Estimation to estimate A and B. P, P_0, and $\sum$ derive from our estimates. Table 4 shows the estimated parameters for P_0, P and Q , and their standard errors in parenthesis.

- Second step: Measuring the realized wedges

After estimating the stochastic process of the wedges $(\sum, P, P_0)$, given real-data variables D_t^{data}, we can use the five essential equations to find wedges s_t^{data}. By putting the superscript of "data" on top of s_t, we do not mean they can be observed in the real word; we intend to say that these wedges can produce the observed variables of data.

- Third step: Isolate the marginal effects of the wedges

Finally, we calculate the share of each wedge in explaining the fluctuations of the macroeconomic variables. To do this, the calculated wedge values are fed back into the model, one at a time (setting others to zero), to assess how much each wedge can attribute to the observed movements of macroeconomic aggregates.

VIII. Results and discussion

We apply the accounting procedure explained in the previous section on the five-wedge benchmark prototype economy of section III using macroeconomic data from Iran. We find that in the 2013 recession, the efficiency wedge explains major parts of the fluctuations in GDP, the investment wedge plays a secondary role, and the other wedges play close to no role. Although the trade wedge accounts for variations in imported intermediate goods, it fails to account for much of variations in GDP. Therefore, based on our calculations, trade barriers—including international sanctions and exchange rate swings—did not contemporaneously affect GDP considerably through the drop in the imported intermediate goods.

Analyzing the entire period shows that the efficiency wedge, investment wedge, and trade wedge together account for almost all variation in GDP, investment and imported intermediate goods. Moreover, our findings indicate that the trade wedge can solely produce moderate fluctuations in GDP. A striking feature of Iran's business cycle is the countercyclical behavior of the labor wedge. Therefore in contradiction to developed countries, the labor wedge has no explanatory power with regards to a recession. Government wedge produces no concurrent fluctuations in either GDP or labor. In what follows, we elaborate these findings in more details.

The 2013 recession

Figure 3 shows GDP and measured wedges—the efficiency wedge ($Ln[A_t]$), the labor wedge $(1-\tau_{l,t})$, the investment wedge$(^1/_{1 + \tau_{x,t}})$, and the trade wedge $(1+\tau_{m,t})$. The trade wedge shows an increasing trend probably caused by the wave of international sanction in 2011. Unlike developing countries, the labor wedge movements are countercyclical with respect to GDP. The productivity wedge has also experienced a downtrend since the second quarter of 2012.

Figure 4 plots the actual GDP as well as simulated GDP produced when each wedge is fed back into the model while the other wedges are kept fixed. The GDP generated by the efficiency wedge and the actual data are similar in terms of both signs of fluctuations and magnitudes of deviations. That is, the efficiency wedge can explain a great proportion of the GDP fluctuations. Of importance is that our equivalent results demonstrate that efficiency in the five-wedge benchmark prototype economy does not vary because of trade barriers, which allows us to conclude that international sanctions have little explanatory powers. Obviously, if we had done the accounting in the standard four-wedge framework; the role of efficiency wedge cannot isolate the impact of productivity movements from international trade barriers.

Interestingly, the simulated GDP from the trade wedge has little fluctuation, and its trend decreases by just 0.7% during the recession period. Therefore, the distortions that resembles with the trade wedge (exchange rate jumps and trade barriers in the detailed model) cannot produce the 2013 recession. It should be noted that this does not mean that trade barriers cannot affect GDP in the subsequent periods.

This finding seems contradicting with the common belief that strict sanctions and exchange rate jumps have a significant impact on GDP. It is important to highlight that we measure the weight of each wedge on the depression. However, it may be that the sanctions act as a catalyst for the recession but other real factors deepen the downturn. Moreover, there are three reasons that may justify our findings. First, exchange rate fluctuation usually acts as a shock absorber. For example, a negative productivity shock decreases export and increases exchange rate. An exchange rate devaluation stimulates export and decreases import, thus it can increases the GDP. However, this standard channel is probably blocked by international sanctions. Iranian firms prefer not to export their products because they cannot transfer their income into the country. Also, as we mentioned before, Iranian firms heavily depend on the imports of intermediate goods. When the exchange rate jumps, the cost of production and as a result the price of domestic goods go up. Thus, unlike developed countries, domestic goods in the short run cannot be fully substituted with the importing final goods.

Second, we prove that exchange rate jumps and trade barriers manifest themselves through the trade wedge. However, the oil boycott is different. There was a quota for oil export; so there was a "quantity effect"[23] in addition to income effect and exchange rate jumps. Other trade barriers only have income and substitution effects. (For example, the exporters have to get less for their product, or a firm should buy the imported intermediate goods at a higher price, but Iran could not sell its oil even at a rate lower than the market price). We measured the exchange rate jump caused by oil boycotts through the trade wedge. Also, we measured the income effect of oil boycotts through the government wedge which does not explain non-oil GDP by much. Since the oil operation has a massive fixed cost and is highly capital-intensive, the reduction in oil production without changes in the level of capital stock decreases the TFP and manifest itself through the efficiency wedge. Therefore, this effect of oil boycotts which is completely different from other sanctions against Iran manifest itself through the efficiency wedge.

---

[23] There is a difference between selling half a unit of a good at the regular price or selling one unit of a good at the half of the regular price. The difference between sudden stop and sanctions like oil boycotts comes from this effect.

13

Third, this result is aligned with that of Kohn et al (2016). They show that the effect of trade barriers on total sales and exports is much lower in the model with financial friction compared to the sunk cost model. They argue that relaxing financial constraint significantly increases exports. Poor domestic policies such as getting loan from commercial banks to pay a lump sum subsidy to households, forcing public banks to increase small loans to entrepreneurs for fast-yielding projects with very loose requirement, financing the housing program all tightened financial constraints for firms. These financial constraints decreased the effects of jump in trade barriers. If these sanctions are imposed on a country with lower financial friction, it could cause more damage.

The unusual behavior of labor wedges during the recession needs further explanations. There are strict labor laws in Iran, which prohibit or make it costly for firms to cut their employees. Similarly, wages cannot be decreased and are highly sticky. During the recession, nominal wages stagnated, but the real wages declined as a result of the high inflation.[24] Therefore, the gap between the no-friction equilibrium and constrained situations declined, which shows itself by an increase in $(1 - \tau_{l,t})$. As a result, if you control for other wedges, firms start to hire more, causing a positive shift in GDP. The more the wage decreases, the more GDP rises which can be seen in the figure.

Figure 5 depicts investment and its simulations produced by various wedges. The investment wedge predicts the downturn in investment in the 2013 recession. The efficiency wedge can also explain a great proportion of the investment drop during the 2013 recession. In contrast, the government wedge is unable to explain investment fluctuations in the recession.

Figure 6 shows that the trade wedge predicts almost all of the fluctuations in importing intermediate goods. International frictions (financial trade barriers, international sanctions, and boycotts) that manifest themselves as trade wedge can account for movements in imported intermediate goods but it fails to explain contemporaneous GDP variations. Moreover, the efficiency wedge explains half of the decline in importing intermediate goods during the 2013 recession.

The efficiency wedge and the investment wedge account for almost all of the fluctuations in GDP. Our findings are in line with previous studies that examine plant level information in this period and find negative productivity trends for major industries (Pilevari and Rahmati (2018), Esfahani, and Yousefi (2018)). Evidence from other countries that experience sharp devaluation confirms our findings that domestic factors play the critical role in depression. Cho and Doblas-Madrid (2013) show the efficiency wedge and the investment wedge explain fluctuations in East Asian financial crisis. A large amount of nonperforming loans destabilized those economies and a mild exogenous shock caused deep recessions. These features of East Asian economies mentioned by Cho and Doblas-Madrid (2013) are similar to the 2012-2013 recession in Iran. Either poor domestic policies[25] or international sanctions[26] were the trigger for a contagion in

---

[24] Actually, in 2013 Iran experienced a stagflation: a severe recession and a high inflation, together.

[25] The new president, Mahmoud Ahmadinejad, was elected as the president of Iran on 2005. He cut the interest rates that public and private banking institutions can charge to 12 percent, whereas the market rate was 24 percent. In early administration, the government forced public banks to increase small loans to entrepreneurs for fast-yielding projects with very loose requirement. Unofficial reports indicate that a high portion of these loans are defaulted.

14

overdue loans. The share of non-performing loans was just below 10% in 2005,[27] while in four years reached the high level of 20%. The banks resisted to impose bankruptcy and accumulated a large stock of these non-performing loans into their balance sheets[28].

Figure 3 shows that the labor wedge decreases before the recession and increases afterwards. In developed countries, the labor wedge has a mild explanatory power to produce GDP fluctuations. In contrast, the labor wedge plays a trivial role in the business cycles of developing countries, and in the case of Iran the labor wedge predicts GDP in the opposite direction. In further research, we need a detailed model to explain this observation, but we can provide a potential explanation here. Monetary base grew by 19.5% between 1990 and 2005, but it grew by 31% between 2005 and 2010. This expansionary policy acts like an inflationary tax and decreases labor wedge before 2013. On the other hand, the Central Bank of Iran has shown more commitment to its policy and obeyed its rule rigorously since 2013[29].

One key point which is necessary to mention is the role of nominal exchange rate jump in 2012-2013 recession. Nominal exchange rate tripled in less than two years[30]. Importantly, as shown in the detailed model, part of the nominal exchange rate jump that was caused by boycotts manifests itself through the trade wedge. By our findings, this part cannot well explain GDP fluctuations in 2012-2013.[31]

Robustness Check

We conduct two types of sensitivity analysis to validate our findings. First, we revise the definition of intermediary imported goods in our accounting steps. In particular, we consider capital goods as imported intermediary, which yields to a calibrated parameter of 0.12 for γ. We rerun the whole accounting procedure with new parameters and wedges and find out that the explanatory power of the trade wedge improved slightly. In a separate experiment, we define capital goods and final goods as the intermediate imports and reach to the calibration of $\gamma = 0.137$. We reach the same conclusion as the previous one. Hence, we conclude that our results are independent of the definition of imported intermediate goods. Under each definition the calibrated value of γ changes in a way that in all setups the trade wedge cannot produce aggregate fluctuations.

Alternative functional forms is our second strategy to check the robustness of results. Our benchmark framework assumes a Cobb-Douglas production function, which dictates unit elasticity between inputs. Alternatively, we use the CES production function in which the elasticity of substitution between the imported intermediate goods and the production is constant but not necessarily equal to one. We conjecture that the two factors of production are complements. Theoretically, this robustness is crucial because in our benchmark exercise we find that the trade wedge moves intermediate inputs. Hence, the degree of complementarity between the production and intermediate imports can hypothetically modify our conclusions. Equation

---

[26] Eight UN Security Council Resolutions were passed between 2006-2012, imposing various sanctions on Iran.

[27] The long run average of non-performing loans in Iran before the crisis was 8%

[28] Out of $27 billion unpaid loans, about $8 billion had been given to ninety recipients. Press TV, "In Iran, 90 people owe $8 billion to banks" Aug, 23, 2009

[29] Monetary base grew 17% in 2013.

[30] Inflation rate also rose up to around 40%.

[31] In an online appendix, we analyze the statistics of the entire period

15

(29) shows the suggesting CES function for final output. Note that in this setup, the final output is the sum of output and imported intermediate goods.

$$y_t = (\gamma(k_t^{\alpha}(A_t L_t)^{1-\alpha})^{\rho} + (1-\gamma)m_t^{\rho})^{1/\rho} \tag{23}$$

where $\rho = \frac{\theta-1}{\theta}$ and θ is the elasticity of substitution between the factors of production. To calibrate θ, we have used equation (30) and quarterly data on real GDP, imported intermediate goods, and real exchange rate:

$$\frac{m_t}{GDP_t} = (\frac{(p_m)(\gamma)}{p_y(1-\gamma)})^{1/(\rho-1)} \tag{24}$$

Since ρ is negative, the ratio of the intermediate goods to output is positively related to $(1-\gamma)$ and negatively related to P_m. By regressing $\frac{m_t}{GDP_t}$ on p_m and p_y, we have calibrated ρ to be -1.5, and the elasticity of substitution between the factors of productions to 0.4. Also, γ is determined in a way that $\frac{m}{GDP}$ in the stationary model fits Iran's data.

Then, we ran the experiment with the new production function and parameters. The results were the same as in the benchmark qualitatively, so we are not going to repeat them here. In conclusion, our findings are robust with different data and production function specification.

Similar to our benchmark findings, the trade wedge by itself can produce the import fluctuations but plays a secondary role in explaining GDP fluctuations and causes moderate movements in GDP. Again, consistent with our conjecture, we find a surge in trade barriers afterwards the 2012 international sanctions, but this increase could not explain the 2013 recession.

IX. Conclusion

Iran's economy experienced a deep recession during 2012-2013. Economists and policy makers speculate various causes, such as international sanctions, poor fiscal policies, and others to be the source of the recession, but there have been no studies to quantify the impact of these factors. This paper is aimed to examine various hypothetical causes of the 2012-2013 recession by defining wedges following Chari et al (2007).

We extend the benchmark model by adding a new wedge called "Trade Wedge" in order to measure the effect of financial trade barriers, such as exchange rate jumps and sanctions on the recession. The trade wedge predicts only 1.1% of decline in GDP during the recession, so the sanctions and embargos that resemble trade wedges in our prototype economy have almost no explanatory power in producing the downturn. However, we do not reject the hypothesis that the sanctions may initiate the crisis, and the accumulated non-performing loans in the banking sector dominantly deepened the recession. Moreover, our finding is limited to sanctions that resemble trade barriers. A sanction, like the oil export embargo, may have contributed to the recession but isn't accounted for in our trade wedge.

In sum, we find that the efficiency wedge explains a great portion of the fluctuations in GDP during the 2013 recessions, and the investment wedge plays a secondary role. Other wedges have almost no explanation power.

References

1. Askari, Hossein, et al. "US Economic Sanctions: Lessons from the Iranian Experience." Business Economics 36.3 (2001): 7-7.
2. Bernanke, Ben, Mark Gertler, & Simon Gilchrist. (1997). *The financial accelerator and the flight to quality*, National Bureau of Economic Research, w4789.
3. Bordo, Michael D., Christopher J. Erceg, & Charles N. Evans. (1997). *Money, sticky wages, and the Great Depression*, National Bureau of Economic Research, w6071.
4. Broda, Christian. "Terms of trade and exchange rate regimes in developing countries." *Journal of International economics*63.1 (2004): 31-58.
5. Caruso, Raul. "The impact of international economic sanctions on trade: An empirical analysis." *Peace Economics, Peace Science and Public Policy* 9.2 (2003).
6. Chakraborty, Suparna, and Keisuke Otsu. "Business cycle accounting of the BRIC economies." *The BE Journal of Macroeconomics* 13.1 (2013): 381-413.
7. Chari, Varadarajan V., Patrick J. Kehoe, & Ellen R. McGrattan. (2007). *Business cycle accounting*, Econometrica 75.3, 781-836.
8. Chari, Varadarajan V., Patrick J. Kehoe, & Ellen R. McGrattan. (2002).*Can sticky price models generate volatile and persistent real exchange rates?*, The Review of Economic Studies, 69.3, 533-563.
9. Cho, Dooyeon, and Antonio Doblas-Madrid. "Business cycle accounting east and west: Asian finance and the investment wedge." *Review of Economic Dynamics* 16.4 (2013): 724-744.
10. Cole, Harold L., & Lee E. Ohanian. (2004). *New Deal policies and the persistence of the Great Depression: A general equilibrium analysis*, Journal of Political Economy, 112.4, 779-816.

11. Dreger, C., Kholodilin, K. A., Ulbricht, D., & Fidrmuc, J. (2016). Between the hammer and the anvil: The impact of economic sanctions and oil prices on Russia's ruble. Journal of Comparative Economics, 44(2), 295-308..

12. Ebrahimain, Mehran. (2014). *Calibrating a Dynamic General Equilibrium Model for Iran's Economy*

13. Echavarria, Paulina Restrepo, Mark LJ Wright, and Lee E. Ohanian. "Bad Investments and Missed Opportunities: Capital Flows to Latin America and Asia, 1950-2004." *2009 Meeting Papers*. No. 1099. Society for Economic Dynamics, 2009.

14. Elliott, Kimberly Ann, and Gary Clyde Hufbauer. "Same song, same refrain? Economic sanctions in the 1990's." *The American Economic Review* 89.2 (1999): 403-408.

15. Gali, Jordi. (1996). *Technology, employment, and the business cycle: Do technology shocks explain aggregate fluctuations*, National bureau of economic research, w5721.

16. Gali, Jordi, J. David Lopez-Salido, & Javier Valles. (2003).*Technology shocks and monetary policy: assessing the Fed's performance*, Journal of Monetary Economics, 50.4, 723-741.

17. Hevia, Constantino. (2014).*Emerging market fluctuations: what makes the difference?*, Journal of International Economics

18. Hufbauer, Gary Clyde, et al. "US economic sanctions: Their impact on trade, jobs, and wages." *Institute for International Economics* 3 (1997).

19. Kengo, Nutahara, and Inaba Masaru. *An Application of Business Cycle Accounting with Misspecified Wedges*. No. 11005. 2011.

20. Kersting, Erasmus K. "The 1980s recession in the UK: A business cycle accounting perspective." *Review of Economic Dynamics* 11.1 (2008): 179-191.

21. Kohn, David, Fernando Leibovici, and Michal Szkup. "Financial frictions and new exporter dynamics." *International economic review* 57.2 (2016): 453-486.

22. Kydland, Finn E., & Edward C. Prescott. (1982).*Time to build and aggregate fluctuations*, Econometrica: Journal of the Econometric Society, 1348-1370

23. Mendoza, Enrique G. "The terms of trade, the real exchange rate, and economic fluctuations." *International Economic Review* (1995): 101-137.

24. Nasseri Ladane (12 February 2012). "Iran Won't Yield to Pressure, Foreign Minister Says; Nuclear News Awaited". Bloomberg. Retrieved 13 February 2012

25. Neumeyer, Pablo A., and Fabrizio Perri. "Business cycles in emerging economies: the role of interest rates." Journal of monetary Economics 52.2 (2005): 345-380.

26. Orsi, Renzo, and Francesco Turino. "The last fifteen years of stagnation in Italy: a business cycle accounting perspective." *Empirical Economics* 47.2 (2014): 469-494.

27. Otsu, Keisuke. *International business cycle accounting*. No. 10, 10. School of Economics discussion papers, 2010.

28. Otsu, Keisuke. "A neoclassical analysis of the Korean crisis." *Review of economic dynamics* 11.2 (2008): 449-471.

29. Preeg, Ernest H. *Feeling Good or Doing Good with Sanctions: Unilateral Economic Sanctions and the US National Interest*. Vol. 21. Center for Strategic & International studies, 1999.

30. Rahmati, Mohammad, & Jacek Rothert (2011). *Business Cycle Accounting in a Small Open Economy*, Mimeo, University of Texas at Austin.

31. Rahmati, Mohammad, Madanizadeh, Seyed Ali, Jabbari, Masoud, & Karimirad, Ali, (2015) *"Business Cycle Accounting: Iran's stagflation."*

32. Šustek, Roman. (2011). *Monetary business cycle accounting*. Review of Economic Dynamics, 14.4, 592-612.
33. Torbat, Akbar E. "Impacts of the US trade and financial sanctions on Iran."*The World Economy* 28.3 (2005): 407-434.
34. Uribe, Martin, and Stephanie Schmitt-Grohé. *Open economy macroeconomics*. Princeton University Press, 2017.
35. Yousefi, Kowsat, "Trade in Iran", (2016), unpublished documents

Appendices

Appendix A. Proofs

The main idea is that frictions in the benchmark prototype economy and the detailed model distort first order conditions and resource constraint in the same way. Then, we can determine which friction manifests itself through which of wedges, so we first solve both models and determine wedges in order to constraints of two models are equal to each other.

Proof of propositions:

i. Detailed model:

From equation (13) and (14) we have

$$c_t + \left(k_{t+1} - k_t(1 - \delta)\right) + e_t x_t = q_t = v_t z_t + e_t m_t$$

$$c_t + \left(k_{t+1} - k_t(1 - \delta)\right) = v_t z_t \tag{25}$$

The first order conditions of households are

$$\frac{u_{l,t}}{u_{c,t}} = -w_t \tag{26}$$

$$\beta E_{t+1}(u_{c,t+1}[r_{t+1} + (1 - \delta)]) = u_{c,t} \tag{27}$$

The first order conditions of firms are

$$r_t = v_t F_k(k_t, l_t) \tag{28}$$

$$w_t = v_t F_l(k_t, l_t) \tag{29}$$

$$m_t = \frac{\gamma q_t}{(1 + r_t \theta_t) e_t} \tag{30}$$

We solve the model to find v_t— the price of value added in production function.

$$q_t = (\frac{\gamma v_t}{(1 - \gamma)(1 + \theta_t r_t) e_t})^\gamma z_t$$

$$(1 - \gamma) q_t = v_t z_t$$

$$v_t = (1 - \gamma)(\frac{\gamma}{(1 + \theta_t r_t) e_t})^{\gamma/(1-\gamma)} \tag{31}$$

20

ii. Benchmark prototype economy with four standard wedges

Household faces the same problem as we mentioned in the benchmark prototype economy, so two first order conditions of household are:

$$\frac{u_{l,t}}{u_{c,t}} = -(1 - \tau_{l,t})\, w_t \tag{32}$$

$$\beta E_{t+1}(u_{c,t+1}(1 + \tau_{x,t+1})[r_{t+1} + (1 - \delta)]) = u_{c,t}(1 + \tau_{x,t}) \tag{33}$$

The production function is $y_t = A_t F\big(k_t(s^t), l_t(s^t)\big)$, and we do not impose any restriction on the form of $F\big(k_t(s^t), l_t(s^t)\big)$.

The first order conditions of firms are

$$r_t = A_t F_k(k_t(s^t), l_t(s^t)) \tag{34}$$

$$w_t = A_t F_l(k_t(s^t), l_t(s^t)) \tag{35}$$

The resource constraint is:

$$c_t(s^t) + \big(k_{t+1}(s^t) - k_t(s^t)(1 - \delta)\big) = A_t F\big(k_t(s^t), l_t(s^t)\big) \tag{36}$$

For the equivalent results, we need $A_t = v_t,\ 1 + \tau_{x,t+1} = 1\ ,\ 1 - \tau_{l,t} = 1$

iii. Benchmark prototype economy with trade wedge

Although we set up this benchmark in Section II, we prove proposition 2 for a more general case. We relax our assumption about the production function. $k_t(s^t)$ and $l_t(s^t)$ combine in an arbitrary form of $F\big(k_t(s^t), l_t(s^t)\big)$. A Cobb-Douglas production function combines the value added and imported intermediary goods. Equation (37) shows this production function.

$$y_t(s^t) = A_t(s^t) F\big(k_t(s^t), l_t(s^t)\big)^{1-\gamma} m_t(s^t)^\gamma \tag{37}$$

Household faces the same problem as we mentioned in the benchmark prototype economy, so two first order conditions of household are the same (i.e. Equation (32), (33))

The first order conditions of firms are:

$$r_t = (1 - \gamma)\frac{y_t(s^t)}{F\big(k_t(s^t), l_t(s^t)\big)} F_k(k_t(s^t), l_t(s^t)) \tag{38}$$

$$w_t = (1 - \gamma)\frac{y_t(s^t)}{F\big(k_t(s^t), l_t(s^t)\big)} F_l(k_t(s^t), l_t(s^t)) \tag{39}$$

$$\tau_m = \gamma \frac{y_t(s^t)}{m_t(s^t)} \tag{40}$$

Since y_t and q_t are final output on their own models and $(1-\gamma)$of their productions is GDP), $y_t = q_t$, so we have $A_t(s^t) = 1$. Equation (30) and equation (40) are equal if $\tau_m = (1 + r_t\theta_t)e_t$. Now, we can easily show that $v_t = (1 - \gamma)\frac{y_t(s^t)}{F(k_t(s^t),l_t(s^t))}$.

$$\frac{\gamma\, v_t}{(1-\gamma)\,\tau_m} = \frac{m_t}{F(k_t(s^t), l_t(s^t))}$$

$$v_t = \frac{m_t(1-\gamma)\,\tau_m}{\gamma F(k_t(s^t), l_t(s^t))}$$

$$\frac{y_t(s^t)}{F(k_t(s^t), l_t(s^t))} = \left(\frac{m_t}{F(k_t(s^t), l_t(s^t))}\right)^\gamma$$

$$v_t = \frac{(1-\gamma)(1+r_t\theta_t)e_t}{\gamma}\left(\frac{y_t(s^t)}{F(k_t(s^t), l_t(s^t))}\right)^{1/\gamma}$$

$$v_t = v_t^{\gamma-1/\gamma}\left((1-\gamma)\frac{y_t(s^t)}{F(k_t(s^t), l_t(s^t))}\right)^{1/\gamma}$$

$$v_t = v_t^{\gamma-1/\gamma}\left((1-\gamma)\frac{y_t(s^t)}{F(k_t(s^t), l_t(s^t))}\right)^{1/\gamma}$$

$$v_t = (1-\gamma)\frac{y_t(s^t)}{F(k_t(s^t), l_t(s^t))}$$

Also, similar to *proposition1*, from two first order conditions of household (i.e. Equation (32), (33)), we have $1 + \tau_{x,t+1} = 1$ and $1 - \tau_{l,t} = 1$.

Figure 1: Private and Public Investment
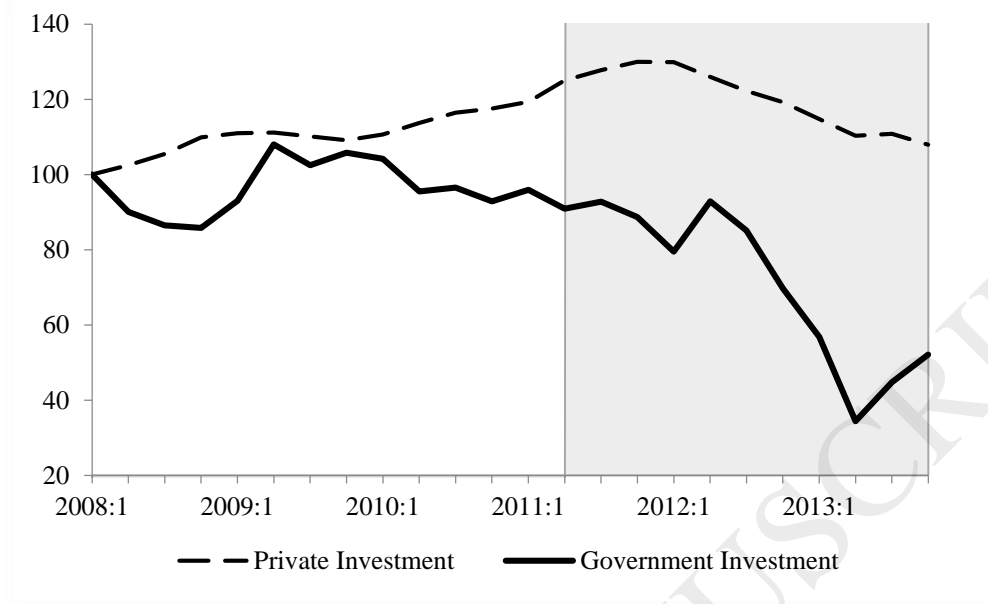
Note: The first sanction about Iran's nuclear program started December 2006. In the beginning, they imposed military and nuclear restrictions, but gradually targeted economic sections. Most strict economic sanctions were imposed after May 2011

**Figure 2: Gross Domestic Product and Oil Export of Iran**
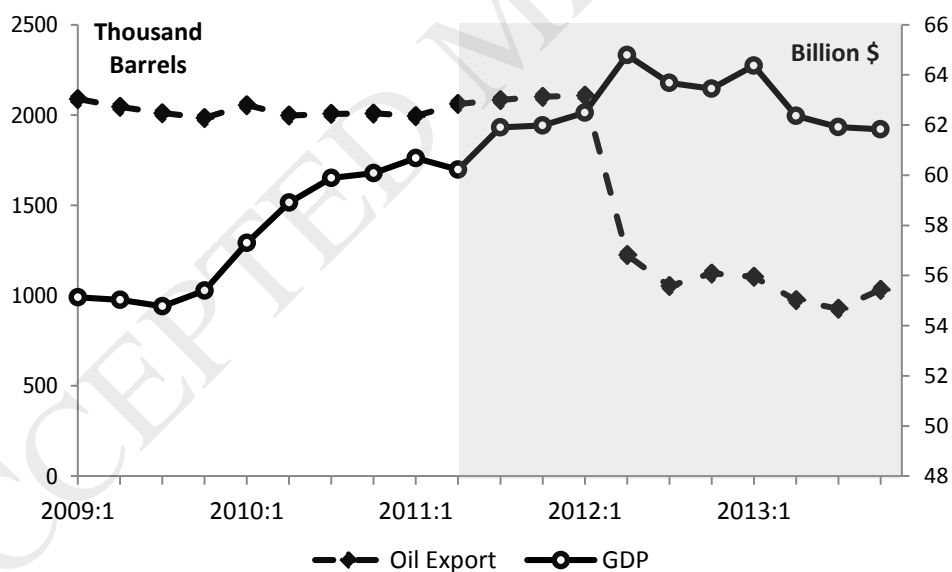
Note: The U.S. bans the world's banks from completing oil transactions with Iran and exempts seven major customers - India, South Korea, Malaysia, South Africa, Sri Lanka, Taiwan, and Turkey - from economic sanctions in return for their cutting imports of Iranian oil in June 2012. The EU ban of Iranian oil exports takes effect in July 2012. GDP (constant 2005) had dropped since 2012.

**Figure 3: GDP Fluctuations and Measured Wedges**
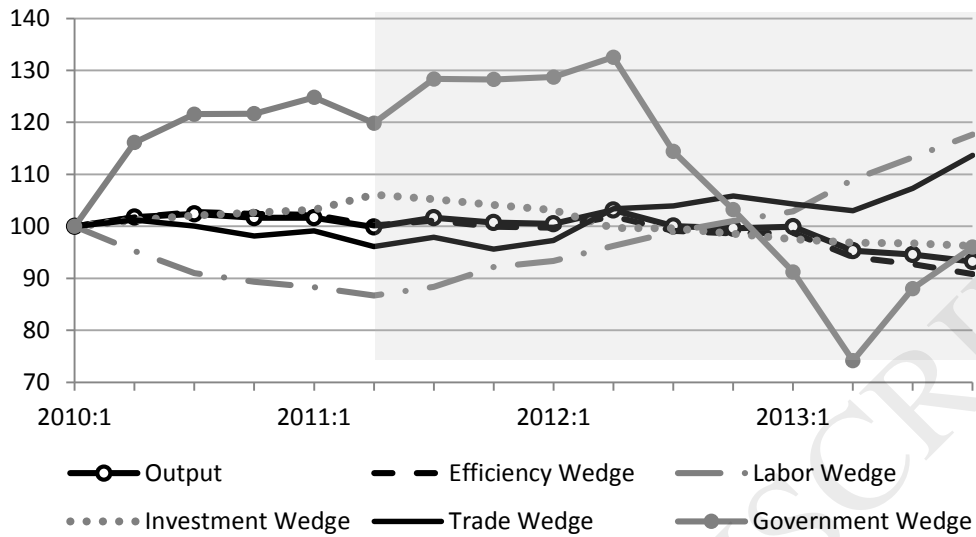
Note: This graph shows real GDP and value of different wedges. Most strict, economic sanctions were imposed after May 2011. GDP reaches its peak in summer of 2012. Then it declines 10% during seven quarters. The trade wedge shows a growing trend after fall of 2011. All series are normalized to their own values in 2010:1.

Figure 4: Actual and Simulated GDP Generated by Each Wedge
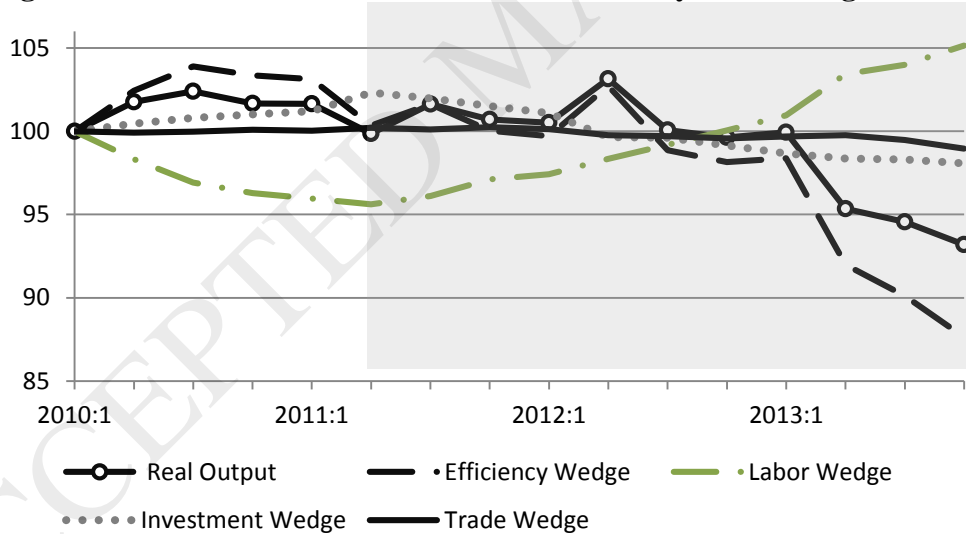
Note: This graph shows real GDP from data and model's prediction for GDP when one wedge is fed back into the model while other wedges are constant. As the graph shows, the efficiency wedge plays a pivotal role in GDP fluctuations, and the investment wedge explains recession to a certain extent. However, when we fed back the trade wedge into the model, the GDP decreases 1.1% while real GDP declines 10%. We do not depict the government wedge's GDP so that it causes almost no fluctuations in GDP. All series are normalized to their own values in 2010:1.

24

Figure 5: Actual and Simulated Investment Generated by Each Wedge
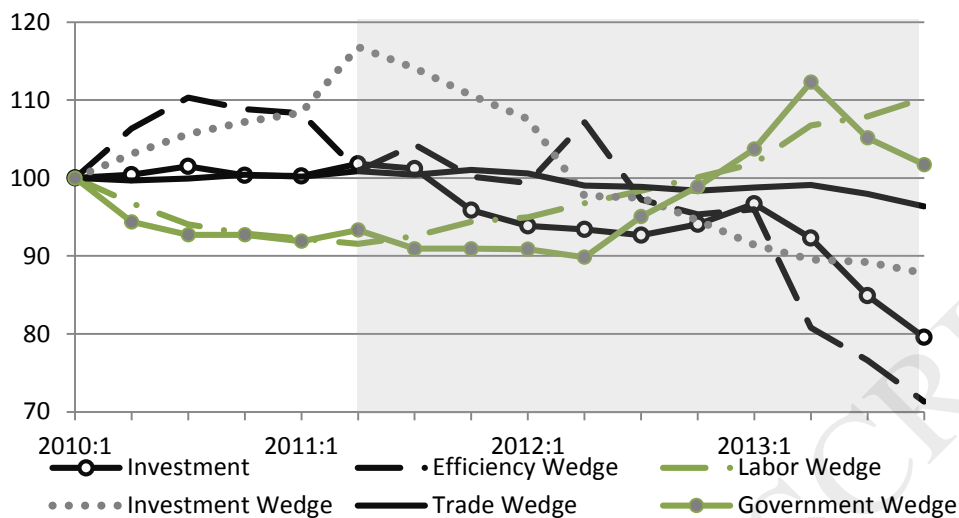
Note: This graph shows real investment from data and model's prediction for investment when only one wedge is fed back into the model while other wedges are constant. As the graph shows, the investment drops 20% from summer of 2011 to winter of 2013. The investment wedge can explain almost all the decline in investment. The government wedge and the trade wedge cause a minor decline in the investment in 2013. All series are normalized to their own values in 2010:1.

Figure 6: Actual and Simulated Imported intermediate goods by Each Wedge
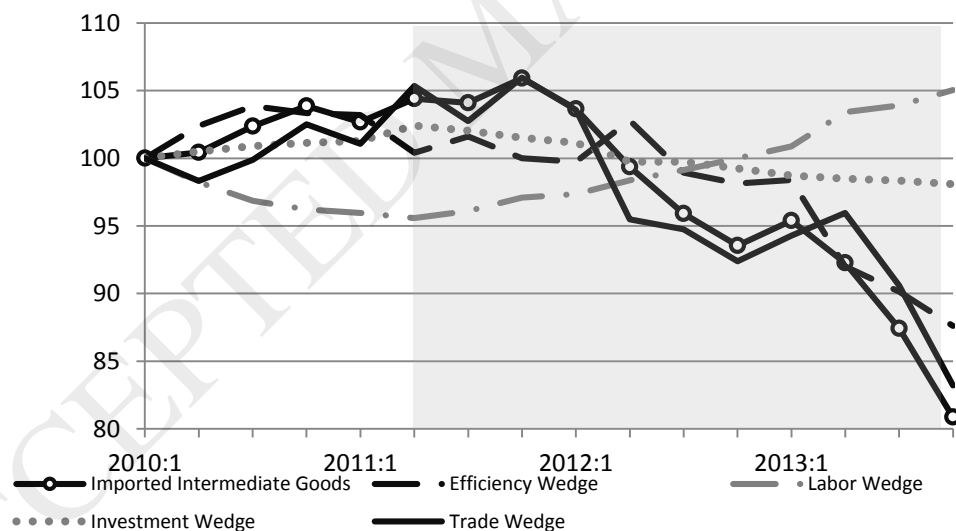
Note: This graph shows imported intermediate goods from data and model's prediction of investment when one wedge only is fed back into the model while other wedges are constant. As the graph shows, the imported intermediate goods reach their peak in winter of 2011, then drop 25% during 8 quarters. The trade wedge explains almost all fluctuations in imported intermediate goods. All series are normalized to their own values in 2010:1.

Table 1: The relation between wedges and frictions

Labor wedges	Efficiency wedges	Government wedges	Investment wedges
Wage Stickiness	Distortions in Providing Raw Materials	Foreign Liabilities Fluctuations	Credit Market Distortions
Monetary Shocks		Government Expenditure Volatility	
Cartel and Market power	Sanctions	Trade Volatility and Sudden Stops	

Table 2: Business Cycles in the U.S. and Emerging Countries

Statistics	United States	Emerging Countries
Standard Deviation		
$\sigma_{tb/y}$	0.94	3.80
$\sigma_{ca/y}$	1.11	3.08
Correlations With y		
g/y	-0.32	-0.08
tb/y	-0.51	-0.21
ca/y	-0.62	-0.24
Means		
$(x+m)/y$	18.9	46.4

Note: this table is from Uribe, Schmitt-Grohé (2017) where the variables y, tb, ca, g, x, and m denote GDP, trade balance, current account, government expenditure, export, and import. The variables y, c, g, x, and m are quadratically detrended in logs and expressed in percent deviations from trend. The variables tb/y, g/y, and ca/y are quadratically detrended in levels. All countries with PPP-converted GDP per capita between 3,000 and 25,000 dollars are considered emerging countries.

Table 3: Calibration of Parameters

Parameter	quarterly Value	Annual Value
α-Capital Share	0.66	0.66
β-Discount Rate	0.985	0.94
δ-Depreciation Rate	0.01046	0.0425
ψ-Leisure Elasticity	2.4	2.4
σ-Consumption Elasticity	1	1
g_n-Population Growth Rate	0.43%	1.75%
g_z-Productivity Growth Rate	0.594%	2.4%
γ-Intermediate Goods Share	0.09	0.09

27

Table 4: Estimates of Parameters

Coefficient of matrix

P_0

$$\begin{bmatrix} -2.518(0.4006) \\ 0.473(0.2331) \\ 0.326(0.1057) \\ -2.017(0.1548) \\ -0.2674(0.105) \end{bmatrix}$$

P

$$\begin{bmatrix} 0.9593(0.06256) & 0 & 0 & 0 & 0 \\ 0 & 0.9966(0.04072) & 0 & 0 & 0 \\ 0 & 0 & 0.9891(0.2392) & 0 & 0 \\ 0 & 0 & 0 & 0.8635(0.05499) & 0 \\ 0 & 0 & 0 & 0 & 0.9966(0.1755) \end{bmatrix}$$

Q

$$\begin{bmatrix} 0.0444(0.8037) & 0 & 0 & 0 & 0 \\ 0 & 0.0168(2.5) & 0 & 0 & 0 \\ 0 & 0 & 0.0233(0.01366) & 0 & 0 \\ 0 & 0 & 0 & 0.106(1.068e^{-20}) & 0 \\ 0 & 0 & 0 & 0 & 0.0340(0.7592) \end{bmatrix}$$

Note: we use quarterly Iran data from 1993:3 to 2013:4 and maximum likelihood estimation to estimate the value of parameters. The numbers in the parenthesis are standard deviations for a bootstrapped distribution with 250 replications.