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Inflation Dynamics in a Dutch Disease Economy

Somayeh Mardaneh[1]

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Abstract

In this paper the effect of foreign sector macro-variable on inflation dynamics and firms' pricing behaviour has been investigated in the context of a small open economy New Keynesian Phillips Curve. This curve is derived and estimated for a developing oil-exporting economy sick with Dutch Disease. This version of NKPC is an extension of Leith and Malley's (2007) small open economy NKPC incorporating oil as a factor of production which is produced in the home country but its price is determined by the world market. Using GMM technique, this curve has been estimated for standard closed and open economy specifications of the Iranian economy that according to the empirical evidence suffers from Dutch Disease. Introducing open economy elements produces three differences in the estimation compared to closed version. First, the degree of price stickiness and the fraction of backward-looking firms decrease. Second, the degree of substitutability is close to unity. Third, the forward-looking behaviour gains ground while the backward-looking behaviour becomes less important. Moreover, the significant estimates of the marginal cost coefficient confirm the importance of the real marginal cost in explaining inflation dynamics in the Iranian economy.

JEL codes: E12, E31, F41

Keywords: Dutch Disease, hybrid New Keynesian Phillips curve, inflation dynamics, Iranian economy, small open economy.

1. Introduction

The present paper studies inflation dynamics in a Dutch Disease (DD henceforth) economy. The origin of the term DD comes from the economic downturn experienced by the Dutch economy during the 1960s, after huge reserves of natural gas were discovered in the North Sea in 1959. In 1977, the term was first introduced in an article in The Economist, to explain the reduced size of the manufacturing sector in the Netherlands due to the discovery of these natural gas resources, and has appeared in the literature since then. See for example Corden (1984). The process started with development of gas fields in this country which turned the Netherlands into

1. Associate Lecturer and Researcher, Department of Economics, University of Leicester, Iran (somaiiehmr@yahoo.com; s.mardaneh@den.ir)

one of the most important gas-exporting countries. The manufacturing industries, on the other hand, started to face a considerable decrease in foreign demand due to them becoming less competitive in the world market caused by the appreciation of the Dutch currency attributable to the trade surplus earned from exporting natural gas. The duration of the disease in the Netherlands, however, was not that lengthy and the country recovered in the early 1970s, when its exports of manufactured goods returned to normal levels. It is suggested that this might not be true for all countries suffering from such a disease.

From an economic point of view, DD refers to the impact on the rest of the domestic economy of substantial and exhaustible revenue earned from exporting a natural resource. This effect has been studied by many authors such as Corden and Neary (1982), Bruno and Sachs (1982), Corden (1984), Krugman (1987), Sachs and Warner (1995), Sosunov and Zamulin (2007). It also explains the transmission mechanism and the effects of natural resource sector revenues on other economic sectors. In other words, DD is a concept that explains the relationship between the increase in a country's exploitation of natural resources and the resulting decline in the size of its manufacturing sector. The reason for this relationship is that an increase in income from exporting the natural resources (like oil or gas) would result in a stronger domestic currency, which makes the country's other exports more expensive, thus making the manufacturing sector less competitive in the world market. DD has also been used to refer to any kind of foreign currency inflows, including the injection of foreign currency as a result of a sharp increase in natural resources' prices.

Two different effects of DD on macroeconomic variables have been considered in the related literature, first introduced by Corden (1984), which is known as the "core model" of DD.

1. Resource Movement Effect: due to the considerable profitability in the natural resource sector, the mobile production factors such as labour leave other sectors to gain more benefits in the boom sector. This movement is followed by various adjustments in the rest of the economy.

2. Spending Effect: discovery of new resources results in a period of boom in the economy and the boom increases the economy's real income, leading to higher spending on services which increases their price. In other words, a real appreciation occurs in the economy[1] for two reasons. First, the surge in the international price of oil increases the foreign currency inflows. Second, the boom also increases the nominal wage in the oil sector, which

1. The magnitude of this effect depends on the marginal propensity to consume.

tends to increase the marginal product of labour and then demand for labour in the sector, resulting in an increase in oil production and a decline in manufacturing production.

Therefore, studying the inflation dynamics in an economy sick with DD is not a trivial task. According to the literature, the New Keynesian Phillips Curve (NKPC henceforth) has been the workhorse model for investigating firms' pricing behaviour and inflation dynamics. This structural equation is estimated by many authors for various specifications of closed form of the NKPC. Gali and Gertler (1999), Gali et al. (2001, 2003 and 2005), Rudd and Whelan (2005, 2006) and Sbordone (2002, 2005 and 2007) estimated different specifications of a closed economy NKPC, often using the well-known generalised method of moments (GMM) technique.

Some of them, however, found that the conventional closed economy NKPC cannot explain inflation dynamics see for example Balakrishnan and Lopez-Salido (2002). The main problem with the closed economy version is that the marginal cost coefficients are often statistically insignificant. The reason for this might be because the real marginal cost in the closed economy version has been approximated by the labour share as the only factor of production. This is not realistic as it ignores the important role of other inputs such as energy and raw materials in production process.

The purpose of the present paper is to investigate the possible relationship between inflation dynamics and foreign sector macro-variables, such as terms of trade (TOT), as well as domestic variables, because it seems that in a DD economy TOT plays an important role. Therefore, a small open economy version of NKPC (SOE NKPC henceforth) is derived and estimated in order to evaluate the impact of expected fluctuations in TOT on inflation dynamics in an economy sick with DD. This version of the NKPC is an extension of Leith and Malley's (2007) SOE NKPC featuring the special characteristics of an oil-exporting economy.

There have been a number of studies of SOE NKPC. Balakrishnan and Lopez-Salido (2002) for the UK, Freystatter (2003) for Finland, Bardsen et al. (2004) for European countries, Gali and Monacelli (2005) for the US, Genberg and Pauwels (2005) for Hong Kong, Holmberg (2006) and Adolfson et al. (2007) for Sweden, Leith and Malley (2007) for G7, Rumler (2007) for Euro area countries, and Mihailov et al. (2009) for OECD countries are examples of the open economy NKPC formulations.

In the present paper a NKPC equation is derived and estimated for an economy sick with DD. To the best knowledge of the author this is the first time that an NKPC equation is derived for an economy sick with DD or for the Iranian economy thus far. Iran has been chosen as a DD economy due to its substantial oil reserves and the high probability of it suffering from the negative effects of large inflows of foreign currency in times of the boom or considerable increase in the international price of oil (see more details in the next section).

There have been a number of studies regarding macroeconomic modeling of the Iranian economy. Habib-Agahi (1971) was the first researcher who linearly modeled the Iranian economy using time series data. Baharie (1973) and Heiat (1978) gave two examples of demand-oriented Keynesian models, while Noferesti and Arabmazar (1993) estimated a model with non-elastic aggregate supply curve. Pahlavani, Wil-son and Worthington (2005) and Valadkhani (2006) both investigated the economic growth using different approaches but a similar structure. Moreover, Mehrara and Oskoee (2007) studied the possible relationship between oil price shocks and out-put ‡uctuation in the Iranian economy. Liu and Adedji (2000) and Bonato (2008) looked into the determinants of inflation in Iran, whereas Celasun and Goswami (2002) studied the short run dynamics of inflation in Iran.[1]

The distinctive feature of this version of SOE NKPC, however, is to incorporate oil in the production function of Leith and Malley (2007) which includes domestic labour and imported intermediate input. Therefore, the marginal cost measure ac-counts for unit labour cost, the cost of domestically produced oil as well as imported intermediate goods.

Introducing DD in open economy modeling of the NKPC suggest that inflation dynamics in a DD economy is affected by both lagged and future inflation, as they are in the closed economy case. Moreover, other driving variables of inflation are: log deviation of labour share from steady state, relative cost of domestically produced oil compared to the imported intermediate goods or terms of trade, and relative cost of domestic labour with respect to domestic and imported intermediate goods.

The key finding of this study is that the estimates of the degree of price stickiness and fraction of backward-looking firms tend to decline with introducing open economy elements in modeling inflation dynamics in Iranian economy.

The reduction of the estimated average time needed for adjusting prices, in the open economy version, indicates that the more frequently a country reset its prices, the less likely they are to display backward-looking behaviour. The estimates of degree of substitutability between inputs are statistically insignificantly different from one, suggesting that it is likely that the factors of production are substituted in response to quarterly price movement due to a possible change in oil prices.

1. See Esfahani et al. (2009) for a survey of the macroeconometric models of the Iranian economy.

Another interesting result is that, with incorporating the open economy factors, forward-looking behaviour is estimated to become more important whereas the backward-looking behaviour plays a smaller role in inflation dynamics. The significant marginal cost coefficient in most cases also confirms that marginal cost, which contains the prices of domestically produced and imported intermediate goods as well as cost of labour force, has significant power in explaining inflation dynamics in Iran.

The rest of this paper is organized as follows. Section 2 explains the symptoms of Dutch Disease and provides the empirical evidence for choosing the Iranian economy as an economy sick with DD. Section 3 derives the small open economy NKPC for Iranian economy. The results for estimation of SOE NKPC for Iranian economy suffering from DD are reported in section 4. Some concluding remarks are provided in Section 5.

2. Symptoms of Dutch Disease and the Iranian Economy

2.1. Why the Iranian Economy?

The purpose of the present paper is to study inflation dynamics through a NKPC formulation derived with the Iranian economy in mind. One may ask why the Iranian economy? In this section I will explain the reasons for choosing Iran and then I will show the possible symptoms of DD in this country.

Iran has one of the world's largest oil fields, which has been explored for more than 100 years; and it is estimated the current reserves will last for 87 years' oil production. Moreover, Iran has the second largest natural gas reserves in the world after Russia.[1] On the other hand, as can be seen in Figure 1, the share of oil revenues in the Iranian national income fluctuated around 22 percent in the 1960-2010 period, with a maximum of 52 percent in 1974 (time of the first oil shock with almost 235 percent increase in oil prices). This share is 30, 13 and 31 percent for 1979, 1990 and 2007, respectively.[2]

Therefore, it can be said that, since the mid-1970s, the oil sector has been the main provider of the foreign exchange necessary for the production process and has also played an expected and crucial role in the economic irregularity in the Iranian economy.

Arman (1998) argued that oil and services sectors contributed approximately 70-75 per cent of GDP in the second half of the 1970s; it has

1. See, for example, Esfahani et al. (2010) and Amuzegar (2008).
2. These are identified oil price shock dates in the first chapter. Oil price shock is defined as the largest percentage increase in the price of oil as a result of a sharp decline in oil supply.

been more or less in recent decades. Oil exports, on the other hand, have made up almost 80 per cent of total export in this country since then. By the end of the 1970s the Iranian economy was an excessively import-dependent economy operating in an excessively protected environment financed through oil revenues.

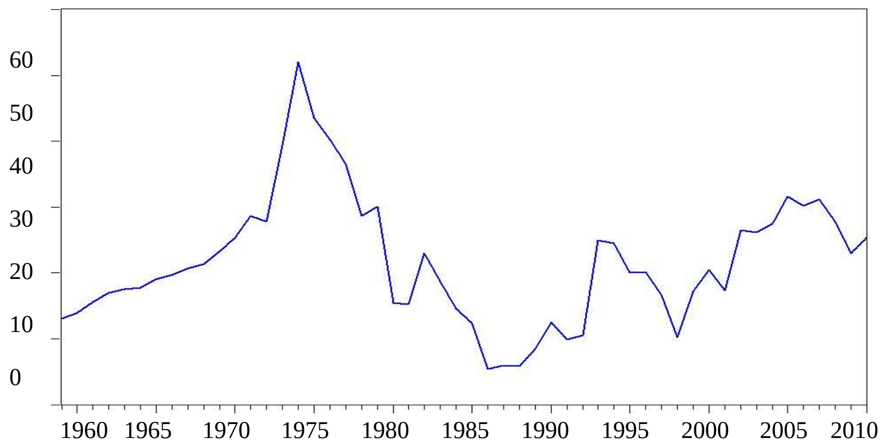

Figure 1: Share of Oil Revenues in Iranian National Income over Time

Iranian oil fields are all owned by the government who is the only recipient of oil revenues. The government exchanges US Dollar for Iranian Rial to finance its expenditures. So, it can be said that the effect of the oil revenues on the economy depends on how they are used by the government. If this revenue is invested in improving the infrastructure and manufacturing sector, to some extent, the adverse impacts of resource movement effect are reduced. Therefore, the surge of oil revenues in a country like Iran inevitably plays an important role in the process of development.

These revenues also can lead to a tendency to centralized economic decision-making, with the government monopolizing the key allocation decisions. Historically, oil prices are extremely volatile; therefore, the issue of how to manage the fluctuations of oil revenues is an important task that government should consider in its policy-making, without losing consistency with its long-term objective of promoting economic development through the expansion of other sectors. Hence, government expenditures must also be taken into account in modeling the DD economy. Considering the important share of oil in economic and political variables, Iran is a good candidate for investigating the inflation dynamics in a DD economy.

Another characteristic of the Iranian economy which should be considered in small open economy modeling is that there are two kinds of foreign exchange markets in the economy: fixed official exchange rate market and free market. Although the government always tries to prevent the free market activity, it has been the dominant source of currency exchanges in recent years. The main reason for such circumstances is the rationing system for foreign exchange and artificially overvalued Rial.[1] The persistence of an overvalued exchange rate, which is one of the main features of an economy suffering from DD, can also reduce the opportunity for other sectors to access international markets. This is one of the reasons why the effect of oil revenue in an oil-exporting country is introduced as a paradoxical concept in the literature. See for example Karshenas (1990) and Karshenas and Pesaran (1995). Therefore, the empirical analysis of the present paper is based on the free market exchange rate, which seems to be the best proxy for understanding the value of the Iranian Rial.

2.2. Dutch Disease Symptoms

DD - its causes and symptoms as well as its impact on macroeconomic variables - is one of the most attractive subjects in oil economics literature. There are several studies looking into DD from different aspects. These studies can be classified into two categories.

The first group considers the most famous effect of DD, i.e. the squeeze of the manufacturing sector or the so called 'de-industrialization' as a result of a boom (discovery of new resources) or a windfall in oil prices. Buiter and Purvis (1980) considered the impact of an increase in the world price of oil as well as oil discoveries in a model of DD, and found that the former leads to a decline in the manufacturing sector while the latter affected the permanent income in general.

Bruno and Sachs (1982) estimated inflation dynamic in a DD model for the UK economy and found that the net effect of the energy sector is to reduce the production of other manufactured goods in the long-run and to improve the TOT on final goods. Wijnbergen (1984) also investigated the effect of the decline of manufactured goods on inflation and employment in Latin American oil producers. Kamas (1986) investigated the DD effects of large increases in foreign exchange earnings from coffee in Colombia and found that the relative price of services rose and the real exchange rate appreciated.

Findings of Benjamin et al. (1989), however, shown that this might not be true for a developing economy such as Cameroon. They found that the

1. Keeping an 'artificially 'overvalued exchange rate is usually used as an essential instrument to encourage the import of capital and intermediate goods 'and also to keep food prices down in the politically sensitive urban centers. Pesaran (1982).

agricultural sector is most likely to be hurt, whereas some of the manufacturing sectors might benefit. Egert and Leonard (2008) found the same results in the Kazakhstan economy between 1996 and 2005, but observed that the real exchange rate in the manufacturing sector has appreciated during the same period.

Fardmanesh (1990) provided a different explanation for the reduction in the size of the agricultural sector instead of the manufacturing sector. He incorporated into the core model of DD the rise in the manufactured goods relative to agricultural products as a result of an increase in the international price of oil. He noted that the domestic relative price of manufactured goods rises in the oil-exporting economy as it is a price-taker in the world market. One reason for this is that the agricultural sector is the major sector, after the natural resource sector, in such countries. Fardmanesh (1991) confirmed this result by a reduced-form three sector model for five developing countries. Usui (1996) took the assumption of deindustrialization in Indonesia as a result of an oil boom as given to run a simple simulation model and reported that, to avoid this Effect, an exchange rate adjustment should be conducted.

The second group of studies focuses on the effect of DD on the economic growth path. Gelb (1988) found that resource abundance lowers growth, and this has been confirmed in other case studies such as Karl (1997) and Auty (1999, 2001). Wijnber-gen (1984) and Krugman (1987) found that there is a negative relationship between the amount of exploitation of natural resources and the size of the manufacturing sector, learning by doing (LBD) and productivity growth.

Matsuyama (1992) and Sachs and Warner (1995) established models in which economic growth is a function of the relative size of the manufacturing sector. The latter shown that most of the oil-exporting countries experienced low growth rates during some periods between 1971 and 1989. Matsen and Trovik (2005) raised the same question about the relationship between DD and lower growth rates and shown that this might not be a problem in itself, but might be part of an optimal growth path because some DDs are always optimal in terms of managing the resource wealth.

More recently in this literature, however, some authors such as Mauro (1995), Lane and Tornell (1996), Collier and Hoeffler (2004) and Caselli and Cunningham (2009) focused on the political economy effects of large windfalls in natural resources and argued that this makes incentives for the rent-seeking activities that are engaged with corruption.

This paper contributes to the literature on DD in the first group.

It is generally believed that every country rich with natural resource reserves, such as Iran, is vulnerable to DD, but to be more precise in setting the micro foundation for derivation of the SOE NKPC for a DD economy, it is worth investigating the general symptoms of the disease in the candidate country. There are several symptoms in the literature for diagnosing DD; some of them are as follows:

- Rise in the price of oil and appreciation of the real exchange rate (exchange rate is defined as home currency price of the foreign currency) simultaneously.
- Ousted manufacturing sector over time.
- Higher growth rate for services sector compared to the manufacturing sector.
- Rise in government expenditures, which results in domestic inflationary pressures.
- Increase in investment in the oil sector.
- Higher average nominal wages in the natural resource sector.

The most important symptom, however, is the first option. It is worth mentioning that all of these symptoms might not be held for a country sick with DD.

I now turn to empirically test the symptoms of DD in the Iranian economy. To test the first symptom, following the literature, a long-run relationship between real Effective exchange rate (REER henceforth) and terms of trade (TOT) is assumed. TOT is mostly approximated by the price of the commodity that makes up more than 50% of a country's export. Since oil makes up almost 80% of Iranian exports, therefore oil price is the best proxy for TOT for this country. This relationship is shown in equation (1).

$$\ln(e_t) = \ln(oilP_t) + u_t \tag{1}$$

where e_t is the steady-state REER, *OilP* refers to oil prices and u_t is disturbance term.

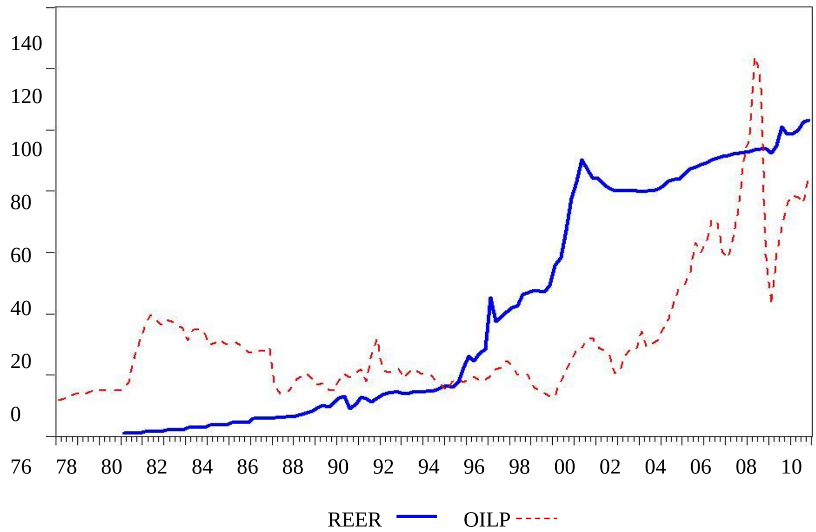

Figure 2: Real Effective Exchange Rate vs. Oil Prices

In the empirical analysis of the present paper free market exchange rate is used because, as mentioned earlier, this has been the dominant source of currency ex-changes in recent decades. Figure 2 shows a positive relationship between these two variables, as theoretically expected, because with a rise in oil prices, foreign currency inflows to the oil-exporting economy increase, i.e. the supply of “petrodollars” in-creases, resulting in appreciation of domestic currency. Before 1994, the relationship between the two variables was different because during that period the government tightly controlled the foreign exchange market as well as foreign trade, in order to maintain the real exchange rate of US Dollar as low as possible by facilitating demand for imports.

The first four of the six symptoms of DD is investigated in the Iranian economy as there was no data available for the last two properties. Panels A to C in Figure 3 show the share of the agricultural, manufacturing and services sector from revenues, respectively. Panel D, on the other hand, depicts the share of government expenditures of GDP. In Figure 3 horizontal axes measure the percentage share of each sector in real GDP, and the vertical axes show the real oil price. Although the share of revenues from the services sector grows due to increases in oil prices, it is not the manufacturing sector which is ousted as a result of DD but is the agricultural sector that declines in response to higher oil prices. This finding is consistent with those of Benjamin et al. (1989) and Fardmanesh (1990, 1991) for developing countries.

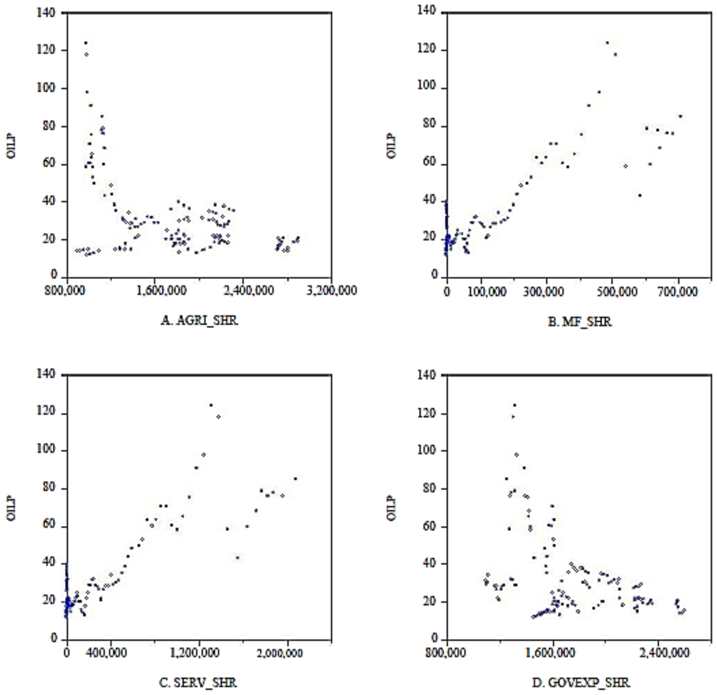

Figure 3: Investigating Dutch Disease Symptoms in the Iranian Economy

One reason for the decline in the agricultural sector could be the migration of the labour force from the sector with the least compensation to the sector with highest earnings, i.e. from the agricultural sector to the oil sector. Suppose that there are two types of workers: ‘skilled’ and ‘unskilled’. Assuming that there are four sectors in the economy, that is the agricultural, manufacturing, oil and services sectors, it is more likely that the agricultural sector is the most unskilled-labour intensive sector. If this is the case, the oil boom leads to skilled workers ‘wages increasing more than the unskilled ones. Therefore, there are enough incentives for the unskilled labour force to migrate to the boom sector. On the other hand, substantial oil revenues provide enough resources to develop the manufacturing and services sectors.

Unlike some studies about DD symptoms, e.g. Stijns (2003) and Benkhodja (2011), there is no positive relationship between increase in oil prices and government expenditures. This can be explained by the privatization programme in Iran after the Iran-Iraq War in 1988, through which almost 30% of state-owned factories and companies were sold to the private sector until the end of 2010.[1]

1. There is no specific data on the percentage of privatization in Iran. This number is calculated from total numbers reported in Comparable Performance of Privatization tables published by the Privatization Organization of Iran.

Overall, it seems that Iranian economy suffers from DD because there is a positive relationship between oil prices and appreciation of real exchange rate. Furthermore, the most unskilled labour intensive sector is ousted due to the higher wages in the boom sector and other sectors benefit from substantial oil revenues.

3. The New Keynesian Phillips Curve for Dutch Diseased Economy

In the DD small open economy model, households maximize their utility from consuming a specific bundle that is produced in the home country or abroad. In other words, goods produced in the home country are not identical to those produced in a foreign country.

$$C_t = \left[\chi \left(c_t^d\right)^{\frac{\eta-1}{\eta}} + (1-\chi)\left(c_t^f\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{2}$$

where C_t is the consumption bundle, $c_t^d = \left[\int_0^1 c_t^d(z)^{\frac{\theta}{\theta-1}} dz \right]^{\frac{\theta}{\theta-1}}$ and $c_t^f = \left[\int_0^1 c_t^f(z)^{\frac{\theta}{\theta-1}} dz \right]^{\frac{\theta}{\theta-1}}$ are CES indices of consumption goods produced at home and abroad, respectively. $0 < \chi < 1$ is home bias in consumption, θ and $0 < \eta < 1$ are elasticity of substitution of consumption bundles within and between countries.[1]

A price index can be defined for each of these two consumption bundles, so the composite price index of home country is:[2]

$$P_t = \left[\chi^\eta \left(p_t^d\right)^{1-\eta} + (1-\chi)^\eta \left(p_t^f\right)^{1-\eta} \right]^{\frac{\eta}{\eta-1}} \tag{3}$$

where $p_t^d = \left[\int_0^1 p_t(z)^{1-\theta} dz \right]^{\frac{1}{\theta-1}}$ and $p_t^f = e_t \left[\int_0^1 p_t^{*f}(z)^{1-\theta} dz \right]^{\frac{1}{\theta-1}}$ are price indices of domestically produced goods and imported manufactured goods. e_t refers to nominal exchange rate (home currency relative to foreign currency).

There is another source of demand for domestically produced oil in an

1. Note that it is assumed that =6, this is a common assumption in the literature and means that the degree of substitutability of goods within and between countries are different. is defined as a mark-up of prices over marginal cost and following the literature is calibrated to = 11.
2. This price index is calculated by minimizing the cost of purchasing a single unit of the composite consumption bundle. For more detail see Leith and Malley (2007).

oil-exporting country: the product of each individual oil-producing firm is also demanded by domestic and foreign producers as intermediate input in their production process. Thus, domestically produced oil used in domestic firms as intermediate input is defined as:

$$o_t^d = \left[\int_0^1 o_t^d(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \quad (4)$$

while the same demand from foreign firms is given by:[1]

$$o_t^{*f} = \left[\int_0^1 o_t^{*f}(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \quad (5)$$

Following Leith and Malley (2007), it is assumed that the government allocates its expenditure in the same pattern as consumers. Therefore, the total demand for output of a typical firm in this economy can be written as the sum of the following demands:

$$c_t^d = \left(\frac{p_t^d}{\chi P_t} \right)^{-\eta} c_t, \; c_t^{*f} = \left(\frac{p_t^d}{(1-\chi) e_t P_t^*} \right)^{-\eta} c_t^* \quad (6)$$

$$g_t^d = \left(\frac{p_t^d}{\chi P_t} \right)^{-\eta} g_t, \; g_t^{*f} = \left(\frac{p_t^d}{(1-\chi) e_t P_t^*} \right)^{-\eta} g_t^* \quad (7)$$

$$o_t^d = \left(\frac{p_t^o}{\chi P_t} \right)^{-\eta} o_t, \; o_t^{*f} = \left(\frac{p_t^o}{(1-\chi) e_t P_t^*} \right)^{-\eta} o_t^* \quad (8)$$

where c_t^d and c_t^{*f} are domestic and foreign private consumption. g_t^d and g_t^{*f} represent domestic and foreign public consumption. o_t^d and o_t^{*f} refer to consumption of domestically produced oil in production in home and foreign countries and p_t^o is the world price of oil.

The degree of substitutability for the domestically produced intermediate input (oil) is the same as government and consumption good. Thus, the total demand for the output of firm z can be shown by,

$$y_t(z) = \left(\frac{P_t(z)}{p_t^d} \right)^{-\theta} \left(c_t^d + g_t^d + o_t^d + c_t^{*f} + g_t^{*f} + o_t^{*f} \right) \quad (9)$$

Thus, the total demand for firm z production is determined by the final

1. Following Rumler (2007), it is assumed that the degree of substitutability between intermediate goods is the same as between consumption goods.

price received by the firm relative to the prices for other domestically produced goods. It also depends on domestic and foreign public and private consumption as well as demand for oil as an intermediate input in domestic and foreign firms.

3.1. Production Technology

In modeling the NKPC for the Iranian economy, open economy effects influence firms' price-setting behaviour through a production function which employs domestic labour, domestically produced oil and imported intermediate goods with a fixed amount of capital in production process. Incorporating the last two inputs in the Iranian firms' production function is crucial for two reasons. First, according to Iranian input-output tables for 1999, the share of oil and its derivatives as intermediate input has been 43 percent which is not negligible. Second, imported intermediate inputs make up almost 40 percent, on average, of total imports from Iran's major trading partners between 1976 and 2010.

$$y_t(z) = \left(\alpha_N N_t(z)^{\frac{\rho-1}{\rho}} + \alpha_o o_t^d(z)^{\frac{\rho-1}{\rho}} + \alpha_m m_t^f(z)^{\frac{\rho-1}{\rho}} \right)^{\frac{\rho}{(\rho-1)\psi}} \bar{K}^{1-\frac{1}{\psi}} \quad (10)$$

where $N_t(z)$, $o_t^d(z)$ and $m_t^f(z)$ are domestic labour, domestically produced oil as well as imported intermediate goods used as variable factors of production in production process by firm *z*, respectively. α_N, α_o and α_m are simply the weights of these factors in production function. These inputs are considered as imperfect substitutes and ρ is the elasticity of substitution between inputs. $\bar{K}$ represents the fixed stock of capital and $1-\frac{1}{\psi}$ refers to the weight of capital in production technology.

As Rumler (2007) argued, when these three variable factors of production are combined with fixed capital, show decreasing marginal returns; so the real marginal cost function should be increasing and dependent on the firm's output,

$$MC_t(z) = \psi \left[\frac{W_t N_t + p_t^o o_t^d(z) + p_t^f m_t^f(z)}{P_t y_t(z)} \right] \quad (11)$$

Although, similar to Rumler (2007), one of the inputs, oil, is produced domestically, but its price is determined by the world market rather than the domestic market that could make a considerable difference in deriving the NKPC as well as analysing firm pricing behaviour.

3.2. Profit Maximisation and Price-setting

The real profit for the firm z in time t is the difference between real income and real costs of this firm and can be shown by:

$$\frac{\Pi_t(z)}{P_t} = \frac{p_t(z)}{P_t} y_t(z) - \frac{W_t}{P_t} N_t - \frac{p_t^o}{P_t} o_t^d - \frac{p_t^f}{P_t} m_t^f \tag{12}$$

These firms optimize their prices with probability $1-\alpha$ in a given period where α refers to the degree of price stickiness, and $\frac{1}{1-\alpha}$ measures the expected number of periods in which price contract is valid. The optimisation problem facing a firm can be written as:[1]

$$\begin{aligned} \frac{\Pi_t(z)}{P_t} &= \left(\frac{OP_t}{p_t^d}\right)^{-\theta} \left(c_t^d + g_t^d + o_t^d + c_t^{*f} + g_t^{*f} + o_t^{*f}\right) \frac{OP_t}{P_t} \\ &-MC_t \left(\frac{OP_t}{p_t^d}\right)^{-\theta\psi} \left(c_t^d + g_t^d + o_t^d + c_t^{*f} + g_t^{*f} + o_t^{*f}\right)^{\psi} + \\ &E_t \sum_{s=1}^{\infty} \frac{\left[\begin{array}{l} \left(\frac{OP_t}{p_{t+s}^d}\right)^{-\theta} \left(c_{t+s}^d + g_{t+s}^d + o_{t+s}^d + c_{t+s}^{*f} + g_{t+s}^{*f} + o_{t+s}^{*f}\right) \frac{OP_t}{P_{t+s}} \\ -MC_t \left(\frac{OP_t}{p_{t+s}^d}\right)^{-\theta\psi} \left(c_{t+s}^d + g_{t+s}^d + o_{t+s}^d + c_{t+s}^{*f} + g_{t+s}^{*f} + o_{t+s}^{*f}\right)^{\psi} \end{array}\right]}{\prod_{z=1}^{s} r_{t+z-1}} \end{aligned} \tag{13}$$

where OP_t is the optimal price at time t and r_t is real gross interest rate which the firm uses to discount its future profits at this rate.

The first order condition for this optimization problem is given by:

$$(OP_t)^{1+\theta(\psi-1)} = \frac{\begin{array}{l} \psi\theta(p_t^d)^{\psi\theta} MC_t \left(c_t^d + g_t^d + o_t^d + c_t^{*f} + g_t^{*f} + o_t^{*f}\right)^{\psi} \\ +E_t \sum_{s=1}^{\infty} \frac{\alpha^s \left[\psi\theta\left(p_{t+s}^d\right)^{\psi\theta} W_{t+s} \left(c_{t+s}^d + g_{t+s}^d + o_{t+s}^d + c_{t+s}^{*f} + g_{t+s}^{*f} + o_{t+s}^{*f}\right)^{\psi}\right]}{\prod_{z=1}^{s} r_{t+z-1}} \end{array}}{\begin{array}{l} (\theta-1)(p_t^d)P_t^{-1}\left(c_t^d + g_t^d + o_t^d + c_t^{*f} + g_t^{*f} + o_t^{*f}\right) + \\ +E_t \sum_{s=1}^{\infty} \frac{\alpha^s (\theta-1)(p_{t+s}^d)P_{t+s}^{-1} \left[\psi\theta\left(p_{t+s}^d\right)^{\psi\theta} W_{t+s} \left(c_{t+s}^d + g_{t+s}^d + o_{t+s}^d + c_{t+s}^{*f} + g_{t+s}^{*f} + o_{t+s}^{*f}\right)^{\psi}\right]}{\prod_{z=1}^{s} r_{t+z-1}} \end{array}} \tag{14}$$

1 All calculations are available upon request.

Equation (14) can be log-linearised to get:

$$\left(\frac{\left(1+\theta\left(\psi-1\right)\right)}{\overline{r}-\alpha}\right)\widehat{OP}_t = \widehat{MC}_t + (\psi+1)\,\hat{\tilde{y}}_t + \hat{P}_t + \theta\left(\psi-1\right)\hat{p}_t^d \quad (15)$$

$$+\sum_{s=1}^{\infty}\left(\frac{\alpha}{r}\right)E_t\left[\widehat{MC}_{t+s} + \left(\psi-1\right)\hat{\tilde{y}}_{t+s} + \hat{P}_{t+s} + \theta\left(\psi-1\right)\hat{p}_{t+s}^d\right]$$

where $\tilde{y}_t = c_t^d + g_t^d + o_t^d + c_t^{*f} + g_t^{*f} + o_t^{*f}$ is the total demand for domestic goods produced by firm *z*. Variables with an over-bar refer to steady-state values and hatted variables represent the percentage deviation of the variable from its steady-state value.

Equation (15) can be quasi-differenced to get the first order difference equation describing the evolution of the optimal price set by profit maximizing firms,

$$\left(\frac{\left(1+\theta\left(\psi-1\right)\right)}{\overline{r}-\alpha}\right)E_t\,\widehat{OP}_{t+s} = \left(\frac{\left(1+\theta\left(\psi-1\right)\right)}{\overline{r}-\alpha}\right)\widehat{OP}_t \quad (16)$$

$$-\widehat{MC}_t - (\psi-1)\,\hat{\tilde{y}}_t - \hat{P}_t - \theta\left(\psi-1\right)\hat{p}_t^d$$

It is assumed that, within the group of firms that are re-setting their prices in a given period, according to Calvo (1983), the firms that do not perform this optimization follow a simple rule-of-thumb behaviour. Therefore, the log-linearised index of output prices can be shown by:

$$\hat{p}_t^d = \alpha\hat{p}_{t-1}^d + (1-\alpha)\,\hat{p}_t^r \quad (17)$$

where $\hat{p}_t^d$ and $\hat{p}_{t-1}^d$ are domestic prices at time *t* and $t-1$, and $\hat{p}_t^r$ is the average reset price in period *t* and can be written as:

$$\hat{p}_t^r = (1-\omega)\widehat{OP}_t + \omega\hat{p}_t^b \quad (18)$$

where ω is the share of firms that use rule-of-thumb mechanism in their price-setting and $\hat{p}_t^b$ is price set according to rule-of-thumb behaviour or average reset price of previous period updated by last period inflation:

$$\hat{p}_t^b = \hat{p}_{t-1}^r + \hat{\pi}_{t-1}^d \quad (19)$$

Substitute equation (19) into equation (18) to get:

$$\hat{p}_t^r = (1-\omega)\overset{\wedge}{OP}_t + \omega\hat{p}_{t-1}^r + \omega\hat{p}_{t-1}^d - \omega\hat{p}_{t-2}^d \quad (20)$$

Combining equations (17) and (20), $\hat{p}_t^r$ can be written as:

$$\hat{p}_t^r = \frac{\hat{p}_t^d}{1-\alpha} - \frac{\alpha\hat{p}_{t-1}^d}{1-\alpha} \quad (21)$$

Putting equation (21) into equation (20) to get:

$$\frac{\hat{p}_t^d}{1-\alpha} - \frac{\alpha\hat{p}_{t-1}^d}{1-\alpha} = (1-\omega)\overset{\wedge}{OP}_t + \omega\left[\frac{\hat{p}_t^d}{1-\alpha} - \frac{\alpha\hat{p}_{t-2}^d}{1-\alpha}\right] + \omega\hat{p}_{t-1}^d - \omega\hat{p}_{t-2}^d \quad (22)$$

Rearranging in terms of $\overset{\wedge}{OP}_t$, considering $\hat{\pi}_{t-1}^d = \hat{p}_{t-1}^d + \hat{p}_{t-2}^d$, equation (22) can be written as:

$$\overset{\wedge}{OP}_t = \frac{(1-\omega)\hat{p}_t^d}{1-\alpha} - \frac{\alpha(1-\omega)\hat{p}_{t-1}^d}{1-\alpha} - \frac{\omega}{(1-\omega)}\left[\frac{\hat{p}_t^d}{1-\alpha} - \frac{\alpha\hat{p}_{t-2}^d}{1-\alpha}\right] - \frac{\omega}{(1-\omega)}\hat{\pi}_{t-1}^d \quad (23)$$

Putting equation (23) into equation (15), solved using the definition of output price inflation at period t i.e. $\hat{\pi}_t^d = \hat{p}_t^d + \hat{p}_{t-1}^d$ to get the NKPC equation:

$$\hat{\pi}_t^d = \frac{\beta\alpha}{\Omega}E_t\hat{\pi}_{t+1}^d + \frac{\omega}{\Omega}\hat{\pi}_{t-1}^d + \frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\left(1+(\psi-1)\theta\right)\Omega}\left(\overset{\wedge}{MC}_t + (\psi-1)\hat{\tilde{y}}_t + \hat{P}_t - \hat{p}_t^d\right) \quad (24)$$

where $\beta = \frac{1}{r}$ is the steady-state discount factor that the firm uses for future profits.

$\Omega = \omega + \beta\omega\alpha + \alpha - \omega\alpha$, and hatted variables refer to deviations from steady-state values.

The NKPC formulae in equation (24) cannot be appropriately estimated, so in the next step this formula should be rearranged to get a tractable equation in terms of estimation. As Rumler (2007) argued because the marginal cost term is not firm specific, equation (11) can be decomposed into the log-linearised prices of all inputs:

$$\overset{\wedge}{MC}_t = \frac{\frac{w}{p}\hat{w}_t + \frac{p^o}{p}\left(\frac{w}{p^o}\frac{\alpha_o}{\alpha_N}\right)^{\rho}\hat{p}_t^o + \frac{p^f}{p}\left(\frac{w}{p^f}\frac{\alpha_f}{\alpha_N}\right)^{\rho}\hat{p}_t^f}{\frac{w}{p} + \frac{p^o}{p}\left(\frac{w}{p^o}\frac{\alpha_o}{\alpha_N}\right)^{\rho} + \frac{p^f}{p}\left(\frac{w}{p^f}\frac{\alpha_f}{\alpha_N}\right)^{\rho}} - \hat{P}_t \quad (25)$$

Substituting equation (25) into equation (24) with some further rearrangement the NKPC can be written as follows:

$$\hat{\pi}_t^d=\frac{\beta\alpha}{\Omega}E_t\hat{\pi}_{t+1}^d+\frac{\omega}{\Omega}\hat{\pi}_{t-1}^d+\frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\left(1+(\psi-1)\theta\right)\Omega}$$

$$\left(\frac{\frac{w}{p}\hat{w}_t+\frac{p^o}{p}\left(\frac{w}{p^o}\frac{\alpha_o}{\alpha_N}\right)^{\rho}\hat{p}_t^o+\frac{p^f}{p}\left(\frac{w}{p^f}\frac{\alpha_f}{\alpha_N}\right)^{\rho}\hat{p}_t^f}{\frac{w}{p}+\frac{p^o}{p}\left(\frac{w}{p^o}\frac{\alpha_o}{\alpha_N}\right)^{\rho}+\frac{p^f}{p}\left(\frac{w}{p^f}\frac{\alpha_f}{\alpha_N}\right)^{\rho}}-\hat{p}_t^d+(\psi-1)\hat{\hat{y}}_t\right) \tag{26}$$

with some further computations the NKPC formulae can be re-written in terms of relative prices of production factors:

$$\hat{\pi}_t^d=\frac{\beta\alpha}{\Omega}E_t\hat{\pi}_{t+1}^d+\frac{\omega}{\Omega}\hat{\pi}_{t-1}^d+\frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\left(1+(\psi-1)\theta\right)\Omega}\left[\hat{s}_{nt}-(\psi-1)\frac{s_{t1}}{1+(1-\psi)s_{t1}}\hat{y}_t\right]$$
$$-\left[\frac{\bar{s}_{m^f}}{1+(1-\psi)s_{t1}}\right]\left(\hat{p}_t^o-\hat{p}_t^f\right)-\left[(1-\rho)\frac{\bar{s}_{o^d}}{s_{t2}}+\rho\frac{\bar{s}_{o^d}}{1+(1-\psi)s_{t1}}\frac{\bar{s}_n}{s_{t2}}\right]\left(\hat{w}_t-\hat{p}_t^o\right)$$
$$-\left[(1-\rho)\frac{\bar{s}_{m^f}}{s_{t2}}+\rho\frac{\bar{s}_{m^f}}{1+(1-\psi)s_{t1}}\frac{\bar{s}_n}{s_{t2}}\right]\left(\hat{w}_t-\hat{p}_t^f\right) \tag{27}$$

Where $s_{t1}=\bar{s}_{o^d}+\bar{s}_{m^f}$, $s_{t2}=\bar{s}_n+\bar{s}_{o^d}+\bar{s}_{m^f}$.$s_n=\frac{wN}{p^d y}$, $\bar{s}_{o^d}=\frac{p^o o^d}{p^d y}$ and $\bar{s}_{m^f}=\frac{p^f m^f}{p^d y}$ are share of labour, domestically produced oil and imported intermediate goods in production process, respectively. $\psi=\frac{(\theta-1)\left(1+\bar{s}_o^d+\bar{s}_m^f\right)}{\theta(\bar{s}_n+\bar{s}_o^d+\bar{s}_m^f)}$ can be derived by steady-state markup and steady-state values of labour, and domestic and imported intermediate goods.

The impact of introducing DD in open economy modeling of the NKPC can be seen through equation (27). Inflation dynamics in a DD economy is affected by the previous period and expected inflation, as they are in the closed economy case. Moreover, other driving variables of inflation are: log deviation of labor share, $\hat{s}_{nt}$, relative cost of domestically produced oil compared to the imported intermediate goods or TOT, $\left(\hat{p}_t^o-\hat{p}_t^f\right)$ relative cost of domestic labour with respect to domestic and imported intermediate goods, $\left(\hat{w}_t-\hat{p}_t^o\right)$ and $\left(\hat{w}_t-\hat{p}_t^f\right)$ respectively.

This specification of NKPC for an economy sick with DD captures other closed and open economy NKPC's with some manipulations. The main difference of this version of NKPC with the general specification of NKPC for a small open economy in Rumler (2007) is that the price of oil, determined by the international market and highly volatile, affects the inflation dynamics in an economy sick with DD. On the other hand, if the economy doesn't produce any intermediate good at all, i.e. $\bar{s}_{o^d} = 0$ this formulation reduces to Leith and Malley's (2007) specification. Finally, if there is no imported intermediate good used in production process, i.e. $\bar{s}_{m^f} = 0$, the resulting NKPC equation would be the same as the standard version of the closed economy derived and estimated in many studies, such as Gali and Gertler (1999), Gali et al. (2001), Balakrishnan et al. (2002), Gali et al. (2005) and Bitani et al. (2005).

3. Estimation of the Model and Empirical Results

3.1. The Data

One of the main difficulties of the present paper, like any other empirical work for a developing country, was collecting the data and constructing variables. For this reason there are only a few empirical works investigating inflation dynamics in developing countries. Although lack and length of the data could somehow affect the results of estimating any model for these countries, the behaviour of the macroeconomic variables in these countries in response to economic and political events is not negligible in terms of global effects.

The data set comprises the quarterly series starting from the first quarter of 1976 to the last quarter of 2010. The main source of the data on domestic variables is the Central Bank of the Islamic Republic of Iran (CBI) online database known as Economic Time Series Database.[1] The data used in this paper are mostly available in annual and quarterly frequencies, but the length of the quarterly series is shorter than that of the annual series. To solve this problem, the quarterly series is seasonally adjusted using the US Census Bureau’s X-12 ARIMA programme and then the quarterly series from 1976q1 is obtained by linearly interpolating (backward) the missing quarterly series from the annual series using the method as per Dees, di Mauro, Pesaran and Smith (2007).[2]

The starting date of the Iranian year is different from that of the

1. Available at: http://tsd.cbi.ir/.
2. The number of obtained data points is different for each variable, because the starting point of the data is not the same for all of them.

Gregorian year: the Iranian year starts on the 21st March. Therefore, the Iranian first quarter contains 10 days of the Gregorian first quarter and 80 days of the Gregorian second quarter. To convert the data to the Gregorian year the rule below is adopted, following Esfahani et al. (2009):

$$G(Q) = \frac{8}{9}\text{Iran}(Q-1) + \frac{1}{9}\text{Iran}(Q) \tag{28}$$

where *G(Q)* is the Gregorian quarter *Q* and *Iran(Q)* is the Iranian quarter *Q*.

The main source of the data for Iran's major trading partners, i.e. China, India, Germany, South Korea, Japan, France, Russia and Italy, is International Monetary Fund (IMF) online database.

Domestic output inflation, $\hat{\pi}_t^d$, is measured as value added GDP deflator, avail-able from CBI database. Other candidates are output deflator and Producer Price Index (PPI), but the former is not available for the Iranian economy and the latter is just available for a short period. Average firm output, y_t, is calculated as the value added GDP for manufacturing, oil, services, public and private sectors avail-able from the CBI database. To construct the labour share variable, as a proxy for marginal cost, nominal compensations of employees for the aforementioned sectors is divided by the value added GDP of those sectors. Nominal compensation and value added GDP data are also available from the CBI online database. This marginal cost proxy makes it possible to analysis of the Iranian inflation dynamics more realistically for three reasons. First, the price of oil as an intermediate input is more volatile than other two factors. This may induce firms to update their prices more frequently to suffer less from unexpected effects of the fluctuations of this input price. Second, according to Iranian input-output tables for 1999, the share of oil and its derivatives as intermediate input has been 43 percent of total inputs used in production which is not negligible. Third, imported intermediate inputs make up almost 40 percent, on average, of total imports from Iran's major trading partners between 1976 and 2010.

To calculate the share of domestically produced oil in production, $\bar{s}_{o^d} = \frac{p^o o^d}{p^d y}$ oil price, oil export and oil production data, available from the CBI database, are used. Oil export is subtracted from oil production to find the domestic demand for oil. To construct a proxy for the share of imported intermediate goods in production, $\bar{s}_{m^f} = \frac{p^f m^f}{p^d y}$ is calculated as the weighted average price for imported goods and services from major trading partners of

Iran. The trade weights are computed based on the IMF Direction of Trade Statistics between 1980 and 2010. m^f is defined as real import of goods and services from the trading partners.

In order to calculate ψ, as elasticity of demand, θ, cannot be econometrically estimated, following literature[1], it is computed as a mark-up of prices over marginal costs, i.e. $\frac{1}{1-\theta}$, which is assumed to be 10%, therefore $\theta = 11$.

3.2. Econometric Specification

The NKPC formulation derived in the previous section incorporates rational expectation forward-looking behaviour, thus the appropriate method to estimate equation (27) is the Hansen (1992) generalised method of moments (GMM), which can easily solve the set of orthogonality conditions implied by rational expectation hypothesis.

In order to estimate equation (27) following Gali et al. (2001), two different specifications of orthogonality conditions are considered. In the first specification, A, these orthogonality conditions are directly imposed while in specification B both sides of equation (27) are pre-multiplied by Ω:

$$\mathrm{A}: \mathrm{E}_t\left(\left[\hat{\pi}_t^d - \frac{\beta\alpha}{\Omega}\hat{\pi}_{t+1}^d - \frac{\omega}{\Omega}\hat{\pi}_{t-1}^d - \frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\left(1+(\psi-1)\theta\right)\Omega}(...)\right]z_t\right) = 0 \quad (29)$$

$$\mathrm{B}: \mathrm{E}_t\left(\left[\Omega\hat{\pi}_t^d - \beta\alpha\hat{\pi}_{t+1}^d - \omega\hat{\pi}_{t-1}^d - \frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{\left(1+(\psi-1)\theta\right)\Omega}(...)\right]z_t\right) = 0 \quad (30)$$

where z_t is the vector of instruments. The instrument set includes four lags of domestic price inflation, $\hat{\pi}_t^d$, wage inflation, $\hat{\pi}^w$, output gap, $\hat{y}$, labor share, $\hat{s}$, real Effective exchange rate[2], $\hat{e}$, import price inflation, $\hat{\pi}^m$ and a constant. This instrument set has been chosen specifically for the Iranian economy based on two criteria: it is highly correlated with repressors and also satisfies the overidentifying restrictions. Hansen' J test is used to test the validity of the overidentifying restrictions since there are more instruments than parameters to estimate. The hat-ted variables are calculated

1 Some examples are Gali et al. (2001), Leith and Malley (2007) and Rumler (2007).

2. Real Effective exchange rate data (free market exchange rate) are available quarterly from IMF INS database.

as deviation from an HP-filtered trend. Coefficients' significance tests are conducted using Newey-West corrected standard errors which can deal with heteroscedasticity of unknown form and autocorrelation. In order to compute the covariance matrix, the number of lags is chosen based on the rule proposed by Newey-West, depending on sample length.

3.3. Empirical Results

In order to study the price-setting behaviour in the Iranian economy, the structural parameters of the NKPC equation, i.e. α, β, ω and ρ are estimated. α measures the degree of price stickiness and ω refers to the share of backward-looking firms while β is the steady-state discount rate of future profits. These three parameters are also known as Calvo (1983) parameters. ρ shows the elasticity of substitution between factors of production. The duration (in months) required for price adjustments are calculated as $\frac{3}{1-\alpha}$.

The NKPC equation in (27) is estimated for closed and open economy models across orthogonality specifications. Models CE_A and CE_B represent a closed economy model of the NKPC for two different specifications, A and B. In other words, in these two sets of estimates the closed form hybrid NKPC with only one factor of production, i.e. labour, which has been widely investigated in the literature, for example Gali and Gertler (1999) and Gali et al. (2001), is estimated for the Iranian economy.

Models OE_A and OE_B denote the open economy estimates of the NKPC for two specifications in which ρ is freely estimated. In models OE_CD_A and OE_CD_B, a Cobb-Douglas production function is replaced with CES formulation by setting ρ equal to 1. Finally, ρ is reduced to 0 in order to investigate the inflation dynamics through a Leontief production technology in models OE_L_A and OE_L_B.

Results for structural parameters' estimates are reported in Table 1. Considering the estimates for the closed economy first, it can be seen that the estimates for Calvo parameters are significant and economically plausible. The average time, in months, needed for all prices in the Iranian economy to adjust, in the closed economy case, is less than seven and eight months for specification A and B, respectively.

Table 1: Estimates of the Structural Parameters of the NKPC for the Iranian Economy

Specifications	α	β	ω	ρ	Duration of Price Adjustment
CE_A	0:55	0:85	0:51	N/A	6.7
	(0:08)	(0:003)	(0:09)		
	(0:04)	(0:002)	(0:07)		
OE_A	0:44	0:87	0:36	0:98	5.4
	(0:14)	(0:001)	(0:12)	(0:31)	
OE_B	0:46	0:89	0:43	1:12	5.6
	(0:08)	(0:007)	(0:10)	(0:58)	
OE_CD_A	0:47	0:98	0:43	1	5.7
	(0:07)	(0:11)	(0:02)		
OE_CD_B	0:51	0:97	0:51	1	6.2
	(0:10)	(0:09)	(0:01)		
OE_L_A	0:45	0:98	0:38	0	5.4
	(0:09)	(0:10)	(0:08)		
OE_L_B	0:48	0:96	0:41	0	5.8
	(0:11)	(0:05)	(0:09)		

Notes: The estimation period is between 1976q1 and 2010q4. Newey-West corrected standard errors are reported in parentheses. In OE_CD_A (B) and OE_L_A (B) parameter ρ is restricted to 1 and 0, respectively. The expected duration of price adjustment is calculated as $\frac{3}{1-\alpha}$.

The open economy estimates of Calvo parameters are also significant and econometrically sound and it seems that introducing the open economy in modeling inflation dynamics in Iranian economy somehow affects the estimates of α, ω in general; however, the β estimates are invariant overall, which is consistent with other studies in the literature.

The degree of price rigidity, α, decreases in response to introducing the open economy, from 0.55 and 0.61 to 0.44 and 0.46 for specifications A and B, respectively. ω estimates show the same pattern, even when Cobb-Douglas and Leontief production functions are replaced with original CES formulation. This means that the fraction of backward-looking firms is reduced by introducing the open economy elements. Meanwhile, the average duration of price adjustment reduces. Estimates of open economy parameter, ρ, are statistically insignificantly different from 1; this may indicate that, when using quarterly data, there is a very high probability that the factors of production are substituted in response to quarterly price movement due to possible changes in oil prices. On the other hand, these results suggest that, the more frequently a country reset its prices, the less likely it is to use backward-looking behaviour.

Furthermore, to analyze the effect of lagged inflation, expected inflation as well as marginal cost on Iranian inflation dynamics, the reduced form coefficients are also estimated. These coefficients are: $\gamma_f = \frac{\beta\alpha}{\Omega}$ and $\gamma_b = \frac{\omega}{\Omega}$

which measure the importance of the forward- and backward-looking behaviour in explaining the domestic inflation in Iran whereas $\lambda = \frac{(1-\omega)(1-\alpha)(1-\alpha\beta)}{(1+(\psi-1)\theta)\Omega}$ shows the explanatory power of the marginal cost in inflation dynamics in the Iranian economy. As Guay and Polgrin (2004) argued, the coefficient of the marginal cost is particularly important because, if it is insignificant, an identification problem of structural parameters might exist in the model, which might lead to the model's unreliability. This set of results, along with the results for testing overidentifying restrictions, *J* test, is reported in Table 2; suggesting that introducing the open economy elements in modeling inflation dynamics for a DD economy alters the effects of expected and lagged inflation on domestic output inflation. According to this set of results, forward-looking behaviour is predominant across specifications but its power increases after introducing open economy effects, while the backward-looking behaviour loses its ground. The estimates of coefficient of marginal cost, λ, are statistically significant in most cases. This suggests that marginal cost, which contains the prices of domestically produced and imported intermediate goods as well as the cost of labour force, has a significant power in explaining inflation dynamics in Iran. The Hansen' *J* statistics, reported in the last column of Table 2, fail to reject the overidentifying restrictions across specification.

Table 2: Reduced Form Estimates of the NKPC for the Iranian Economy

Specifications	γ_f	γ_b	λ	**J- test**
CE_A	0:59	0:41	0:13	6:27
	(0:03)	(0:13)	(0:11)	(0:17)
CE_B	0:53	0:47	0:11	5:91
	(0:09)	(0:14)	(0:006)	(0:31)
OE_A	0:74	0:25	0:08	7:33
	(0:05)	(0:04)	(0:001)	(0:28)
OE_B	0:61	0:39	0:10	8:01
	(0:11)	(0:12)	(0:005)	(0:45)
OE_CD_A	0:71	0:29	0:05	6:95
	(0:05)	(0:01)	(0:003)	(0:35)
OE_CD_B	0:66	0:34	0:03	5:41
	(0:01)	(0:08)	(0:002)	(0:47)
OE_L_A	0:67	0:32	0:07	5:97
	(0:02)	(0:09)	(0:008)	(0:52)
OE_L_B	0:60	0:40	0:06	6:19
	(0:02)	(0:12)	(0:001)	(0:31)

Notes: The estimation period is between 1976q1 and 2010q4. Newey-West corrected standard errors are reported in parentheses. In OE_CD_A (B) and OE_L_A (B) parameter ρ is restricted to 1 and 0, respectively. The expected duration of price adjustment is calculated as $\frac{3}{1-\alpha}$.

To investigate whether the parameter estimates are statistically significantly different across specifications, following Rumler (2007), a *t* test is employed on the differences between the estimates in Table 1. The test statistics is $\frac{\hat{\alpha}_{CE} - \hat{\alpha}_{OE}}{\sqrt{\hat{\sigma}_{\hat{\alpha}_{CE}} + \hat{\sigma}_{\hat{\alpha}_{OE}}}}$ where $\hat{\sigma}_{\hat{\alpha}_{CE}}$ and $\hat{\sigma}_{\hat{\alpha}_{OE}}$ are the standard errors of $\hat{\alpha}_{CE}$ and $\hat{\alpha}_{OE}$ estimates. The test statistics is t-distributed with $(n_1 + n_2 - k_1 - k_2)$ degrees of freedom where n_1 and n_2 are the number of observation in estimation of CE and OE, respectively, and k_1 and k_2 are the number of coefficients to be estimated in these two models. The results for this test are presented in Table 3.

Table 3: Differences in Coefficients' Estimates across Specifications

	Specification A		Specification B	
	α	ω	α	ω
CE-OE	0.11	0.15	0.15	0.23
% difference	20	29.5	24.6	34.9
t-value	0.231	0.571	0.491	-0.152

Notes: CE-OE is the difference between the estimated values of α and ω for specifications A and B.

The results in Table 3 indicate that, when incorporating open economy properties in modeling inflation dynamics in an oil-exporting developing country suffering from DD, the estimates of α and ω are smaller in values; suggesting that the more volatile the prices of inputs the more likely that firms update their prices more frequently. In other words, firms that use crude oil, whose prices are highly volatile, as input in production process it is more likely that they reset their prices more frequently than those that do not. This way, they can offset some of the unexpected effects of oil prices' fluctuations.

4. Conclusions

In the present paper a small open economy hybrid New Keynesian Phillips curve is derived and estimated for a developing oil-exporting economy suffering from Dutch Disease. This term refers to the impact on the rest of the domestic economy of substantial and exhaustible revenue earned from exporting a natural resource. Evidence from the Iranian economy shows that the sector that faces decline in response to an oil price increase is the agricultural sector, not the manufacturing sector as is claimed in the literature.

In an economy sick with DD (Iran in this paper), firms produce their product using domestic labour, capital and domestically produced intermediate goods, oil, and imported intermediates, and sell these products both at home and abroad. The advantage of this framework is that the terms of trade effects can be investigated in more detail compared to traditional closed economy specifications which only take the labour costs into account. It is assumed that the firms in the DD economy update their prices according to Calvo (1983), so that they can only optimize their prices after a random interval. This set-up yields an open economy version of a hybrid NKPC for a DD economy. This curve was then estimated for two different specifications of orthogonality conditions. In order to make the results comparable with other studies, general closed economy hybrid NKPC is also estimated.

The main finding of the present paper is that introducing open economy elements to the marginal cost measure affects the estimates of parameters governing the pricing behaviour of the firms. The degree of price stickiness and fraction of backward-looking firms, particularly, decline when open economy features are modeled. The average duration required for price adjustments is also meaningfully lower.

Estimates of elasticity of substitution between inputs, , are statistically in-significantly different from 1, suggesting that, when using quarterly data, it is more likely that the factors of production are substituted in response to quarterly price movement, for instance due to a possible changes in oil prices. The coefficient on expected inflation rises while the coefficient on the backward-looking parameter loses its ground in the presence to the introduction of open economy elements. The coefficient on marginal cost is statistically significant almost in all cases, indicating that marginal cost - which contains the prices of domestically produced and imported intermediate goods as well as the cost of labour forces - has a significant power in explaining inflation dynamics in the Iranian economy. The t-test on the differences between the parameter estimates across specifications suggests that firms that use inputs with higher price volatilities reset their prices more frequently than those that do not, in order to offset the unexpected effects of such fluctuations.

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