Business Cycle Accounting of Trade Barriers in a Small Open Economy

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April, 2018

Abstract

To what extent a short-term decline in the output of a small open economy can be explained by trade barriers? We extend the Business Cycle Accounting method of Chari et al. (2007) to a small open economy model with an additional time-varying wedge that resembles financial trade frictions related to the barriers on imports. As an empirical application, we show that international sanctions against Iranian economy is a good example of financial trade barriers, therefore we apply this method to Iran data for recession of 2012-13. The results indicate that efficiency and investment wedges account for most of the fluctuations during the sanction period, 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

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I. Introduction

International movements can cause business cycles in small open economies. One important example of external restrains is trade barrier. We know the barriers are determinants in aggregate fluctuations, but the answer to question of how much of the decline in aggregate variables stems from international trade barriers is still unknown. Chari, Kehoe and McGrattan (2007) –CKM from now- 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 measure various wedges that are equivalent to detailed models, in order to quantify which theory plays primary role in generating business cycles -especially the Great Depression[3]. We extend their framework to small open economies considering international barriers.

We show theoretically that the standard CKM framework that has four efficiency, investment, labor and government wedges, cannot work in a small open economy; thus, we introduce a new wedge named, "trade wedge". The idea of adding trade wedge rests on the insight that trade barriers varying over time in small countries and behaving like a source of deviation from equilibrium conditions. As a result, they cause fluctuations of terms-of-trade and other international variables.[4] That is, trade barriers distort the foreign prices relative to domestic goods, which can look like distortions due to other wedge.[5] Noticeably, both efficiency and trade wedge cause movements in total aggregate production, so the exclusion of trade barriers shall obscure the interpretation of efficiency wedge[6]. Therefore, it is crucial to separate a foreign wedge in equilibrium from other wedges, because they are initiated from different sources and suggest separate policies.

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 restrains like trade barriers and boycott unreasonably map into the efficiency wedge. In contrast, in our benchmark model with five wedges trade barriers map into the trade wedge, so in the accounting outcome they are isolated 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 the extent of effectiveness of trade sanctions in generating this recession. The case of Iran is a good example because its economy experienced deep recession during the last phase of international sanctions against its nuclear activity. Specifically, using our method one can ask if international sanctions had any impact on Iran, does it come from financial trade barriers or other channels? Up to our knowledge, Earlier studies attempt to examine the economic impact of international sanctions, using aggregate statistics without any econometric structural approaches. The results indicate that efficiency and

[3] In section II we review this literature.
[4] 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.
[5] Loosely speaking, in CKM framework labor wedge distorts the labor market and investment wedge distorts intertemporal capital decision.
[6] 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.

investment are the key wedges that can produce 2012-2013 recession. It is important to note that trade wedges have little power to explain the magnitude of 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 in section IV, and the equivalence results are provided here. This section provides a basis of how we separate efficiency from trade wedge. Section V described the recession of 2012-2013 in Iran, and the calibration of deep parameters follows in section VI. The accounting procedures and steps are discussed in section VII. Results and findings are reported in section VIII. The final section concludes.

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 of 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, translate into its equivalent detailed economy. Its advantage is a way to compare the performance of competing explanations in a simple framework.

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	

Their benchmark prototype economy is constructed for the U.S. with little shocks from the rest of the world. Their only source of foreign shocks is a movement in net export that in their setup is analogous to the 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. In order to quantify the dynamic short-term effects of a large change in trade costs, we need a new wedge to capture this effect.

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 variable 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.

Uribe and Schmitt-Grohé (2017) study business cycles in poor, emerging and rich countries, and shows that they behave differently in each group as demonstrated in Table 2. They conclude that business cycles in emerging and poor countries are twice 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. The last but not the least, 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 in 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.

The second group extends the Business Cycle Accounting method to study their own questions, which require some amendments in 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, whereas 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 another wedges— trend shock and country risk—to account for the fluctuations in Mexico during the Tequila Crises, especially in trade balance and current accounts[14]. 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; thus it develops a new benchmark model.

A related Literature on Sanctions: A long history of economic sanctions backs to the World War I Elliott, Clyde, and Hufbauer (1999) record 170 sanctions in the 20^{th} 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 find that moderate sanctions reduce bilateral trade by 27%, while sever sanctions decrease it by 91%. In a similar study, Caruso (2003) uses a gravity model and shows sever multilateral sanctions reduces trade by 81%. Following the recent international sanction against Russia, Dreger et al. (2016) study a similar question to ours that how much of Ruble deprecation on 2014 stems from the sanction after the crisis in Ukraine versus the sharp decline in oil price. They examine this question using VAR models and high frequency observations; they find that the depreciation can be related 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 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):

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

[14] 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.

The utility function is:

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

where β is discount factor, and $1/_\sigma$ is intertemporal elasticity of substitution[15].

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

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

where $T_t(s^t)$ is the lump sum transfer to households, $g_t(s^t)$ is the government wedge 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 as:

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

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:

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

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

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

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

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

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

The feasibility constraint in our model follows:

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

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 simplicity in notations.

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

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

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

$$r_t = A_t F_k(k_t(s^t), l_t(s^t)) \quad (8)$$

$$w_t = A_t F_l(k_t(s^t), l_t(s^t)) \quad (9)$$

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

IV. Equivalence Results of Trade Barrier Wedges

In this section, we show that in a 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 sanction, and boycotts[16]. The aggregate final output producer combines composite value-added goods z_t and imports m_t according to produce q_t as:

[16] 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

$$q_t = z_t^{1-\gamma} m_t^{\gamma} \quad (11)$$

where $0 < \gamma < 1$; and it chooses z_t and m_t to solve:

$$Max\ q_t - \nu_t z_t - e_t m_t - \theta_t r_t e_t m_t \quad (12)$$

subject to (6), where ν_t is the price of composite value-added, r_t is the interest rate, and θ_t is the fraction of imports that firms have to pay in advance for input bills, and $0 < \theta_t < 1$. The financial frictions are θ_t and look like 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

$$z_t = F(k_t, l_t) \quad (13)$$

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

$$Max\ \nu_t z_t - w_t l_t - r_t k_t \quad (14)$$

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,

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

subject to the budget constraint

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

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

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

where $\xi_t$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, drops consequently the export, and depreciates both nominal and real exchange rate. Trade balance implies that[17]

$$\mathrm{x}_t = m_t \quad (18)$$

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

[17] 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*

$$(1-\tau_{l,t}) = \left({}^{1}\!/_{1+\tau_{x,t}}\right) = 1 \quad (19)$$

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*[18]*.*

Proposition 1 shows that the effects of sanctions (financial trade barriers) are manifest in 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*

$$(1-\tau_{l,t}) = \left({}^{1}\!/_{1+\tau_{x,t}}\right) = 1 \quad (20)$$

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*[19]*.*

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.

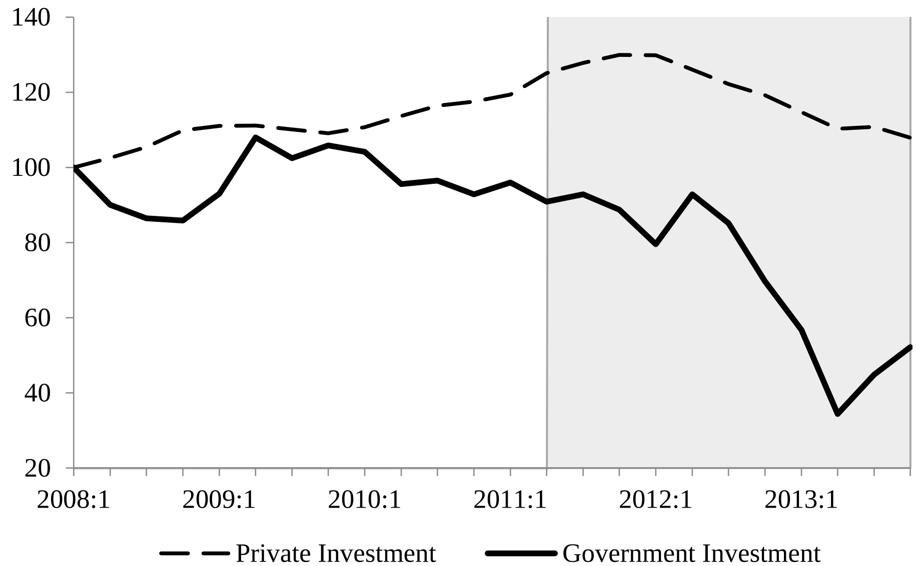
V. Iran Case Study: Trade Barriers, International Sanction, and Recession

Iran has been the subject to various international sanctions in the past four decades. On 1979 right after the revolution, the United States started the first economic sanctions on 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 end up with serve economic recession during 2012-2013. These sanctions are enacted by several agreements among developed countries imposing economic restrictions on Iran to force the country to halt its nuclear activities. However, no economic studies have yet examined the impact of these U.N. policies, in particular, to what extent these restraints on Iran's economy were effective? Is there any causality between these sanctions and server recession? To study these questions and evaluate the policy impact of sanctions, it is crucial to understand the background of Iranian economy.

[18] See appendix A for the proof of the proposition.
[19] 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[20] were reduced by 7.4% of GDP in 2012. All these falls are indicating 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.

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

The international trade sanction restrains exports of 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[21] during 2006-2012 due to Iran's nuclear programs, imposing severe sanctions on Iran.[22] The most severe sanctions started in 2012 boycotted Iran's oil export[23] and restricted financial transactions through preventing foreign banks to service Iranians. As a result, credit and legal risk progressively

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

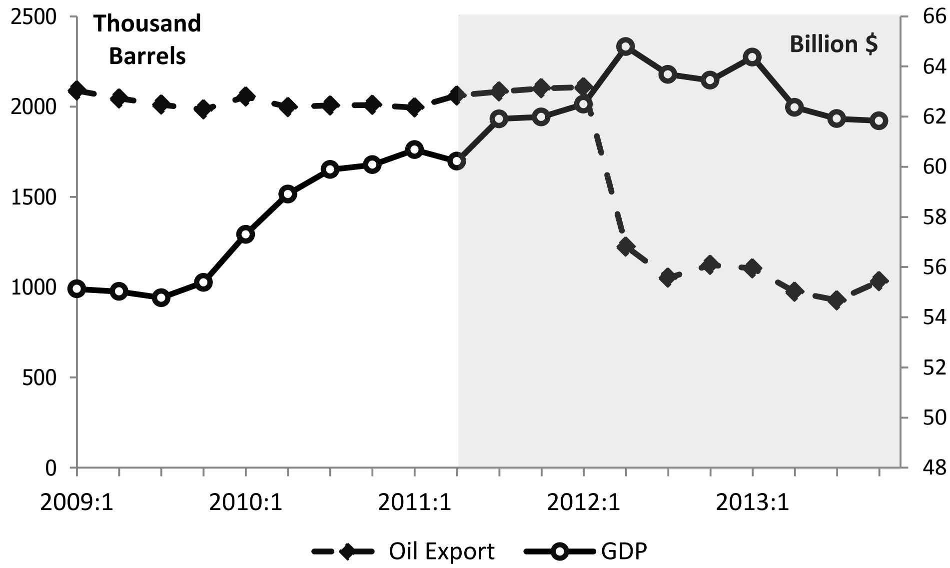
[21] United Nations Security Council Resolutions: 1696 (31 July 2006), 1737 (23 December 2006), 1747 (24 March 2007), 1803 (3 March 2008), 1835 (27 September 2008), 1929 (9 June 2010), 1984 (9 June 2011), 2049 (7 June 2012)

[22] 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[22]. 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.

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

increased such that the necessary gross margin for letter of credit was tripled between 2012 and 2013. Moreover, the European Union also imposed restrictions on trade with Iran, in particular in energy sector, and prohibited any technology transfers. 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[24]. As shown in Fig. 2, the oil exports dropped substantially after the oil sanctions.

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.

Moreover, these strict sanctions coincide with poor domestic policies. The government has started an energy reform since 2010. In 2010, 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.[25] Moreover, the government committed to pay annually 25 B$ lump sum unconditional cash transfer, without any determined sources to fund the payment[26]. 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 build about 1.8 Million low-cost houses. To finance this project, the government borrowed from the Central Bank. More importantly, the money base grows 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.

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

[25] 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)

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

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.[27] Table 3 summarizes the calibration of parameters for the annual and the quarterly data.

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

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

$$\frac{-u_l}{u_c} = w_t \tag{21}$$

Using equation 2, we have

$$[l_t/(1-l_t)]H_t w_t = xC_t \tag{22}$$

where H_t is total working hours, $\text{number of employees} \times \text{average working hours}$, 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.[28].

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

[27] 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

[28] 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.

no trend; while population growth rate is 1.75%. Therefore, based on our calibration, we reach to α=0.66, and $g_z = 2.4\%$.

The elasticity of substitution between 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 by the model and compared them with data. The model with $\sigma = 1$ generates comparable moments to real data.[29]

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[30].

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

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 $\sum$ are 5×5 matrices, and P_0 is a 5×1 vector representing the optimal amount of wedges. The number of parameters that should be estimated depends on the number of constraints imposed on P and $\sum$. For instance, since $\sum$ is a symmetric and negative semidefinite matrix, it suffices if we calculate the upper triangular matrix Q so that: $\sum = Q.Q'$. In this case we have to estimate 5 parameters for P_0, 25 paraments for P, and 15 parameters for $\sum$. 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[31].

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

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

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

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

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

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

[30] 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.

[31] Because we have only 82 quarters, using 45 parameters makes the estimation inaccurate. We report other variations of P_0, P, Σ in appendix B.

where D_t is the real data for Iran at time t. X_t is the state variable which k_t is the only endogenous state variables. Households know his 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 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 of export, 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.

Table 4: Estimates of Parameters

Coefficient of matrix

$$P_0 \quad \begin{bmatrix} -2.442(2.666e^{-11}) \\ 0.481(2.071e^{-8}) \\ 0.308(1.275e^{-8}) \\ -2.010(2.114e^{-7}) \\ -0.1694(4.970e^{-10}) \end{bmatrix}$$

$$P \quad \begin{bmatrix} 0.9594(5.183e^{-20}) & 0 & 0 & 0 & 0 \\ 0 & 0.966(5.352e^{-21}) & 0 & 0 & 0 \\ 0 & 0 & 0.9892(9.652e^{-23}) & 0 & 0 \\ 0 & 0 & 0 & 0.8636(7.052e^{-65}) & 0 \\ 0 & 0 & 0 & 0 & 0.9966(5.445e^{-126}) \end{bmatrix}$$

$$Q \quad \begin{bmatrix} 0.0444(7.127e^{-39}) & 0 & 0 & 0 & 0 \\ 0 & 0.0168(1.683e^{-21}) & 0 & 0 & 0 \\ 0 & 0 & 0.0233(2.336e^{-23}) & 0 & 0 \\ 0 & 0 & 0 & 0.106(1.068e^{-20}) & 0 \\ 0 & 0 & 0 & 0 & 0.0340(3.406e^{-18}) \end{bmatrix}$$

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.

- 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

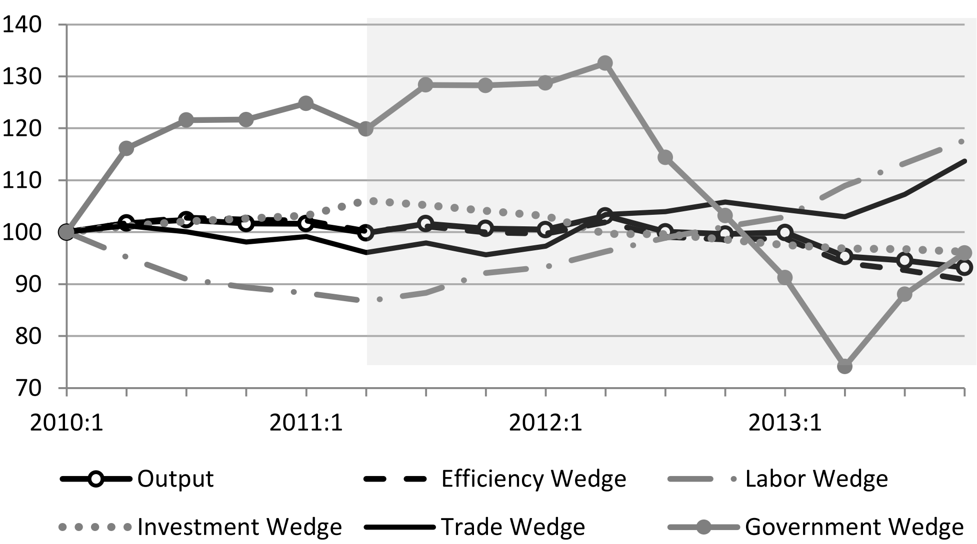
We apply the accounting procedure explained in the previous section on the five-wedge benchmark prototype economy of section III using macroeconomic data from Iran. We find that in the 2013 recession, the efficiency wedge explains major parts of the fluctuations in GDP, and the investment wedge plays a secondary role, while other wedges play close to no role. Although the trade wedge accounts for variations in imported intermediate goods, it fails to account for GDP movements much. 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 movements of 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 to produce the 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

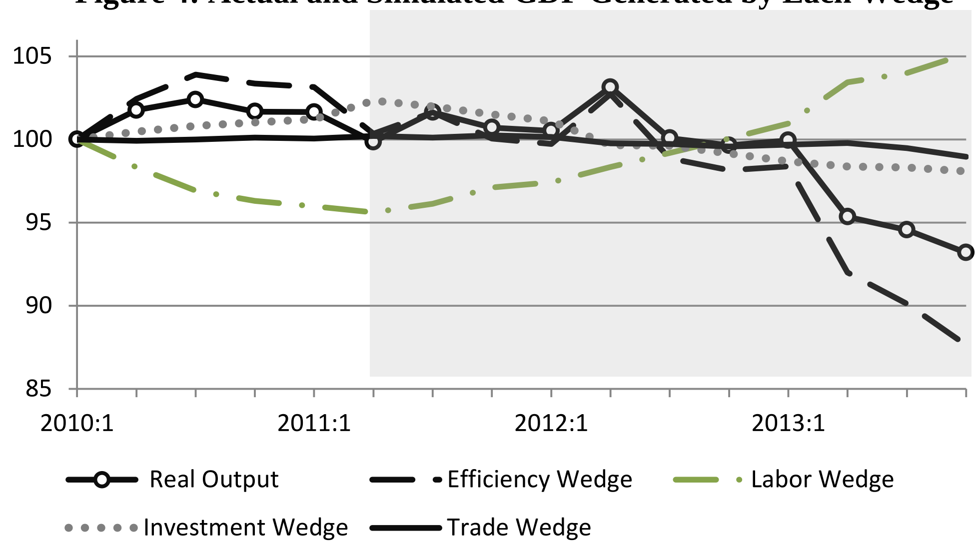
Figure 3 shows GDP and measured wedges—the efficiency wedge ($Ln[A_t]$), the labor wedge (1-$\tau_{l,t}$), the investment wedge($^1/_{1+\tau_{x,t}}$), and the trade wedge (1+$\tau_{m,t}$). The trade wedge shows an increasing trend probably caused by the wave of international sanction in 2011. Unlike 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 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 some 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.

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 move 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 significant impact on GDP. It is important to highlight that we measure the weight of each wedge on the depression. However, it is likely that the sanctions ignite the recession but other real terms deepen the downturn. Moreover, there are three reasons that may justify our findings. First, exchange rate fluctuation usually acts like 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 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 depends 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 do not well substitute with the importing final goods.

Second, we proved that exchange rate jumps and trade barriers manifest themselves through the trade wedge. However, oil boycott is different. There was a quota for oil export; so there was a "quantity effect"[32] besides 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 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 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 manifesting 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.

Third, this result is aligned with 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 compare to the sunk cost model. They discuss that relaxing financial constraint significantly increases exports. Poor domestic policies— such as getting loan from commercial banks to paying lump sum subsidy, forcing public banks to increase small loans to entrepreneurs for fast-yielding projects with very loose requirement, financing the housing program— tightened financial constraints for firms. These financial constraints decreased the effects of jump in trade barriers. If these sanctions imposed on a country with lower financial friction 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 regulated. During the recession, nominal wages were stagnated, but the real wages declined as a result of the high inflation.[33] 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 is completely visible in the figure.

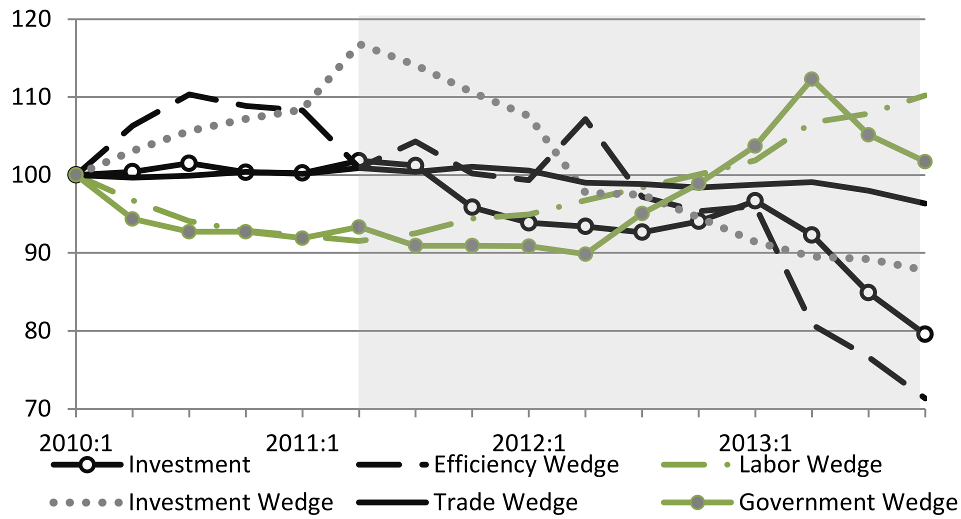
Figure 5 depicts investment and its simulations produced by various wedges. The investment wedge predicts the downturn in investment in the 2013 recession. The efficiency wedge can also explain a great proportion of the investment drop during the 2013 recession. In contrast, the government wedge is unable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

[32] 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.
[33] Actually, in 2013 Iran experienced a stagflation: a severe recession and a high inflation, together.

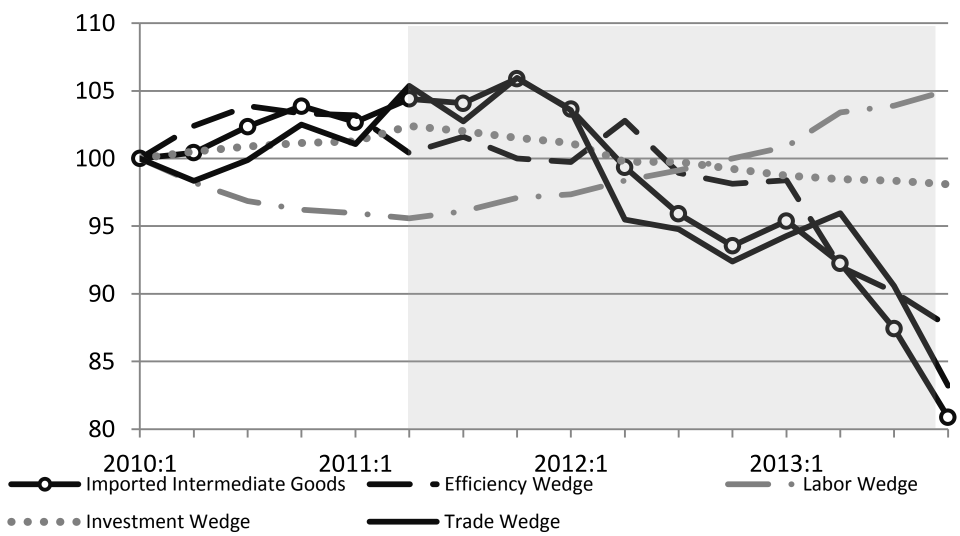
boycotts) that manifest themselves as trade wedge can account for movements in imported intermediate goods but it fails to explain contemporaneous GDP movements. Moreover, the efficiency wedge explains half of the decline in importing intermediate goods during the 2013 recession.

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.

In sum, the efficiency wedge and the investment wedge account for almost all 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 dip recessions. These features of East Asian economies mentioned by Cho and Doblas-Madrid (2013) are similar to 2012-2013 recession in Iran. Either poor domestic policies[34] or international sanctions[35] were the trigger for a contagion in overdue loans. The share of non-performing loans was just below 10% on 2005,[36] 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[37].

Figure 3 shows that 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 19.5% from 1990 to 2005, but it grew 31% from 2005 to 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 imposed more discipline since 2013[38].

One key point which is necessary to mention is the role of nominal exchange rate jump in 2012-2013 recession. Nominal exchange rate was tripled in less than two years[39]. Importantly, as shown in the detailed model, the part of 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.

Analyzing the entire period

We now extend our analysis over the entire period to measure the role of each wedge in explaining the business cycles in Iran. For this purpose, we measure the time series of wedges and simulate the GDP movements for the period 1993:3 through 2013:4, using HP-filtered data. We first consider the standard deviation of wedges relative to GDP and their correlations with GDP. We then measure the correlation between wedges at different lags and leads. This analysis

[34] 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.

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

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

[37] 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

[38] Monetary base grew 17% in 2013.

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

is summarized in Table 5. Second, we determine the standard deviations of the predicted GDP relative to Iran's GDP data and their correlation with real data showing in Table 6. These tables summarize the important features of wedges and predicted outputs created by them for 1993-2013.

In panel A of Table 5, we summarize statistical features of wedges. The substantial standard deviation of trade wedge relative to GDP, 3.81, indicates that trade barriers are highly volatile, more than official tariff volatility, which is not too much[40]. The efficiency wedge has a standard deviation the same as GDP and is highly correlated with it. On the contrary, the labor wedge has negative correlation with GDP, which is contradictory to most countries' business cycles. The giant standard deviation of government wedge is due to the oil export; because oil is its largest component, and oil market conditions deeply affect it (remember that the government wedge is the sum of government consumption and net export). One of the important features of the Iran business cycle is that wedges have high standard deviations relative to GDP more than a "usual business cycle"; this feature might implicate a poor stabilization policy in Iran.

In panel B of Table 5, we determine the cross correlation of different wedges in various lags and leads. The cross correlation of the trade wedge with the efficiency wedge and investment are highly negative (i.e., the increase in trade frictions coincide with the increase in frictions that manifest themselves with the efficiency wedge and the investment wedge).

[40] The standard deviation of official tariff relative to output is 1.57.

Table 5: Summary Stats of Wedges, 1993:3-2013:4

A. Summary Statistics						
	Standard Deviation	Cross Correlation of Wedges with GDP at $Lag\ k =$				
Wedges	Relative to GDP	-2	-1	0	1	2
Efficiency	0.99	0.44	0.71	0.92	0.64	0.31
Labor	2.39	-0.11	-0.24	-0.33	-0.31	-0.18
Investment	2.28	0.12	0.13	0.13	0.37	0.30
Government consumption	17.91	-0.20	-0.21	-0.19	0.01	0.03
Trade	3.81	-0.31	-0.40	-0.43	-0.45	-0.39

B. Cross Correlation						
		Cross Correlation of X with Y at $Lag\ k =$				
Wedges(x,y)		-2	-1	0	1	2
Efficiency , Labor		-0.40	-0.53	-0.53	-0.39	-0.19
Efficiency, investment		0.46	0.44	0.07	0.04	-0.01
Efficiency, government consumption		0.03	0.03	-0.19	-0.12	-0.07
Efficiency, trade		-0.51	-0.49	-0.38	-0.24	-0.08
Labor, investment		-0.49	-0.53	-0.50	-0.35	-0.14
Labor, government consumption		-0.02	-0.22	-0.28	-0.24	-0.18
Labor, trade		0.40	0.36	0.25	0.15	0.01
Investment, government consumption		-0.13	0.00	0.43	-0.31	-0.35
Investment, trade		-0.29	-0.44	-0.48	-0.76	-0.57
Government consumption, trade		0.46	0.47	0.50	0.42	0.29

Note: Statistics based on logged and HP-filtered series. Panel A shows the standard deviation of wedges relative to standard deviation of GDP, and the correlation between each wedge and the real GDP. Panel B shows correlation between different wedges.

Panel A of Table 6 shows statistical properties of predicted GDP of each wedge. The predicted GDP of the efficiency wedge is highly correlated to the real GDP, and its magnitude is

more than four-thirds as much as real GDP. The investment wedge makes fluctuations as much as GDP, but the resemblance is low. Also, trade wedge fluctuates 58% as much as Iran's GDP and is positively correlated with it, which demonstrates that the trade wedge plays a secondary role in explaining Iran's business cycles during 1993-2013 even though it had no explanatory power for the 2013 recession. We will come back to the discussion of this finding later. The labor and government wedge make negative correlated fluctuations compare with GDP in data, which means that both wedges had no power to explain business cycles of Iran.

Panel B of Table 6 shows cross correlation between predicted GDP of each wedge. The correlation betweenGDP from the trade wedge and GDP from the efficiency wedge is 0.47 with two period lag, and the correlation between the GDP of the trade wedge and GDP of the investment wedge with one period lag is is 0.67. The main difference between the results in Iran and developed countries is the explanatory power of the labor wedge. Labor wedge has a high explanatory power for business cycles in developed countries, but it has almost no explanatory power in Iran, which can be due to the countercyclical behavior of the labor market in the developed countries. Values generated by the efficiency wedge are highly correlated with the data, and also there is a weaker correlation between data and the output values generated by the trade wedge.

Table 6
PROPERTIES OF THE OUTPUT COMPONENTS, 1993:3-2013:4

A. Summary Statistics						
Output Components	Standard Deviation Relative to Output	Cross Correlation of Wedges with output at $Lag\ k =$				
		-2	-1	0	1	2
Efficiency	1.34	0.44	0.71	0.92	0.64	0.30
Labor	1.60	-0.04	-0.07	-0.10	-0.35	-0.25
Investment	1.14	0.10	0.09	0.08	0.35	0.28
Government consumption	0.32	-0.20	-0.21	-0.18	0.01	0.04
Trade	0.58	0.25	0.34	0.37	0.40	0.35
B. Cross Correlation						
		Cross Correlation of X with Y at $Lag\ k =$				
Output Components (x,y)		-2	-1	0	1	2
Efficiency , Labor		-0.47	-0.55	-0.16	-0.12	-0.06
Efficiency , investment		0.45	0.43	0.06	0.03	-0.02
Efficiency, government consumption		0.02	0.03	-0.18	-0.12	-0.17
Efficiency, trade		0.47	0.42	0.29	0.16	0.01
Labor, investment		-0.12	-0.27	-0.89	-0.36	-0.11
Labor, government consumption		-0.04	-0.26	-0.73	-0.02	0.10
Labor, trade		-0.24	-0.27	-0.24	-0.35	-0.13
Investment, government consumption		-0.13	0.03	0.49	-0.30	-0.34
Investment, trade		0.43	0.53	0.55	0.67	0.45
Government consumption, trade		-0.35	-0.37	-0.37	-0.39	-0.32

Note: Statistics based on logged and HP-filtered series. Panel A shows the standard deviation of predicted GDP of each wedge relative to standard deviation of real GDP, and the correlation between predicted GDP of each wedge and the real GDP. Panel B shows correlation between predicted GDP of different wedges.

In summary, the efficiency wedge has a primary role in accounting of Iran's business cycle, and the investment and trade wedge plays a secondary role. Therefore, trade frictions can cause moderate fluctuations thorough imported intermediate goods channel, but the efficiency wedge is the key to explaining Iran's business cycles.

Although the trade wedge is unable to explain the 2013 recession, Table 5 indicates that to some extent it accounts for the fluctuations of GDP in the entire period. The trade wedge, as how we introduced it, increases the cost of import. In other words, other factors those were in effects before the sanctions like tariff changes, varying country risks, changes in export subsidies resemble trade wedges in our modeling. Yousefi (2016) shows that in Iran the import tariffs are highly volatile and even change several times within a year. Iran obtains the observer status in the WTO, one year before in 2006; the country began a radical reform and unified its import tariffs. The duties on import are gradually converging to its previous conditions. In terms of interest rates, like other developing countries the political risks are hardly predictable in Iran and country's international financing cost fluctuates a lot overtime. In the same line, Neumeyer and Perri (2005) finds that in emerging markets stabilizing default risks can reduce significantly the output volatility.

Robustness Check

To do a sensitivity analysis, we have run two experiments. In the first one, capital goods import is also added to the intermediate goods import by a calibrated value of 0.12 for γ. The results to this experiment were only a bit stronger than the previous part, and the explanatory power of the trade wedge improved slightly. In the second experiment, capital goods and final goods import is also added to the intermediate goods import by a calibrated value of 0.137 for γ. The results of this experiment were also the same as the previous one. Therefore, we can conclude that the results mentioned in this part are not dependent on the specific type of modeling imports. With different types of imports, calibrated value of γ changes too, and it has no significant effect on either the trade wedge or the GDP.

The other robustness check is choosing alternative production function. We use a Cobb-Douglas production function in our benchmark model. We now use a CES production function in which the elasticity of substitution between the imported intermediate goods and GDP is constant and less than one (the two factors of production are complements). Equation (29) shows the new production function for final output (note that final output is the sum of output and imported intermediate goods).

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

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:

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

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.

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

The trade wedge accounts for the effect of trade barriers on importing intermediate goods by firms. It accounts import fluctuations very well, but plays only a secondary role in explaining GDP fluctuations and causes moderate fluctuations in GDP. We expect that trade barriers have surged since 2012 as a result of the international sanctions; the increase in trade wedge confirms this hypothesis, but this increase could not explain the 2013 recession. Therefore, international strict sanctions could not affect GDP through the import channel contemporaneously— sanctions may affect through other channels, but we are now almost sure that the import channel is not one of them. These barriers may have their effects on GDP in the subsequent years as we can observe relatively positive correlations with the GDP lags.

IX. Conclusion

Iran's economy experienced a deep recession during 2012-2013. Economists consider various factors, such as international sanctions, monetary policies, and others to be the cause of this recession, but they are not sure about the magnitude of these effects. This study is aimed to explain the 2012-2013 recession by defining wedges following Chari et al (2007).

We defined a new wedge called "Trade Wedge" in accordance to Iran's economy in order to measure the effect of financial trade barriers, such as exchange rate jumps and sanctions on importing intermediate goods by firms, which has decreased drastically during recession.

The trade wedge predicts only 1.1% decline in GDP in the 2013 recession, so sanctions that represent themselves by trade wedge has almost no explanatory power in accounting movements in GDP. We do not reject the hypothesis that strict, economic sanctions have no effect**;** we state that financial trade barriers such as sanctions cannot affect GDP through imports, contemporaneously. The trade wedge can explain part of the business cycles in Iran and caused moderate fluctuation in GDP from 1993 to 2013.

We found that the efficiency wedge explains a great portion of the fluctuations in GDP during the recessions specifically the 2013 recession, while the investment wedge, which accounts for investment movements very well, plays a secondary role; other wedges have almost no explanation.

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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

$$c_t + \left(k_{t+1} - k_t(1-\delta)\right) + e_t \mathrm{x}_t = q_t = \nu_t z_t + e_t m_t$$

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

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

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

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

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

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

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

$$(1-\gamma)q_t = \nu_t\, z_t$$

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

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 $A_t = \nu_t$, $1+\tau_{x,t+1} = 1$, $1-\tau_{l,t} = 1$

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

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

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

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

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

$$\nu_t = \nu_t^{\gamma-1/\gamma}\Big((1-\gamma)\frac{y_t(s^t)}{F\big(k_t(s^t), l_t(s^t)\big)}\Big)^{1/\gamma}$$

$$\nu_t = \nu_t^{\gamma-1/\gamma}\Big((1-\gamma)\frac{y_t(s^t)}{F\big(k_t(s^t), l_t(s^t)\big)}\Big)^{1/\gamma}$$

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

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 $1 - \tau_{l,t} = 1$.

Appendix B. Extension estimation

Now, we extend our estimation by estimating 21 parameters. We relax our constraint and trade wedge affect the investment wedge and the efficiency wedge, and vice versa. Our findings are robust.

Table 6

ESTIMATION OF PARAMETERS

Coefficient of matrix

$$P_0 \quad \begin{bmatrix} -2.442(2.666e^{-11}) \\ 0.481(2.071e^{-8}) \\ 0.308(1.275e^{-8}) \\ -2.010(2.114e^{-7}) \\ -0.1694(4.970e^{-10}) \end{bmatrix}$$

$$P \quad \begin{bmatrix} 1.052(1.609e^{-6}) & 0 & 0 & 0 & -0.0636(2.947e^{-6}) \\ 0 & 0.962(1.290e^{-12}) & 0 & 0 & 0 \\ 0 & 0 & 0.9572(2.797e^{-6}) & 0 & 0.0167(3.924e^{-8}) \\ 0 & 0 & 0 & 0.8840(2.164e^{-6}) & 0 \\ -0.241(3.850e^{-7}) & 0 & 0.1722(1.813e^{-8}) & 0 & 0.7932(2.607e^{-6}) \end{bmatrix}$$

$$Q \quad \begin{bmatrix} 0.0441(3.783e^{-9}) & 0 & 0 & 0 & 0 \\ 0 & 0.0159(5.474e^{-19}) & 0 & 0 & 0 \\ 0 & 0 & 0.01977(5.105e^{-31}) & 0 & 0 \\ 0 & 0 & 0 & 0.1065(1.635e^{-5}) & 0 \\ 0.0487(1.007e^{-7}) & 0 & -0.1611(1.812e^{-12}) & 0 & 0.0305(4.438e^{-17}) \end{bmatrix}$$

Note: we use quarterly Iran data from 1993:3 to 2013:4 and maximum likelihood estimation to estimate the value of parameters.