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A Computable General Equilibrium Model of International Sanctions

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Abstract

We detail recent international sanctions against the Iranian economy and its government. The effects of these sanctions on the Iranian economy, the Iranian government and rural and urban Iranian households disaggregated by income decile are modelled using a Computable General Equilibrium (CGE) model which uses endogenous taxes to simulate the effects of sanctions. Results suggest that sanctions on Iranian oil exports had a serious negative effect on the Iranian economy, with very strong negative changes on real revenue earned by the Iranian government, but much more limited effects on the well-being of Iranian rural and urban households.

J.E.L. Classification Codes: F51, Q34, C68

Keywords: sanctions; oil; Iran; CGE model

This is work in progress and should not be quoted without prior approval of the authors. Correspondence should be directed via email to Robert Waschik at robert.waschik@vu.edu.au.

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1 Introduction

International sanctions have become an important tool for use against a target country to pursue various foreign policy goals. According to data from the Institute for International Economics (2002), there were only five countries affected by economic sanctions in 1950s. This number increased to 47 in the 1990s. Advocates of sanctions believe that economic pressures can be effective in altering the target country's policies without military intervention (Baldwin, 1985). However, others argue that sanctions on a target country have not resulted in anticipated outcomes while imposing considerable costs on citizens who have little influence on the behaviour of their governments (Drezner, 1999; Elliott, 1998; Hufbauer et al., 1990; Pape, 1997).

According to Hufbauer et al. (2007), economic sanctions "mean the deliberate, government-inspired withdrawal, or threat of withdrawal, of customary trade or financial relations". International economic sanctions are regarded as a less expensive alternative to military intervention (Kaempfer and Lowenberg, 2007). While the main goal of economic sanctions is to interrupt a target country's economic and diplomatic relations in order to alter its political and military behaviour, these measures are increasingly being employed against weaker and more dependent nations without full consideration of their impact on the welfare of citizens in these countries, particularly vulnerable groups of households. The literature of sanctions argues that broad economic sanctions unintentionally damage the well-being of citizens in targeted countries, by deteriorating the quality and access to education and public health care services and worsening their economic conditions (Cortright et al., 2001; Drury and Li, 2006; Weiss, 1999; Weiss et al., 1997). As a dramatic example, Pape (1998) cites evidence that suggests that comprehensive UN sanctions imposed on Iraq in the 1990s had devastating humanitarian consequences, causing the deaths of as many as 567000 Iraqi children while significantly reducing Iraq's GDP.

There is considerable evidence that economic sanctions aimed at imposing hardships on the economy of a target country can severely disrupt economic activities in sanctioned sectors and consequently restrict economic growth in the sanctioned country (Andreas, 2005; Neumeier and Neuenkirch, 2014; Crawford and Klotz, 1999; Dizaji and Van Bergeijk, 2013; Hufbauer et al., 2007; Jacobson, 2008; Neumeier and Neuenkirch, 2014). Kaempfer and Lowenberg (2007) note that there is "no doubt that embargoes or restrictions on flows of goods and capital impose welfare costs on the target economy". While some studies have estimated the aggregate effects of sanctions on target countries, few if any have employed economic models to estimate the welfare losses imposed by economic sanctions on different economic agents and households in sanctioned countries.

Over the past three decades, considerable effort has been expended by the United States (arguably the most prominent actor on the sanctions scene) to induce the international community to develop a sanctions policy against Iran due to concern over attempts by Iran to develop weapons of mass destruction and humanitarian concerns. Since 2011/2012, strict economic sanctions have been imposed by the US, the EU and others on Iran's economy in an attempt to discourage the government of Iran from continuing to engage in the development of a nuclear weapons capability (Abrams et al., 2012; O'Sullivan, 2010; Schott, 2012). These recent sanctions have effectively targeted Iranian oil exports, which make up a significant source of revenue for the government of Iran. In this paper we seek to analyze the impact of comprehensive economic sanctions on Iran's economy in general, on the government of Iran and on households of different socio-economic backgrounds, especially those from the lower and middle classes of society. But the recent sanctions against Iran were applied over a period when the government of Iran undertook a major reform of large domestic subsidies on heavily distorted food and energy products. An examination of the recent economic performance of Iran would conflate the effects of this significant subsidy reform with those of the international sanctions against Iran. This problem motivates our use of a Computable General Equilibrium (CGE) model to simulate the effects of international sanctions, where we generate counterfactual results which mimic as closely as possible the changes in Iranian exports and imports of sanctioned commodities.

The paper proceeds as follows. Section 2 gives a summary of international sanctions against Iran, including a description and recent performance of the sectors of the Iranian economy which have been most strongly affected. This information, particularly the observed decreases in Iranian production and exports of oil since the strict US and EU sanctions were enforced, is used to validate the performance of the CGE model in simulating the effects of international sanctions against Iran. The dataset, production technology and utility functions which comprise the CGE model are described in Section 3. We populate the CGE model with data on production, consumption and trade from the Global Trade Analysis Project (GTAP), a popular CGE model used extensively in such exercises. We augment the GTAP8 dataset with information from the Statistical Centre of Iran (SCI) which enables us to disaggregate private demand to ten urban and ten rural consumer groups, and to accurately allocate ownership of factors of production between urban and rural households and the government in Iran. The latter is of fundamental importance, since international sanctions primarily target Iran's oil exports, and the rents derived from the ownership of all capital and natural resources employed in the production of energy products in Iran accrue to the government of Iran.

The CGE model uses endogenous trade taxes to simulate the effects of sanctions on Iranian exports and imports of sanctioned commodities. Section 4 reports and interprets quantitative estimates of the effects of economic sanctions on Iranian government revenue and on the well-being of Iranian rural and urban households. Results suggest that international sanctions could reduce aggregate welfare in Iran by 14-15%. But aggregate results mask considerable differences in the effects of sanctions on urban and rural households and on the government in Iran. While the lowest-income rural and urban households could see welfare losses of 5-10%, medium- to high-income households actually experience an improvement in welfare, with the highest-income rural households experiencing welfare gains of 3%. But the international sanctions effectively target important sources of revenue for the government of Iran, resulting in reductions in real government revenue of 40-50%. Simulations demonstrating the sensitivity of results to exogenously specified parameters in the CGE model including trade elasticities and the intersectoral mobility of capital used to produce oil in Iran are presented in Section 5, while Section 6 concludes.

2 International Sanctions and the Iranian Economy

The Iranian economy has been exposed to ongoing political and economic sanctions by the United States, including trade and financial sanctions since Iran's 1979 Islamic revolution. But the goals of U.S. sanctions policy against Iran have changed over time. According to Katzman (June 2013), U.S. economic sanctions in the mid-1980s were aimed at limiting Iran's strategic power in the Middle East in general, and forcing Iran to stop supporting terrorism in particular. Since the mid-1990s, U.S. sanctions have targeted Iran's petroleum sectors and nuclear program with the objective of weakening Iran's economy. In the meantime, European nations refused to follow U.S. policy to impose economic sanctions against Iran (Pollack and Takeyh, 2005). In 1996, the U.S. Senate approved the "Iran and Libya Sanctions Act" (ILSA), prohibiting foreign investment in any oil and gas development projects in Iran of over $40 million during any 12-month period (Hufbauer et al., 2012). In spite of ongoing sanctions imposed by the U.S. on economic sectors in Iran that contributed to the proliferation of sensitive nuclear and missile programs, and despite international opposition, Iran has nonetheless developed its missile and nuclear programs with major assistance from the Russian government (Ataev, 2013).

The ILSA ran for five years and was twice renewed by the U.S. Senate, in 2001 and 2006. Over those fifteen years, the ILSA combined with other problems in the Iranian economy including economic mismanagement to produce a considerable drop in the growth of Iranian oil production (Schott, 2012). The European Union (EU) joined the U.S. in imposing economic sanctions against Iran from 2006 as a result of Iran's contentious nuclear program. Since 2010, the EU sanctions have mainly targeted the oil and gas, transportation and financial and insurance sectors in the Iranian economy (Patterson, 2013). In 2010, the Iran Sanctions Act of 1996 was substantially amended and expanded into the Comprehensive Iran Sanctions Accountability and Divestment Act (CISADA), limiting the sale of gasoline, other petroleum products as well as refinery-related equipment to Iran (Hufbauer et al., 2012; Katzman, August 2014). Since 2010, many other countries including Australia, Canada, Japan, South Korea and Switzerland have adopted economic sanctions against Iran due to its nuclear ambitions.

The U.S. and the EU launched a new series of tough energy sanctions against Iran in late 2011 and early 2012. The main objective of these sanctions was to discourage Iran from developing its nuclear program by reducing Iran's oil-export revenues. In early 2012, the U.S. enacted a new generation of financial sanctions against Iran's Central Bank, restricting Iran's ability to use the international financial system. The new financial sanctions posed a serious problem for the Iranian government for both non-oil transactions as well as oil-related transactions between the Central Bank of Iran and any foreign financial institutions (Farzanegan, 2011), successfully forcing Iran to agree to receive payment for oil in either the national currencies of oil importing countries or gold (Katzman, March 2012). In July 2012, the EU imposed an embargo on the import, purchase and transport of Iranian crude oil (Katzman, June 2013). The EU also banned imports of petrochemical products from Iran. EU financial sanctions came into force in October 2012, banning the provision of financial communication services with the Central Bank of Iran, except for humanitarian transactions with Iranian banks (Farzanegan, 2013). Notably, EU sanctions also prohibited European-based insurers of oil tankers from providing coverage for any vessels carrying Iranian crude (Van de Graaf, 2013).

Both politicians and oil-market experts initially believed that the new U.S. and EU sanctions which targeted Iranian exports of petroleum, natural gas, oil and chemicals would not force Iran to slow down the progress of its nuclear program since they would

	Oil exports by destination						
Year	World	Europe	Asia and Pacific	Africa	Oil Prod'n	Petrol Prod'n	Gas Prod'n
2007	2639	847	1469	148	4030.7	1498.0	111900
2008	2574	749	1542	147	4055.7	1587.0	116300
2009	2406	568	1538	127	3557.1	1726.1	175742
2010	2583	878	1571	134	3544.0	1743.3	187357
2011	2537	741	1392	127	3576.0	1748.7	188753
2012	2102	162	1839	101	3739.8	1811.9	202431
2013	1215	128	1085	2	3575.3	1918.4	199293

Source: OPEC (various years)

Table 1: Iran – Oil Exports and Energy Production (1000b/d, except Gas, 1000000 cu m)

not significantly shrink Iran's oil exports (Van de Graaf, 2013). But these sanctions proved remarkably effective in curtailing Iranian oil exports, in no small part due to the dominant position held by UK insurance companies in insuring the world's oil tankers (Van de Graaf (2013, p.154)). EU oil imports from Iran which had accounted for more than a quarter of Iran's oil exports (see Table 1) fell dramatically, and reports by the International Energy Agency in early 2013 (International Energy Agency, 2013) and Iran's oil minister revealed that Iran's oil exports fell by 40 percent from 2011 levels, and Iran's oil-export revenues dropped by over $40 billion in 2012 because of new sanctions. Table 1 highlights the effectiveness of these expanded international sanctions against the Iranian oil sector.

2.1 Impacts of International Sanctions on Iran's economy

Before describing the general equilibrium model used to study the effects of international sanctions on Iran's economy, this Section provides a brief background on certain macroeconomic variables and key economic sectors of Iran's economy, and the impacts of international sanctions on these sectors.

After 1979, Iran endured almost two decades of revolution, war and reform as well as international pressures which brought about considerable socio-economic disruption, heavy military and civilian casualties, and a drop in the production and export of energy commodities. Over the past three decades, the burden of the eight-year war, a drop in domestic production in the 1980s and massive shortages in fuels, medicines and necessities, high inflation as well as increasing speculation and a growing black market all combined to produce strong grounds for direct government intervention in Iran's economy (Esfahani and Pesaran, 2009). Energy commodities and other sizable industries and enterprises are under the control of the state, while the private sector has a negligible authority to run small businesses (Esfahani et al., 2013).

From the beginning of 2002, the Iranian government committed itself to implementing trade reforms, exchange rate unification, ratification of the law on foreign investment, the licensing of three private banks and tax reform, intended to adjust distortions and structural imbalances. The government in Iran has since launched several market-oriented reforms aimed at reversing the recent downward economic spiral, including the reform of food and energy subsidies. However, international sanctions combined with years of government mismanagement and widespread corruption have left the economy vulnerable to very high inflation and negative growth rates (Hufbauer and Schott, 2006; Katzman (June 2013); Plaut (2013); International Monetary Fund (2014)). For instance, the Statistical Centre of Iran (SCI) reported that the inflation rate in Iran reached 35 percent in December 2013, and the economy faced an unemployment rate of around 13 percent. Devarajan and Mottaghi (2014) note that the economy of Iran has experienced negative growth rates of -3.0 and -2.1 percent for 2012 and 2013 respectively. Since the tightening of energy and financial sanctions against Iran in 2012, the Iranian currency (Rial) lost more than 80% of its exchange value (Monshipouri and Dorraj, 2013). But it is difficult to attribute the effects on macroeconomic variables like inflation and growth rates to one policy (international sanctions) or the other (food and energy subsidy reform) since both occurred over the same period and both represented large economic shocks to the Iranian economy. This problem of disentangling the effects of such policies is well suited to CGE modelling which can isolate the effects of one set of economic shocks in clearly specified counterfactual simulations.

2.2 Iran's Energy Sector under International Sanctions

According to Central Bank of Iran (2010), the oil and gas sector dominated the economy of Iran, accounting for an estimated 90 percent of foreign exchange revenues and providing 60 percent of government earnings in fiscal year 2008-2009. Iran possesses the world's second largest natural gas reserves and the fourth largest proven oil reserves (International Energy Agency, 2012). Even though Iran boasts vast gas resources, the country has been incapable of becoming a leading global gas exporter because natural gas produced by the underdeveloped sector is mostly used to meet domestic demand. In 2010, 59 percent of Iran's total domestic energy consumption came from natural gas

(U.S. Energy Information Administration, 2013).

Revenue from Iran's oil and gas sectors makes up the major share of government revenue, so these have been a major target of the latest international economic sanctions against Iran. According to U.S. Energy Information Administration (2013), the toughening of sanctions against Iran in 2012 resulted in a 40 percent decrease in Iran's oil exports, though Iran was still producing 3.5 million bpd over the period of 2012-2013, with the unsold crude oil being stockpiled in onshore and floating storage (International Energy Agency; International Energy Agency, 2012; 2013). Prior to 2010, Iran had stockpiled crude oil in floating storage in order to increase profits from the world energy market. However, since 2010 there has been a correlation between Iran's floating oil storage and the toughening of sanctions against Iran's energy sector (Lee, 2004; Mann, 2013; U.S. Energy Information Administration, 2013). According to International Energy Agency (2013), estimates of Iran's crude oil stockpile in floating storage in 2013 were around 20-25 million barrels. Estimates also show that Iran has a total onshore storage capacity of 25 million barrels, and that most of this capacity is filled (International Energy Agency, 2013).

According to Hufbauer et al. (2012), the average welfare loss caused by U.S. sanctions on Iran over the period 1984-2005 was around $80 million, less than one percent of Iranian GDP over that period. But over the period of 2006-2012, international sanctions against Iran produced an average welfare loss of $5.7 billion, equivalent to about 1 to 3 percent of Iranian GDP (Hufbauer et al., 2012). Kitous et al. (2013) used a CGE model to simulate the effects of increasingly strict application of an embargo on Iranian oil exports, suggesting a fall in Iranian GDP relative to baseline of 6-17% (Kitous et al. (2013, p.17)). But both Hufbauer et al. (2012) and Kitous et al. (2013) focus on the effects of sanctions on macroeconomic aggregates, and do not decompose the effects of sanctions on different economic agents within Iran. To our knowledge, no study has analyzed the economic impacts of these sanctions on separate economic agents in Iran.[1] Since the primary target of international sanctions against Iran is the behaviour of the government of Iran, and since the impact of these sanctions on needy and vulnerable households in Iran is a source of concern, we specifically decompose the impacts of international sanctions on the government of Iran and on 20 Iranian household types in rural and urban areas, grouped according to income.

[1] Farzanegan et al., 2015 use a CGE model to decompose the effects of international sanctions against Iran on different rural and urban households in Iran, but do not give an explicit treatment of their effect on government revenue in Iran, arguably the most important consideration when looking at the effects of sanctions against Iran. They also adopt an external closure through which international sanctions result in an appreciation of the Rial.

3 Data and CGE Model

3.1 Data

We begin with version 8 of the GTAP dataset which depicts a global general equilibrium of production, consumption, and trade for 129 countries/regions and 57 commodities produced using 5 primary factors of production and intermediate inputs for the year 2007, described in Narayanan et al. (2012). We aggregate GTAP regions into three separate regions: Iran, a single aggregate of all countries/regions which apply sanctions on trade with Iran ('SAN'), and an aggregate rest-of-world ('RoW') of all remaining regions. Given the description of international sanctions on trade with Iran in Section 2, the aggregate region 'SAN' of countries applying sanctions on trade with Iran includes:

> Canada, the United States, Mexico, Central America, Australia, New Zealand, Japan, Republic of Korea, China, Hong Kong, Taiwan, Malaysia, Singapore, India, Sri Lanka, the 28 EU countries, South Africa

The commodity aggregation (available from the authors on request/See the Appendix, Table A-1) is constructed to allow us to reflect multilateral sanctions as accurately as possible, and to accommodate disaggregation of private consumption using information from the Urban and Rural Household Income and Expenditure Survey from the Statistical Center of Iran (SCI) (Statistical Centre of Iran, 2005). To highlight how the economies of Iran and the two aggregated regions differ, Table 2 reports output value shares implied by the aggregated GTAP8 dataset. Commodities with an ^{x}-superscript (oil, petroleum products, metals) are those where sanctions are applied on Iranian exports to 'SAN' countries, while commodities with an ^{m}-superscript (petroleum products, metals, motor vehicles) are those where sanctions are applied on Iranian imports from 'SAN' countries. Economic activity in Iran has long been dominated by the oil sector, and before their recent reform in 2010, large state fuel subsidies resulted in a petrol sector which is considerably larger (as a share of the value of output) than that in other regions (see Gharibnavaz and Waschik (2014)). As a result, the share of output accounted for by the manufacturing and service sectors is notably smaller in Iran.

3.2 CGE Model

Since international sanctions on trade with Iran focus on oil and petrochemical products, we adopt a specification of the demand side of the CGE model which follows that in

Sector	Iran	Sanction Countries	Rest of World
Wheat and Cereal Grains	1.5	0.3	0.9
Raw Milk	1.1	0.2	0.6
Meat	1.0	0.9	2.1
Vegetable Oil	0.4	0.3	0.8
Dairy	2.1	1.0	1.4
Sugar	0.1	0.1	0.3
Other Primary Agriculture	2.2	0.9	2.5
Other Processed Agriculture	2.7	2.7	3.7
Coal	0.0	0.2	0.3
Oil^{x}	21.1	0.4	6.5
Gas	2.7	0.3	1.7
Electricity	3.5	1.8	2.7
Petrol^{x,m}	9.3	2.5	3.6
Metal Products^{x,m}	6.5	10.1	9.2
Motor Vehicles^{m}	2.5	3.1	1.8
Manufactures	4.4	15.1	11.6
Transport	4.9	4.9	5.9
Services	34.0	55.3	44.5

Table 2: Output Value Shares from GTAP8 Dataset (2007)

other studies which focus on energy markets like the GTAP-E model.[2] For each of the 18 production sectors, production technology is represented with a series of nested CES production functions, as shown in Figure 1. The central case values for the substitution elasticities in Figure 1 are similar to those used in Rutherford and Paltsev (2000) and Fischer and Fox (2007). We adopt the GTAP primary factor substitution elasticities, available from Chapter 14 in Narayanan et al. (2012), reflected on the right side of Figure 1 as σ_{va}. We also adopt the GTAP factor transformation elasticities, which imply that labour and capital are perfectly mobile factors. Land and natural resources are specific factors used only in the production of primary agricultural commodities and primary energy commodities, respectively.

For each region private and public demand derives from the maximization of a CES function of an aggregate 'energy' good and an aggregate 'non-energy' good, with a CES substitution elasticity $\sigma = 0.5$. The 'energy' aggregate is a Cobb-Douglas function of energy goods (coal, oil, gas, petrol, electricity, gas distribution), while the 'non-energy' aggregate is a Cobb-Douglas function of the remaining commodities. In all regions, each agent's endowment of primary factors of production is assumed to be

[2]See Burnieaux and Truong (2002), Rutherford and Paltsev (2000) or Fischer and Fox (2007), among many others for a more detailed description of the structure of production and consumption.

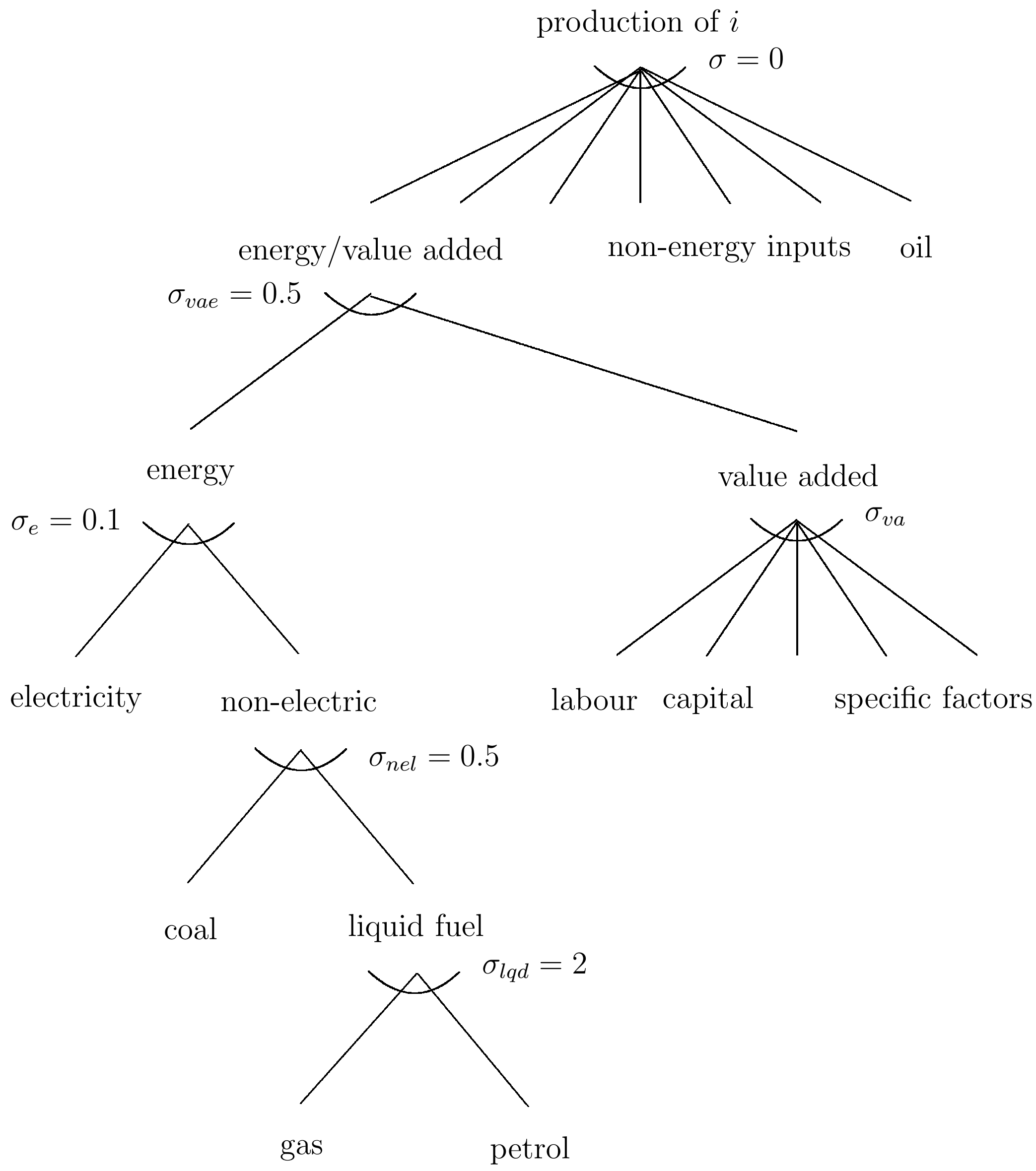

Figure 1: Structure of Production

fixed. These primary factors are all supplied to the production sectors in each region, and factors are assumed always to be fully employed. For the aggregated regions of sanction countries 'SAN' and the rest of the world 'RoW', real aggregate public demand is fixed. A single representative agent owns all primary factors of production, and all tax revenue is assumed to be costlessly collected and redistributed to this representative consumer.

But many features of the international sanctions applied to trade with Iran and of the Iranian economy in general make it inappropriate to adopt such a structure for private and public demand and factor ownership in Iran. We need to model the distribution of the ownership of factors of production in Iran to reflect the reality of factor ownership in Iran. As such, we assume that the government owns all Natural Resources, and earns all rents generated by capital employed in the energy sectors in Iran. Private consumers earn all income generated from the use of Land and Labour, and also earn all income from capital usage, except for capital used in the energy sectors. This reflects the reality in Iran where the government earns all income from value added except labour in energy sectors. In Iran, all tax revenue accrues to the government. Government revenue is used to fund (exogenous) investment and to purchase services, primarily education, health care and defense.

It is common to close the public and external sectors in CGE models by assuming that aggregate public demand and the capital account are both exogenous. We do assume that aggregate government spending in the 'SAN' and 'RoW' regions is exogenous. But since international sanctions should result in such large negative changes in real government revenue in Iran, it would be inappropriate to make aggregate government spending exogenous. Likewise, since international sanctions will have such a strong negative effect on Iranian trade, it would be inappropriate to make Iran's capital account exogenous, since in equilibrium, the current and capital accounts for any country/region must sum to zero. While it is uncommon to have an endogenously determined capital account balance, it is appropriate here since financial sanctions have also limited Iran's access to international capital markets. For clarity, we assume that Iran's capital account balance moves in fixed proportion with aggregate government spending, so international sanctions will cause an equi-proportionate reduction in real government spending (revenue) and the current (capital) account balance. Of course, we must also make the trade and capital account balance endogenous in the 'SAN' and 'RoW' regions, so we assume that the current/capital accounts there move in proportion with each region's real income. Iran is a small trading partner with 'SAN' and 'RoW', so it makes intuitive sense that international sanctions will have only a small effect on the trade and capital account balances in 'SAN' and 'RoW'.

We are also interested in the distributional consequences of the application of international sanctions in Iran, since it is often argued that sanctions impose a significant burden on private consumers and can disproportionately affect low-income or disadvantaged consumers. As such, it is necessary to disaggregate private consumption in Iran. To capture the disparate effects of international sanctions on low and high income consumers, and to reflect the fact that sanctions could have different effects on urban versus rural consumers, we disaggregate private consumption in Iran into ten rural and ten urban consumption groups by income decile. This requires us to disaggregate both private income and expenditure for Iran in the GTAP8 dataset. To disaggregate private expenditure, we use the Income and Expenditure Survey published by the Statistical Centre of Iran (2005) to calculate expenditure shares $\theta_{i,h,n}$ at different income deciles $n \in (1, 2, \ldots, 10)$ of households $h \in (urban, rural)$ which are consistent with the 18 aggregated commodities i. These shares are reported in Tables A1 and A2 of Gharibnavaz and Waschik (2014). We also use the SCI Income and Expenditure Survey to disaggregate income by household. The Survey includes information on all wages and salaries obtained from self-employment in agricultural and non-agricultural activities, private and public sector employment, and other income during the reference period. As noted earlier, all natural resource rents accrue to the government in Iran, as does income earned by capital employed in energy sectors. Remaining income in the GTAP8 dataset is allocated to disaggregated urban and rural households using shares reported in Table A3 of Gharibnavaz and Waschik (2014), where income categories in the SCI Income and Expenditure Survey are matched to GTAP8 factors. After disaggregating household income by source and household expenditure by commodity, the income equals expenditure constraint for each household will no longer be satisfied, because the accounting disaggregation does not take account of savings. Data on savings by households is not available from the Iranian Statistical Centre. To rebalance household accounts, we assign that share of aggregate savings to each household so that their income equals expenditure constraint is satisfied. Since the initial dataset is balanced, assigning the remaining savings to the government will then balance the government account. Private and government savings is assumed to be exogenous throughout. Allocating savings between households and the government in this way leaves the government in Iran with an 80% share of aggregate savings in the benchmark equilibrium.

As is common in CGE models, we follow Armington (1969) and incorporate imports into the model by treating domestic and imported varieties of the same good as differentiated products by domestic users of those goods. Intermediate inputs in production and inputs into private and public consumption are assumed to be CES aggregates of domestically produced goods and their imported counterparts. We adopt the Armington substitution elasticities σ^i_{dm} from the GTAP8 dataset, available from Narayanan et al. (2012), and assume that the substitution elasticity between imports of good i from different regions is given by $\sigma^i_{mm} = 2 \cdot \sigma^i_{dm}$. There are a number of distortions in the GTAP8 dataset reflected by *ad valorem* taxes on private and public consumption, usage of intermediate inputs by firms, production of outputs and trade. The CGE model is solved using MPSGE in GAMS.

4 Counterfactual Results

The effects of international sanctions on trade with Iran are simulated using the CGE data and model described in Section 3 by generating a counterfactual general equilibrium in which trade between sanction countries in the aggregated region 'SAN' and Iran is reduced consistent with the description of international sanctions in Section 2. The desired reductions in sanction country imports from Iran are achieved by introducing an endogenous tax on sanction country imports of oil, petroleum products and metals from Iran. We also introduce an endogenous tax on 'SAN' exports to Iran of sanctioned commodities, to reflect sanctions on exports of petroleum products, metals and motor vehicles from 'SAN' to Iran. These endogenous taxes adjust until 'SAN' trade with Iran of sanctioned commodities falls to $1-k$ of its level in the initial benchmark equilibrium. This allows us to illustrate successive tightening of sanctions on 'SAN' exports to Iran and 'SAN' imports from Iran by increasing $k \in (0, 1)$.

The effects of sanctions imposed by 'SAN' on trade with Iran are reported in Table 3 for successive tightening of sanctions from $k = 0.25$ of benchmark trade in sanctioned commodities to $k = 0.75$. The data on Iranian oil exports reported earlier in Table 1 suggest that sanctions resulted in a reduction in Iranian oil exports of 54.0% from 2007 to 2013. While most countries/regions in the aggregate 'SAN' region reduced oil imports from Iran dramatically by the end of 2013, there were many 'SAN' countries (including China, India, Japan, Korea and Turkey) which still imported significant quantities of oil from Iran. For example, China accounted for over 21% of benchmark Iranian oil exports,[3] and Katzman (August 2014, p.38) suggests that from 2011-2013, Chinese oil imports from Iran fell by only 20-25%. In the counterfactual equilibrium for $k = 0.75$ (so that 'SAN' exports to Iran and imports from Iran of sanctioned commodities fall by 75%), total Iranian oil exports by volume fall by 54.8%, so we choose $k = 0.75$ as representative of the level of sanctions that simulates changes in Iranian oil exports which are broadly consistent with those actually observed.[4]

Table 3 shows that the sanctions had only a very small negative effect on welfare in

[3]Benchmark country/region trade shares for the disaggregated GTAP8 dataset for all sanctioned Iranian exports and imports are available from the authors on request/reported in the Appendix in Table A-2 for countries/regions with trade shares greater than 1.0%.

[4]The default GTAP8 Armington elasticity which governs the substitutability between domestic and imported oil is 5.2. When we adopt this value, the 'RoW' region responds to international sanctions of 75% of benchmark trade between Iran and 'SAN' with such a large increase in imports of Iranian oil that total Iranian oil exports fall by only 39.8%. This response in 'RoW' imports of Iranian oil is inconsistent with the data reported in Table 1, so to generate oil trade and production changes which are consistent with those actually observed, we adopt an Armington elasticity for oil of 3.5. Specifically, we set $\sigma_{dm}^{oil} = 3.5$ and $\sigma_{mm}^{oil} = 7.0$.

Welfare	k=0.25	k=0.50	k=0.75
urban1	−2.47	−4.00	−5.34
urban2	−0.99	−1.51	−2.02
urban3	−0.71	−1.04	−1.39
urban4	−0.43	−0.57	−0.79
urban5	−0.13	−0.06	−0.11
urban6	−0.19	−0.18	−0.28
urban7	0.12	0.34	0.41
urban8	−0.05	0.05	0.02
urban9	0.07	0.24	0.25
urban10	−0.09	−0.04	−0.12
rural1	−4.42	−7.21	−9.63
rural2	−1.91	−2.98	−4.04
rural3	−0.86	−1.25	−1.76
rural4	−0.10	0.06	−0.01
rural5	0.25	0.65	0.78
rural6	0.54	1.14	1.44
rural7	1.13	2.13	2.74
rural8	1.20	2.25	2.91
rural9	1.38	2.53	3.27
rural10	1.42	2.52	3.23
govt	−22.74	−35.05	−42.65
Iran	−7.45	−11.49	−14.13
San	−0.01	−0.06	−0.15
RoW	0.15	0.31	0.49

Table 3: Welfare Effects of International Sanctions (%Δ)

region 'SAN' which imposes sanctions. For a level of sanctions of $k = 0.75$, 'SAN' welfare falls by 0.15%, but the 'RoW' region which does not impose sanctions sees a welfare improvement of 0.49% of benchmark welfare.[5] This result obtains because the 'RoW' region includes large oil exporters, so the 'RoW' region benefits from an improvement in terms of trade as the international sanctions result in an increase in world oil prices. But aggregate welfare in Iran falls by over 14%. The largest share of this change in welfare is accounted for by changes in government activity in Iran, which sees real revenue fall by over 42%. This is due primarily to a decrease in rents earned from government-owned factors employed in oil production. For example, real rents earned by natural resources in Iran (almost all of which are derived from ownership of natural resources specific to the oil sector) fall by almost 70%.

[5]Welfare effects are the percentage change in Hicksian equivalent variations, except for the government sector in Iran where they are changes in real aggregate government revenue, and for Iran where they are a weighted average of welfare changes for households and real aggregate government revenue.

While the government in Iran bears the largest share of the effects of international sanctions, the lowest-income rural and urban households also fare poorly, experiencing a 9.6% and 5.3% welfare loss, respectively. But sanctions cause resources to move out of oil production and into production of agricultural commodities, so the real return to land increases. Since land is mostly owned by rural households and since higher income rural households own more land, medium- and high-income rural households actually see an increase in welfare after the imposition of international sanctions. Finally, international sanctions are focused on highly capital-intensive energy and metals sectors, so the real return to capital in Iran falls while the real return to labour rises, and the wage-rent ratio increases by almost 11%. Since rural households derive relatively more income from the ownership of labour than urban households who earn relatively more income from capital, international sanctions cause larger welfare gains in rural households than urban households for all but the three lowest-income deciles.

In the counterfactual where the level of international sanctions is set at 75%, the trade results are roughly consistent with those reported in Table 1. But in this counterfactual, the production of oil in Iran falls by 19.5%, while the production data reported in Table 1 suggest that Iranian oil production fell by only 11.3% over the period 2007-2013. As noted in Section 2, there is evidence that the Iranian government purchased and stockpiled oil from Iranian production facilities in response to international sanctions on exports of Iranian oil. Results in Table 3 presume that no oil was stockpiled by the Iranian government. To show the effects of oil stockpiling, we re-run the counterfactual simulations with the level of sanctions $k = 0.75$, assuming that the Iranian government stockpiles a share s of the oil which would otherwise have been purchased by sanction countries. But it is difficult to find evidence on the volume of oil stockpiled by the Iranian government. As noted earlier, International Energy Agency (2013) estimates that Iran has total (floating plus onshore) storage capacity of around 45 million barrels. Of course, this oil will not be stockpiled indefinitely, and there is evidence (see The Economist (30 March 2013) and Luers et al. (2012, p.37-8), for example) that Iran has the ability to sell stockpiled oil on the black market. Iran can also sell its stockpiled oil to a non-EU country where the Iranian oil can be refined or blended and even ultimately re-exported to the EU, a practice that was consistent with EU sanctions (Van de Graaf (2013, p.152)). If Iran can turn over its stockpiled oil five times per year, that is approximately equivalent to 20% of the oil which would have been purchased by sanction countries,[6] so

[6] In the benchmark equilibrium, 'SAN' accounts for 98.6% of Iran's oil exports, so 20% of the reduction in 'SAN' oil imports over year 2007 production with $k = 0.75$ is $4.0307 \cdot 365 \cdot 0.986 \cdot 0.75 \cdot 0.20 \approx 218$ million barrels per year, approximately equal to five times Iran's storage capacity of 45 million barrels.

	s=0.0	s=0.10	s=0.20	s=0.30
urban1	−5.34	−5.58	−5.86	−6.16
urban2	−2.02	−2.28	−2.57	−2.88
urban3	−1.39	−1.68	−2.00	−2.34
urban4	−0.79	−1.12	−1.47	−1.85
urban5	−0.11	−0.45	−0.81	−1.20
urban6	−0.28	−0.61	−0.96	−1.34
urban7	0.41	0.06	−0.31	−0.72
urban8	0.02	−0.31	−0.67	−1.05
urban9	0.25	−0.05	−0.38	−0.74
urban10	−0.12	−0.37	−0.65	−0.95
rural1	−9.63	−10.02	−10.44	−10.90
rural2	−4.04	−4.59	−5.17	−5.80
rural3	−1.76	−2.30	−2.88	−3.50
rural4	−0.01	−0.61	−1.25	−1.93
rural5	0.78	0.15	−0.53	−1.25
rural6	1.44	0.81	0.14	−0.58
rural7	2.74	2.08	1.38	0.63
rural8	2.91	2.26	1.59	0.86
rural9	3.27	2.65	1.99	1.29
rural10	3.23	2.75	2.25	1.70
govt	−42.65	−45.82	−49.16	−52.50
Iran	−14.13	−15.51	−16.92	−18.36
San	−0.15	−0.15	−0.16	−0.17
RoW	0.49	0.50	0.51	0.52
stock_g		7.47	14.79	22.11
stock_y		2.53	5.01	7.49

Table 4: Welfare Effects with Iranian Government Oil Stockpiling (%Δ)

to reflect stockpiling of oil by the government of Iran, we run simulations for $s = 0$, 0.10, 0.20 and 0.30. We include an endogenous subsidy on government oil purchases which adjusts to the point where the government purchases/stockpiles $s \cdot k$ of the initial oil imports by 'SAN' countries. More stockpiling requires larger government purchases of oil, which require larger values for the endogenous subsidy. Since all tax revenue accrues to the government in Iran, this endogenous subsidy is a direct cost to the government for stockpiling oil.

The welfare effects with stockpiling of oil by the Iranian government are reported in Table 4, where the first column ($s = 0$) corresponds to the last column in Table 3. As we would expect, oil stockpiling by the Iranian government has only the smallest effect on regions 'SAN' and 'RoW'. But as oil stockpiling increases from 0-30% of benchmark oil imports by sanction countries, the decrease in aggregate welfare in Iran worsens from just over 14% to almost 18.4%. All households in Iran see larger welfare losses or smaller welfare gains as the government stockpiles oil in response to international sanctions. Since stockpiling of oil results in smaller reductions in oil production, the shift in the Iranian economy away from energy production is smaller, and the increase in the wage/rent ratio is smaller (9.0% when $s = 0.20$, compared to 11% when $s = 0.0$), as is the real return to land (21% when $s = 0.20$ compared to over 23% when $s = 0.0$). But again, the largest share of Iran's welfare loss due to stockpiling is borne by the government in Iran, as the decrease in real government revenue in Iran worsens from over 42% with no stockpiling ($s = 0$) to almost 50% with $s = 0.20$. Since the Iranian government is effectively protecting its oil sector by subsidizing oil consumption to stockpile oil, the price of oil in Iran does not fall by as much as when there is no stockpiling, and real rents earned from natural resources in oil production do not fall as far as they do without stockpiling. But this gain to government revenue (relative to the counterfactual where there is no stockpiling) is much more than offset by the cost of the subsidy to pay for the stockpiling of oil. For example, with $s = 0.20$, real natural resource rents fall by $US18.5 billion compared to their level in the benchmark, while they drop by almost $US20.8 billion with no stockpiling. But the cost of the subsidy to stockpile oil is just over $US7.4 billion when $s = 0.20$, so real government revenue falls by considerably more when the Iranian government stockpiles oil.

The welfare changes reported in Table 4 take no account of the value of stockpiled oil which the Iranian government accumulates. While we presume that the Iranian government has the ability to sell its stockpiled oil on the black market, it is not clear which price should be used to value this stockpiled oil. For example, Van de Graaf (2013, p.152) argues that sanctions will enable Asian nations (especially China, India, Japan and South Korea) to "extract discounts" on the oil which they do purchase from Iran. To address this issue we report the value of the Iranian government's oil stockpile at the bottom of Table 4, expressed as a share of benchmark government revenue (stock_g) and as a share of benchmark national income in Iran (stock_y). These values are derived using the price of oil in the RoW region, and as such they represent an upper-bound on the value of Iran's stockpiled oil if it can all be sold at no discount at prevailing world prices. For example, if Iran must accept a 50% discount to sell its stockpiled oil, then when $s = 0.20$, the government of Iran would recover $14.79 \cdot 0.50 = 7.40\%$ of its lost revenue, so government revenue in Iran would fall by $-49.16 + 7.40 = -41.77\%$, compared to the drop in welfare of 42.65% when no oil is stockpiled. The aggregate welfare loss in Iran would be $-16.92 + (5.01 \cdot 0.50) = -14.42\%$ when $s = 0.20$, compared to -14.13% when no oil is stockpiled.

5 Sensitivity Analysis

Since international sanctions are focused directly on Iranian exports and imports, the effects of international sanctions will be strongly affected by the central case values for the Armington elasticities. To illustrate, we focus on the counterfactual where the level of international sanctions is set at $k = 0.75$ and the level of Iranian government stockpiling of oil is set at $s = 0.20$. We reset the value of the Armington elasticity to $0.75 \cdot \sigma_{dm}^{gtap8}$ and $1.5 \cdot \sigma_{dm}^{gtap8}$, where σ_{dm}^{gtap8} is our central case value for the Armington elasticity which we adopted from the GTAP8 dataset. In each case, after resetting the Armington elasticity, we reset the substitution elasticity between imports from different regions to $\sigma_{mm} = 2 \cdot \sigma_{dm}$.

Table 5 shows that changes to the specification of the Armington elasticity have very little effect on welfare in the 'SAN' and 'RoW' regions. But increasing (decreasing) the Armington elasticity improves (worsens) the welfare for all economic agents in Iran. Changes in the Armington elasticity will have little effect on trade between Iran and 'SAN' countries since so much of this trade is controlled by sanctions. But *cet. par.*, higher Armington elasticities will increase trade flows between Iran and the 'RoW' region. As a result, damage to the Iranian economy due to the strong negative effect of international sanctions on Iran's trade balance and its terms of trade will be mitigated when the Armington elasticity is increased.

The final example we use to illustrate sensitivity of welfare results considers the mobility of capital in oil production. Oil production costs in Iran are due almost entirely to capital costs and rents accruing to natural resources. Intermediate inputs and labour account for slightly less than 3% and 1%, respectively, of the cost of producing of oil in Iran in the benchmark. Capital costs account for just over two-thirds of oil production costs, while the remaining 28% of production costs accrue to natural resources. As noted earlier, capital and natural resources in oil production in Iran are all owned by the government, but while natural resources are modelled as a specific factor, capital is treated as perfectly mobile. As a result of international sanctions, there is a large drop in rents earned by natural resources. But since capital is modelled as being perfectly mobile, large amounts of capital leave the oil sector. As a result, the decrease in the real return to capital (-3.0% when $k = 0.75$ and $s = 0.20$) is much smaller than the decrease in the real return to natural resources (-61.7%).

$k = 0.75 \quad s = 0.20$

	$0.75 \cdot \sigma_{dm}^{gtap8}$	σ_{dm}^{gtap8}	$1.5 \cdot \sigma_{dm}^{gtap8}$
urban1	−10.38	−5.86	−2.35
urban2	−5.51	−2.57	−0.37
urban3	−4.84	−2.00	0.07
urban4	−4.29	−1.47	0.55
urban5	−3.37	−0.81	0.97
urban6	−3.57	−0.96	0.88
urban7	−2.74	−0.31	1.34
urban8	−3.18	−0.67	1.08
urban9	−2.62	−0.38	1.18
urban10	−2.71	−0.65	0.82
rural1	−18.31	−10.44	−4.41
rural2	−11.48	−5.17	−0.60
rural3	−8.05	−2.88	0.80
rural4	−5.95	−1.25	1.98
rural5	−5.08	−0.53	2.53
rural6	−4.05	0.14	2.91
rural7	−2.39	1.38	3.80
rural8	−1.94	1.59	3.82
rural9	−1.21	1.99	4.00
rural10	0.02	2.25	3.66
govt	−52.39	−49.16	−45.78
Iran	−19.78	−16.92	−14.52
San	−0.16	−0.16	−0.16
RoW	0.55	0.51	0.48
stock_g	15.05	14.79	14.59
stock_y	5.10	5.01	4.94

Table 5: Sensitivity of Welfare Effects to Armington Elasticity σ_{dm} (%Δ)

But it is arguable that at least some of the capital used in oil production is more appropriately modelled as a specific factor, since it will have little or no productive value in other sectors. Since such a large share of value-added in oil production (and of government revenue in Iran) is accounted for by capital in oil production, it is important to illustrate how results depend upon the treatment of capital in the oil sector. For example, if we treat 20% of the capital which is initially used in oil production in Iran as a specific factor, then this capital will not be able to flee the oil sector when the introduction of international sanctions causes a large decrease in oil production in Iran. The ensuing drop in the real return to mobile capital should be much smaller, and more of the costs of the international sanctions will be borne by the immobile and specific capital in the oil sector. More importantly, since such a large share of government

	s=0.0		s=0.20	
	all mobile capital	20% specific capital	all mobile capital	20% specific capital
urban1	−5.34	−2.16	−5.86	−3.22
urban2	−2.02	0.22	−2.57	−0.70
urban3	−1.39	0.72	−2.00	−0.22
urban4	−0.79	1.39	−1.47	0.37
urban5	−0.11	1.87	−0.81	0.86
urban6	−0.28	1.82	−0.96	0.81
urban7	0.41	2.38	−0.31	1.36
urban8	0.02	2.08	−0.67	1.08
urban9	0.25	2.28	−0.38	1.33
urban10	−0.12	1.88	−0.65	1.04
rural1	−9.63	−5.38	−10.44	−6.90
rural2	−4.04	−0.97	−5.17	−2.58
rural3	−1.76	0.94	−2.88	−0.59
rural4	−0.01	2.15	−1.25	0.60
rural5	0.78	2.80	−0.53	1.22
rural6	1.44	3.27	0.14	1.73
rural7	2.74	4.31	1.38	2.76
rural8	2.91	4.37	1.59	2.88
rural9	3.27	4.76	1.99	3.31
rural10	3.23	4.82	2.25	3.63
govt	−42.65	−48.51	−49.16	−54.02
Iran	−14.13	−14.90	−16.92	−17.53
San	−0.15	−0.14	−0.16	−0.15
RoW	0.49	0.47	0.51	0.50
stock_g			14.79	14.66
stock_y			5.01	4.96

Table 6: Welfare Effects with Specific Capital in Oil Production (%Δ)

revenue depends upon rents from capital used in oil production, the share of the burden of international sanctions borne by the government in Iran will increase, and that borne by households in Iran will fall.

To demonstrate these concerns over the modelling of capital used in oil production in Iran, we re-run the counterfactual where sanctions are set at $k = 0.75$ for central case values of all other exogenously specified parameters (including Armington elasticities) after assuming that 20% of the capital used in oil production in Iran is a specific factor. Table 6 shows how welfare changes are affected by specification of capital mobility in the oil sector in Iran. When some capital in oil production is modelled as a specific factor, all households are better off, the government in Iran is worse off, and overall welfare in

	%Δ in oil production	%Δ in oil exports
no specific capital	−15.6	−59.3
20% specific capital	−10.7	−54.7
changes from Table 1	−11.3	−54.0

Table 7: Change in oil production and export with k=0.75, s=0.20

Iran worsens slightly, compared to the case where all capital is perfectly mobile. With less capital leaving the oil sector due to the imposition of international sanctions, the decrease in the real return to mobile capital is smaller. For example, with $k = 0.75$ and $s = 0.20$, the real return to mobile capital falls by only 0.5% when 20% of capital in oil production is specific, while it falls by 3.0% when all capital is perfectly mobile. While the increase in the real return to labour is also smaller when some capital in oil production is specific (5.0% with 20% specific capital versus 5.7% with all mobile capital), the gain in the real return to capital is much larger than the loss in the real return to labour, so households are all better off, to the point where all but the three lowest-income rural and urban household groups experience welfare increases when 20% of the capital initially used in oil production is modelled as being a specific factor.

With more specific factors in oil production, the elasticity of supply of oil is smaller, so for a given level of international sanctions and government stockpiling of oil, the drop in Iranian oil production is smaller. As shown in Table 7, with $k = 0.75$ and $s = 0.20$, the counterfactual changes in oil production and oil exports match the actual changes over the period 2007-13 from OPEC statistics reported in Table 1 much more closely when 20% of capital in oil production is specific. The real return to the factors which are specific to oil production (natural resources and 20% of the capital used to produce oil in the benchmark) falls by less (55.5% when $k = 0.75$ and $s = 0.20$) than when all capital is perfectly mobile (61.7% when $k = 0.75$ and $s = 0.20$). But total real government revenue from 20% of the capital used in oil production is so much lower when this capital is specific that real government revenue in Iran falls by considerably more when this capital used in oil production is modelled as a specific factor.

6 Conclusion

After protracted negotiations which began in November 2013, Iran and the P5+1 (the five Permanent Members of the UN Security Council plus Germany) signed the Joint Comprehensive Plan of Action (JCPOA) in Vienna on 14 July 2015. Contingent upon a positive report by the International Atomic Energy Agency (IAEA) that Iran has complied with the terms of the JCPOA and that all outstanding issues between Iran and the IAEA have been resolved, the JCPOA calls for the lifting of economic sanctions which had been imposed by the US, the EU and other countries on Iran's economy in an attempt to discourage the government of Iran from continuing to engage in the development of a nuclear weapons capability. In this paper we analyzed the welfare impact of these comprehensive economic sanctions on Iran's economy. We incorporated endogenous taxes into a global Computable General Equilibrium (CGE) model to simulate the effects of these sanctions and the stockpiling of oil by the Iranian government. The GTAP8 dataset was augmented with information from the Statistical Centre of Iran (SCI) to disaggregate private and public consumption and income in Iran between the government in Iran and 10 rural and 10 urban household groups to highlight the welfare effects of sanctions not only on the Iranian economy in general but also on urban and rural households disaggregated by income level. We also adopted a non-standard closure by endogenizing the aggregate public and external sectors in Iran, so that the CGE model would more realistically simulate the effects of sanctions, since the primary target of international sanctions was the behaviour of the government of Iran.

While results suggest international sanctions caused a decrease in aggregate welfare in Iran of 14-15%, these welfare costs were very unevenly distributed through the Iranian economy. The lowest-income urban and rural households fared poorly, seeing welfare losses of 5% and 10%, respectively, while the sanctions had much more limited effects on middle- and upper-income households, with the four highest-income rural household deciles experiencing a welfare increase of 2-3%. But the government in Iran has borne the largest share of the effects of international sanctions, with real government revenue falling by 40-50%. Results also suggest that oil stockpiling by the Iranian government left all urban and rural households worse off, though it gave the government the ability to mitigate some of its welfare losses. Since international sanctions directly target Iranian exports and imports, results are sensitive to specification of Armington/trade elasticities. Higher trade elasticities dampen the negative terms of trade effects which sanctions exert on the Iranian economy and their negative effect on Iran's trade balance. Furthermore, modelling some of the capital used in oil production in Iran as a specific factor increases the burden of international sanctions which is borne by the government in Iran and improves the welfare of all households relative to the case where all capital is perfectly mobile.

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Appendix - not to be published

Sector	GTAP8 Sectors (sector code)
Wheat	Wheat (wht), Cereal Grains (gro), Plant-based Fibers (pbf)
Milk	Milk (rmk)
Meat	Cattle, Sheep, Goats, Horses (ctl), Fishing (fsh), Cattle, Sheep, Goats, Horse (cmt), Meat Products (omt)
Vegetable oil	Oil Seed (osd), Vegetable Oils and Fats (vol)
Dairy products	Animal Products (oap), Dairy Products (mil)
Sugar	Sugar (sgr)
Primary agricultural products	Paddy Rice (pdr), Vegetables, Fruits and Nuts (v_f), Sugar cane and Sugar beet (c_b), Crops (ocr), Wool, Silk-worm Cocoons (wol)
Processed agricultural products	Processed Rice (pcr), Food Products (ofd), Beverages and Tobacco Products (b_t)
Coal	Coal (coa)
Oil^{x}	Oil (oil)
Gas	Gas (gas), Gas manufacture, distribution (gdt)
Electricity	Electricity (ely)
Petroleum products^{x,m}	Petroleum and Coal Products (p_c)
Metals^{x,m}	Chemical, rubber, plastic prods (crp), Mineral products n.e.c. (nmm), Ferrous metals (i_s), Metals n.e.c. (nfm), Metal products (fmp)
Motor Vehicles^{m}	Motor vehicles and parts (mvh)
Manufactures	Forestry (frs), Minerals n.e.c. (omn), Textiles (tex), Wearing apparel (wap), Leather products (lea), Wood products (lum), Paper products, Publishing (ppp), Transport equipment n.e.c. (otn), Electronic equipment (ele), Machinery and equipment n.e.c. (ome), Manufactures n.e.c. (omf)
Transport services	Transport n.e.c. (otp), Sea Transport (wtp), Air Transport (atp)
Services	Water (wtr), Construction (cns), Trade (trd), Communication (cmn), Financial services n.e.c. (ofi), Insurance (isr), Business services n.e.c. (obs), Recreation and other services (ros), PubAdmin/Defence/Health/Educat (osg), Dwellings (dwe)

Table A-1: Sectors in Aggregated GTAP8 Data Base

	Iran Exports to			Iran Imports from		
	oil	p_c	met	p_c	met	mvh
^{s}China	21.33	41.14	9.94	4.71	16.80	22.45
^{s}Japan	25.99	9.77	2.18		2.12	7.35
^{s}Korea Republic of		9.06	2.49		7.75	13.71
^{s}Taiwan	20.56	3.19	3.33		1.63	
^{s}Malaysia					1.20	
^{s}Singapore	1.05	6.80		2.71		
Thailand			1.23			
^{s}India		7.12	8.96	24.41	3.10	1.01
Pakistan			2.61			
Rest of South Asia			2.89			
^{s}United States of America				1.02		
Argentina						1.13
Brazil						1.57
^{s}Belgium			2.47		1.43	
^{s}France	9.91	2.07			3.66	19.25
^{s}Germany			1.71		8.50	8.82
^{s}Italy	12.12		7.07		3.54	3.23
^{s}Netherlands				1.73		
^{s}Spain			2.50		1.29	2.99
^{s}Sweden						1.12
^{s}United Kingdom					2.17	1.24
^{s}Switzerland					2.41	
^{s}Romania						1.61
Russian Federation					12.65	
Ukraine					1.72	
Kazakhstan				2.78	4.67	
Rest of Former Soviet Union			1.98	3.57		
Armenia		1.40	1.38			
Azerbaijan			1.34	12.42		
Kuwait			3.47			
Qatar			1.24			
Saudi Arabia			6.29		1.63	
^{s}Turkey		1.33	5.49		3.29	2.62
United Arab Emirates		3.64	9.17	40.75	9.83	5.23
Rest of Western Asia		1.44	9.47			
Egypt			1.16			
Ethiopia		1.63				
^{s}South Africa	5.19					

Countries which are members of the 'SAN' region are preceded with an ^{s} superscript.

Table A-2: Benchmark GTAP8 Country/Region Trade Shares with Iran