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FIRM HETEROGENEITY AND POLITICAL ECONOMY OF INTERNATIONAL TRADE

BY

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DISSERTATION

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ABSTRACT

In this dissertation I examine a set of crucial topics in the political economy of international trade, with an emphasis on firm-level heterogeneity. The first chapter is an empirical study of the new trade theories in which firm heterogeneity and trade costs play central roles in shaping the patterns of international trade. It examines the empirical basis for the theoretical insights offered by Helpman, Melitz, and Rubinstein (*QJE* 2008), HMR. A crucial element in this analysis is identifying a variable that affects the fixed costs of exporting from one country to another, but not the variable costs ("excluded variable"). We argue that the nature of the variable that HMR had selected for this purpose and some errors in the dataset weaken their empirical case for the theoretical observations. We propose an alternative "excluded variable" that addresses those concerns. It benefits from the existence of panel data contemporaneous with the trade data and it fulfills the empirical requirements for an excluded variable regardless of the model specification. The results confirm HMR's finding that firm heterogeneity plays a significant role in the response of trade volumes to trade costs. However, the magnitude of selection and heterogeneity biases in trade elasticities caused by the absence of appropriate corrections are smaller than those presented in HMR. The option to use panel data opens up possibilities for further research on the role of country-level variables in shaping trade patterns. We examine two such variables—GDP and Rule of Law—and find that they have tangible effects on shaping trade, though not as strong as often found in traditional gravity regressions. Our study also casts doubt on the use of some bilateral indicators, such as common religion and language, proposed as alternative excluded variables. Instead, it points to other indicators that may be useful in the future studies of trade flows and related topics.

The second chapter examines the determinants of formations of trade partnerships and bilateral flows in oil trade and how these factors ultimately affect the world prices and trade pattern. We use the approach developed by HMR to specify and estimate a model of bilateral oil trade controlling for the role of selection in partnership formation and source heterogeneity in the flow of oil among countries. The results show that ignoring these controls introduces significant biases in the estimation of the elasticities of oil trade with respect to its determinants. We employ the estimation results to analyze the role of various factors in the formation of partnerships and

bilateral flows in oil trade and examine how these factors affect the cost of oil for each country and their ultimate impact on world prices and trade pattern. We use the model to carry out a series of global equilibrium simulation exercises to demonstrate the usefulness of the model. In particular, we show that for the rise in oil prices during 1997-2007 to have been caused by economic growth around the world, the demand and supply price elasticities must have been closer to their short run estimates found in the literature. Moreover, relatively high growth in OECD countries followed by rapid growth in transition countries and India and China account for the bulk of the rise in global oil prices. We also show that the model can be used to explore various scenarios of oil price responses to international security issues, especially the conflicts of Iran with the West.

Finally, the third chapter analyzes the bilateral trade patterns of oil substitutes around the world and how it links with the crude oil trade. We construct price and quantity indices for three forms of energy—natural gas, coal and electricity (GCE)—that are substitutes for each other and oil. In order to estimate a model of bilateral trade in GCE forms of energy we use the approach developed by HMR. We use the model to carry out a series of global equilibrium simulation exercises. We show that the rise in GCE prices during 1997-2007 may be explained by economic growth around the world, with an estimated long-run price elasticity of world supply of GCE which is around 0.60. Moreover, high growth in China and India followed by rapid growth in transition countries and OECD countries account for the bulk of the rise in global GCE prices. We also show that the model can be used to explore various scenarios of GCE price responses to international conflict issues.

To My Dearest Mom

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Our work relates to the existing literature through a wide variety of topics. There are at least four general dimensions: (1) the gravity approach to analyze trade flows, (2) the impact of institutional factors on trade in a gravity framework, (3) the interaction of international conflict and trade, particularly oil trade, and (4) the link between crude oil prices and economic growth.

1.1 Gravity Model of International Trade

The gravity model has become a widely-used workhorse for studying the determinants of bilateral trade flows. The main result of the model, the *gravity equation*, relates trade between two countries to the levels of economic activity in those countries and to the inverse of trade costs factors such as distance. Despite being applied in a variety of contexts, its theoretical foundations have remained rather unclear. The first applications of the gravity equation in international trade appeared independently in Tinbergen (1962) and Poyhonen (1963), both of which were purely empirical studies, not concerned about theory. The first formal attempt to provide micro-foundations for the gravity equation was Anderson (1979), who derived it directly from a theoretical model of differentiated products, with each variety being produced by only one country. Since then, many other models with very different structures have also been used to generate the trade equations of general gravity form (Helpman and Krugman, 1985; Bergstrand, 1985, 1989, and 1990; Markusen and Wigle, 1990; Eaton and Kortum, 1997; and Deardorff, 1998). For surveys covering the literature until early 2000s, see Helpman (1998) and Evenett and Keller (2002).

Anderson and van Wincoop (2003 and 2004) introduced a new and elegant micro-foundation for the gravity equations. One of their main contributions was to highlight the role of "multilateral resistance" terms that measure the overall effects of import and export costs for each country. They showed that exports from country j to country i depends on the price of j's goods in i relative to the overall price index for all of j's products and the overall price index for i's purchases. The "multilateral resistance" terms may also be viewed as measures of "remoteness" of a country from its potential trade partners. Anderson and van Wincoop (2003) estimated a gravity model with “multilateral resistance” terms. However, since the calculations behind those terms are cumbersome, in recent empirical studies their effects have typically been captured via exporter and importer fixed effects.

Explaining and taking account of the zero trade flows in the empirical applications of the gravity equation have been two other important concerns in the literature. One approach to deal with the problem has been to view actual trade as the outcome of gravity equation, augmented by a random factor that may yield zero trade when it is sufficiently low. Under this assumption, the Heckman selection method or a Poisson pseudo-maximum likelihood estimator can be used for correcting the bias caused by the zero trade flows (see, for example, Anderson and Marcouiller, 2002, and Santos Silva and Tenreyro, 2006). A number of authors have pointed out that such corrections could be improved by considering non-random factors that may affect the formation of trade partnerships, in particular trade restrictions and fixed costs (Romer, 1994; Evenett and Venables 2002; Haveman and Hummels, 2004; Baldwin and Harrigan, 2007; Hallak, 2006; Eaton and Kortum, 2002; and Anderson and van Wincoop, 2004). HMR build on this argument and use it to address the selection bias in gravity equations with help from a Probit model of trade partnership, where the factors determining the fixed costs of trade play an important role. HMR also make the important point that heterogeneity of firms may play a non-trivial role in both partnership formation and trade level. Their empirical results indeed confirm that failing to control for the heterogeneity and selection effects could significantly bias the trade elasticity estimates based on the gravity approach.

The most popular empirical applications of the gravity model are those that examine the impact of various forms of regional economic integration, such as the role of regional trade agreements (Frankel et al., 1998), currency unions (Rose, 2000; Rose and van Wincoop, 2001), membership in GATT/WTO (Rose, 2004; Subramanian and Wei, 2007). Many studies draw attention to a number of other aspects of trade costs, such as common borders, common language, common legal system, common religion, colonial and ethnic ties (Gould, 1994; Frankel et al., 1998; Rauch and Trindade, 2002). HMR introduce indicators of regulation costs as determinants of fixed cost of trade and use them to estimate a model with trade partnership formation, from which they derive controls for heterogeneity and selection biases in the gravity equation. We will discuss the institutional factors included in these studies in more detail below.

1.2 Institutional Factors and International Trade

While the initial idea behind gravity models was that trade must be inversely related to geographic distance, it was later realized that many non-geographic factors could also affect trade costs and shape the volume of trade. In particular, the role of differences in language, legal system, and many other characteristics were added to the gravity equations as potential drivers of trade costs. In recent years, there has been greater recognition that institutions governing economic activity and policymaking may also be consequential for trade through their impact on transaction costs. For a review of these issues, see Anderson and van Wincoop (2004).

There are many empirical papers on gravity model that incorporate institutional factors.[1] Among the important contributions to this part of the literature, Anderson and Young (2002) employ a general equilibrium framework to show that trade insecurity in the form of imperfect contract enforcement generates a price mark-up when entry into the international market entails fixed costs. They derive the ad valorem tariff equivalent of the imperfection in contracting. This measure increases as institutional quality decrease and, thus, helps explain the low levels of North-South trade compared to that of North-North, despite greater differences in relative factor endowments between North and South Countries than among North countries. This result is empirically investigated by Anderson and Marcouiller (2002), who use three indicators of institutional quality derived from a World Economic Forum (WEF) dataset, which consists of a survey of 3000 firms in 58 countries in 1997. Two of the indicators are meant to measure whether government policies are transparent and impartial and whether the legal system is effective in enforcing contracts. The third indicator is a "composite security" index that serves as a broader institutional quality measure. The effective contract enforcement is particularly important since insecurities associated with international trade create some hidden transaction costs which may dampen trade. Using 1996 bilateral import data for 48 countries, they find that the transparency of government significantly increases trade whereas contract enforceability has a marginally significant positive effect. The "composite security" index is found to have a highly significant and positive effect on imports. Anderson and Marcouiller (2002) deal with the zero

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[1] See, for example, Groot, Linders, Rietveld and Subramanian (2004), Duc, Lavallee and Siroen (2009), Li and Samsell (2009), Linders, Groot and Rietveld (2005), Linders, Slangen, Groot and Beugelsdijk (2005) and Kim and Reinert (2009).

trade observations in their sample by running Tobit regressions, which unlike the Heckman selection approach, assume that the formation of partnerships and the level of trade are determined by the same process. The results support the important role of institutions in trade. However, as Anderson and Marcouiller (2002) point out, there may be two problems associated with constructing institutional variables based on the WEF survey. First, the sample is not completely random as the participants are from currently running firms; none has chosen to shut down or relocate. Second, the expectations in each country may be different than those in other countries, hence the results might not be comparable.

Dutt and Traca (2009) examine the impact of corruption on trade in a gravity model and find ambiguous effects of corruption on trade, depending on whether evasion or extortion effects dominate. At low initial levels, an increase in corruption could increase trade flows. At high initial levels, on the other hand, increased corruption might not contribute to trade and, indeed, extortion might dominate and reduce trade flows. To test this hypothesis, Dutt and Traca (2007) add the ICRG corruption indicators for the importing and exporting countries to the right-hand side of a gravity model. They estimate the model using OLS with time and country fixed effects. They also run the model using Heckman selection procedure to deal with zero trade flows, though they do not incorporate exclusion restriction to ensure the reliability of the procedure. The probability of trade equation shows that corruption is significant for the exporting but not for the importing side of trade. On the other hand, the trade level equation shows that corruption is significant for the importing side, but ceases to be significant for the exporting side.

Similarly, using selection-based gravity modeling of trade flows, Francois and Manchin (2007) analyze the impact of infrastructure and institutional quality on the bilateral trade patterns. Their institution variables are taken from "Economic Freedom of the World" database which consists of several measures reflecting "economic freedom," such as freedom to trade, credit markets regulation, property rights, size of government, and more. Their import data covers the period 1988-2002, but there are only 6 observations available for the institutional variables (in five year increments for 1985-2000, and for 2001 and 2002). Francois and Manchin (2007) interpolate for the years with missing values. They use exporter, importer, and time fixed effects, but do not use an excluded variable for the trade level regression. Their results show that both the bilateral trade partnership formation and variations in the level of bilateral trade depend significantly on institutional quality and access to good transportation and communication systems.

1.3 Conflict and International Trade

There is a vast literature on the interaction between international conflict and trade. Since the measures of conflict and time span of samples vary among most of those studies, making comparisons is not an easy task. However, all the efforts are to answer either one or both of these two questions: Does trade reduce conflict? Does conflict reduce trade?

One group of studies addresses the first question. Many of these studies claim support for the so-called Kantian (or liberal) thesis that *trade brings peace*.[2] A recent example is Xiang, Xu and Keteku (2007), who estimate a Logit model for 1870-1992 period using the onset of Militarized Interstate Disputes (MID) as a dependent variable. They argue that the lack of support for the liberal thesis in some studies is due to the exclusion of an indicator for major powers. They lag all right hand side variables one year to avoid simultaneity and use four different measures for trade: (1) The square root of the product of the ratios of dyadic trade over total trade for each country in the dyad. (2) The square root of the product of the ratios of dyadic trade over each country's GDP. (3) The minimum of the ratios of dyadic trade over GDP for each country (Depend Low). (4) The maximum of the ratios of dyadic trade over GDP for each country (Depend High). The first two measures are included separately on the right-hand side, whereas the last two enter into regressions together. Only Depend High measure turns to be insignificant in explaining MID's. By looking at the significance of these measures, Xiang, Xu and Keteku (2007) conclude that increased trade lowers the probability of international conflict.

The empirical results supporting the liberal thesis have faced a range of criticisms, such as exclusion of fixed effects, simultaneity between conflict and trade, and inappropriate specification.[3] For example, Kim and Rousseau (2005) estimate a simultaneous equation Probit model for 1960-1988 and find that the positive effect of economic interdependence on conflict

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[2] See, among others, Polachek (1980), Russet and Oneal (2001), Garztke and Li (2003), Dorussen (2006), Oneal, Russet and Berbaum(2003), Reuveny (2001), Xiang, Xu, Keteku (2007), Chang, Polachek and Robst (2007) and Reuveny and Kang (1996).

[3] Barbieri (2002), Beck, Katz and Tucker (1998), Keshk, Pollins and Reuveny (2004), Goenner (2004), Green, Kim and Yoon (2001) and Kim and Rousseau (2005).

disappears, while the negative effect of conflict on probability of trade stays. A similar result is obtained by Keshk, Pollins and Reuveny (2004) by using MID's as conflict indicator. They did not find any support for the liberals' claim that *trade brings peace* but show that conflict reduces trade. A more recent study by Glick and Taylor (2010) find that the impact of trade on conflict is not statistically significant when controlling for dyad fixed effects. Morrow (1999) argues that based on the theory of initiation and escalation of conflicts the impact of trade interdependence on conflict is uncertain. Although being in a trade relationship can lower the incentives to engage in a war, lower willingness of the target to get into a fight makes it an easier target for coercion from the perspective of the initiator.

Whether conflict has a significant impact on trade is also ambiguous in the existing literature. Many studies find a negative impact of conflict on trade[4], whereas Polachek (1980), Morrow, Siverson and Taberes (1998) and Mansfield and Pevehouse (2000) did not find any significant effects. Kim and Rousseau (2005) examine the impact of conflict on the probability of trade and find that the conflict reduces the probability of two countries engage in trade. One of the studies that find conflict reduces the trade is Anderton and Carter (2001). Their primary focus is to investigate the impact of wars on dyadic trade of 14 major power dyads that are involved in war since 1870. They also analyze 13 cases where at least one partner in a dyad is a non-major power. The variables they use to control for conflict are War Level and War Trend. War Level is a binary variable that equals 0 for every year passed without an occurrence of war and takes the value 1 after. War Trend is initially set to 0 and counts the years after a war begins. Their results show that the War Level coefficients are positive for 2 dyads in their sample and negative and also significant in 7 out of 12 dyads. The coefficients of War Trend are positive in 3 cases; 2 are significant and contradict with the hypothesis that war disrupts trade and negative in the other 11 dyads with 8 of them are significant. They conclude that they have found reasonably strong evidence in favor of the argument that war lowers trade.

Mansfield and Pevehouse (2000) argue that Preferential Trading Arrangements (PTA) play an important role in reducing the military disputes and increasing the trade flows. They estimate various models using 1950-1985 data and MID's as conflict variable and show that their

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[4] Oneal, Russet and Berbaum (2003), Anderton and Carter (2001), Andrew Long (2008), Simmons (2005), Pollins (1989), Keshk, Pollins and Reuveny (2004) and Glick and Taylor (2010).

results are robust to different specifications and estimation methods. Moreover, their results do not depend on whether they focus on the onset of MID's or ongoing MID's. They don't find any statistically significant impact of MID's on bilateral trade flows. Their results also show that PTA's reduce military disputes and have an important effect on the relationship between trade flows and conflict.

Another study that finds an insignificant effect of conflict on trade is Morrow, Siverson and Taberes (1998). They focus on a relatively long time period 1907-1990 and use directed dyad exports as dependent variable and MID's as conflict variable. They estimate their model with various specifications and also check for possible simultaneity. Their results show that neither the conflict nor the amount of trade between a dyad has any significant effect on each other.

Crude oil has been long neglected in both trade and conflict literature despite being regarded as a strategic commodity. To date, we could not find any study that focuses solely on crude oil trade, but there are a few papers that partly or indirectly analyze it.

The earliest study is by Polachek (1980), which examines the liberal view that trade reduces conflict. He argues that conflict may be particularly sensitive to the trade in strategic commodities such as oil. By looking at the impact of conflict on trade for selected countries, he notes that with its concentration on oil exports, Saudi Arabia has very low, in fact negative, trade-conflict elasticity as an importer and very high positive trade-conflict elasticity as an exporter. His conclusion is that "a country exporting an exceedingly strategic commodity can use its monopoly power without worry about being hostile" and "oil importers *minimize* hostility to Saudi Arabia".

In a more recent study, Helmers and Pasteels (2005) apply a gravity framework to disaggregated trade data in 19 ISIC sectors to examine the trade potentials of transition economies and developing countries. Using 2002-2003 average of trade data for 103 countries they estimate a gravity model and include a tariff measure. When they use this tariff measure at disaggregated level they ignore the actual realizations and use the lowest tariff applied by an importing country to all of its trading partners. In their gravity estimations they also add a variable to account for conflict intensity between a dyad. Their conflict variable is taken from Heidelberg Institute for International Conflict Research changing between 0 to 4, 0 being in peace and 4 being in war. The conflict index takes account of the intensity and also the duration of conflict. They use exporter and importer fixed effects to account for multilateral resistance terms of Anderson and Wincoop (2003) and Poisson Pseudo Maximum Likelihood procedure as their estimation method. They find negative and significant effect of conflict on trade in 5 out of 19 sectors including petroleum industry.

Nugent and Yousef (2005) examine whether intra-regional and extra-regional trade of MENA countries is less than what the theory predicts using gravity framework. They also work on simulations of alternative trade regime scenarios to strengthen the trade within MENA countries and between MENA and European Union countries. They use the bilateral trade in 1970-1992 in five year increments for 186 countries and also disaggregate data into energy (oil-gas) and non-energy sub-groups. The indicator variables for one or both partners being an oil exporter display high negative significance for non-energy and total trade. The role of being an oil exporter in explaining energy trade is somewhat different. If both partners are oil exporters it reduces the trade between them significantly, whereas if only one partner is an oil exporter it has a positive effect on trade. Hence, they conclude that the high endowment of energy resources can be the reason why MENA countries trade less than their potential. Their comparison of predicted and actual values of trade also shows that MENA countries' performance is below their potential in international trade.

1.4 Economic Growth and Oil Prices

Understanding the reasons behind the fluctuations in oil prices and the impact of oil prices on economy has been long receiving the attention of many economists. Most studies focus on the latter and use empirical methods to quantify the negative effects of high oil prices on macroeconomic indicators. After the early 1970's, many economists came to believe that the changes in price of oil were an important determinant for macroeconomic fluctuations. However, this view has started to change in the past decades as economic conditions have changed and the assumptions behind that belief have been challenged (Barsky and Kilian, 2004). It has been commonly observed in empirical studies that the statistical relationship between the oil price and the macroeconomic variables has weakened over time. Notably, two oil shocks since 1990 which were comparable to those in 1970's have not been followed by stagflation, which was associated with the earlier oil shocks.

Barsky and Kilian (2004) review the belief that increase in oil prices are the reason for macroeconomic problems like high inflation rates, lower productivity and growth. They examine a number of theories in detail for the negative effects of oil prices on macroeconomic performance with references to actual data and to results of many studies that challenge the belief (Olson, 1988; Hulten, Robertson and Wykoff, 1989; Bohi, 1991). They argue that none of the models supporting this belief can provide solid empirical support and conclude that the evidence for the "alleged" link from oil price changes to macroeconomic performance has been mostly overstated. Moreover, implications of some theories would not be supported by US macroeconomic data. They also show that in explaining stagflation in real GDP oil price shocks are neither necessary nor sufficient. As a result their conclusion is that the impact of oil market fluctuations is much less than what has been usually considered.

Blanchard and Gali (2008) use data from industrialized economies and compare the effect of oil price shocks on growth, inflation and other macroeconomic indicators before and after 1983. Their VAR analysis shows that the dynamic effects of oil shocks have decreased considerably over time, with much smaller effects on macroeconomic measures such as output and employment. They also use a theoretical model to examine four hypotheses to explain the reasons for reduced effects of oil price shocks over time. Their calibration results favor all of the four: different nature of oil shocks, lower share of oil in production, more flexible labor markets, and developments in monetary policy. Hence, they conclude that the mixed results obtained in previous studies are due to the time-varying impacts of oil prices on macro-economy.

In order to understand the reasons behind the increase in oil prices many explanations have been proposed including the role of speculation in oil futures and spot markets, negative shocks to oil supply, intentional restrictions of crude oil production by OPEC, and changes in global economic activity. Barsky and Kilian (2004) compare the popular explanations for the source of oil price shocks such as the role of cartels, major political events in Middle East and embargoes. They argue that these factors are not exogenous contrary to common view but dependent on global macroeconomic conditions. Moreover, by observing the recent events one can see the connection of high oil prices to these factors are quite loose. The turmoil in Middle East occurs without causing any increase in price of oil and the latter occurs even in the absence of such shocks. On the other hand, OPEC is no more a powerful group, lost his influence since 1986 and not able to force a prolonged increase in oil prices since then. In addition, they stress the importance of macroeconomic conditions on the price of oil directly by shifting the demand for oil. Two important examples are the drop in oil price after the Asian crisis of 1997-1998 and after the first signs of recession emerged in US economy in late 2000.

Hamilton (2009) agrees with Barsky and Kilian (2004) that the 2007-2008 oil price shock was due to increasing demand for crude oil which is fueled by the high growth in world economy and stagnating world production of crude oil. But he argues that the previous oil price shocks were mainly caused by disruptions in oil supply. He discusses the fundamentals of economics to explain the oil price increase. He also explains the view that speculators in importing countries cause an increase in spot prices by forecasting the oil shortages. He also notes that a very low price elasticity of oil demand, much lower than the standard estimates, is needed to rationalize both economic fundamentals and role of speculation arguments.

Kilian and Hicks (2009) explain the increase in oil prices during 2000-2008 by the unexpected strong growth in world economy, especially in Asia. In their model they don't rely on econometric estimates to infer demand shocks but use direct measures of demand shocks based on professional GDP forecasts provided by Economist Intelligence Unit. Their main conclusion is that the rise in global demand due to unexpected growth in emerging economies like China and India played the biggest role in increase in real price of oil until the first half of 2008. This is further supported by the unexpected high growth in some OECD economies, especially in Japan. Similarly, much of the decline in the real price of oil is explained by large negative growth shocks after the first half of 2008 in both economies.

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CHAPTER 2

IDENTIFYING FIRM HETEROGENEITY AND SELECTION EFFECTS IN TRADE FLOWS

2.1 Introduction

The decline in trade costs over the past several decades has been associated with rapid growth in world trade. This expansion seems to have come about largely as a result of increased variety of products being exported (expansion at the extensive margin), rather than increased volumes of existing products (intensive margin) or formation of new trade partnerships among country pairs that did not transact with each other before (Yi, 2003; Hummels and Klenow, 2005; Kehoe and Ruhl, 2009). To understand the forces behind these trends and the factors that shape the pattern of trade around the globe, the gravity model has been put to use as the main workhorse with increased details and sophistication.[1] However, the estimation of the gravity model has been fraught with difficulties. In particular, a major problem has been the prevalence zero trade in bilateral relationships, which could be the source of large biases in the estimation of trade elasticities.[2] In recent years, the idea that the zero trade flows may be due to the fixed costs of exporting has been proposed as a means of dealing with the selection bias in the gravity equation (see Hallak, 2006, Baldwin and Harrigan, 2007, and Helpman, Melitz, and Rubinstein, 2008). The latter study, HMR hereafter, further notes that in the presence of firm heterogeneity, such fixed costs may account for the large role of the extensive margin, an effect that could bias the measurement of trade elasticities unless it is separated carefully from the changes at the intensive margin.

In their seminal paper, HMR show how the potential estimation biases in the gravity equation may be addressed by means of a model of trade with heterogeneous firms based on the

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[1]The literature on gravity models has grown truly large. For an excellent survey of gravity models and their results and challenges, see Anderson and van Wincoop (2004).

[2] About half of aggregate bilateral trade flows are zero in typical cross-country data samples. This share is much larger at more disaggregate product levels. See, Evenett and Venables (2002), Anderson and van Wincoop (2004), and Haveman and Hummels (2004) among many other studies.

framework developed by Melitz (2003). They derive two structural equations from their theoretical model and then estimate them empirically. The first equation determines the probability that there are positive exports from country *j* to country *i*, or "directed dyad *ji*." HMR estimate this equation as a Probit regression using the data for the set of all potential dyads. The second equation is a version of the gravity relationship, which determines the volume of exports from country *j* to country *i* when there are positive exports. Using the Probit estimation, HMR derive the Mills ratio, which is a standard correction for the selection bias a la Heckman (1979), and another term that helps correct for the role of unobserved firm heterogeneity. This approach offers an effective way of measuring the impact of trade costs on the extensive and intensive margins of trade.

A critical element required for HMR's empirical exercise is a variable that affects the probability of trade, but not its level, hence helping to ensure that the selection bias correction is not collinear with the other explanatory variables in the gravity equation.[3] For this purpose, HMR use an indicator of entry regulation costs, which they argue affects the fixed costs of trade, but not the marginal costs. Their empirical tests using that indicator seem to support the theoretical claim. However, HMR's empirical results suffer from two problems. First, the indicator of entry regulation costs (obtained from Djankov et al., 2002) is for 1999, while the data for the dependent variables are for the 1980s. Since many countries had gone through regulatory reform in the 1980s and 1990s, it is difficult to treat the variable selected by HMR for exclusion from the gravity equation as exogenous. Second, the data for other variables included in the regressions, especially the geographic distance between trade partners, contain errors. Once one corrects for those errors, the indicator of entry regulation costs ceases to be a valid excluded variable for the trade volume regression, thus putting the empirical results found by HMR in doubt. HMR also suggest an indicator of "Common Religion" as an alternative excluded variable, but that one also fails the exclusion restriction tests. Using either of these variables in

[3] In principle, one may be able to estimate the gravity equation without employing an "excluded variable" in the Probit regressions since the inverse Mills ratio is generally non-linear in the parameters. Indeed, Wei and Zhang (2009) use this approach. However, this is not a satisfactory approach since a large Monte Carlo literature suggests that in general the bivariate normal models with no exclusion restriction perform rather poorly.

conjunction with different datasets in other studies has also led to a similar conclusion (see, for example, Wei and Zhang, 2009).[4]

We argue that despite the data problems in the HMR paper, their theoretical claim can be sustained empirically if one employs an alternative proxy for the fixed costs of exporting. Our proposed proxy is the *Risk of Contract Repudiation* by the government, which is an index constructed by Stephen Knack and Philip Keefer (1995), using International Country Risk Guide (ICRG) dataset of the Political Risk Services, Inc. We argue that like the entry cost index used by HMR, the Contract Repudiation index should be expected to largely affect the fixed rather than variable costs of exports. Indeed, it seems to work in this way empirically. It also enjoys the advantage of having panel data for a large number of countries since the early 1980s. This allows the right-hand-side variables in the regressions explaining trade to enter contemporaneously or with a lag, rather than with a significant lead over the dependent variables on the left-hand side. Also, panel estimation enables us to assess the role of time-varying variables such as total country-level production and to control for directed-dyad fixed effects, thus addressing the problem of unobserved factors in bilateral relationships. Our results confirm HMR's insight that firm heterogeneity plays a non-trivial role in the response of trade volumes to trade costs. However, the magnitudes of the selection and heterogeneity biases in trade elasticities caused by the absence of appropriate corrections turn out to be smaller than those measured by HMR.

We make our case by starting in section 2.2 with a brief review of the HMR model. We then describe the data and highlight the problems with HMR's estimation in section 2.3. In section 2.4, we argue why the exporter Contract Repudiation index may primarily influence the fixed costs of trade, rather than the variable costs. We then proceed to estimate the HMR model and discuss its results, using our data and alternative excluded variable. Section 2.5 concludes the paper.

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[4] In HMR regressions, the indicator of "Common Language" also appears to have the potential to serve as the excluded variable and has been used in other studies, for example, Belenkiy (2009) and Shepotylo (2009). However, our dataset again casts doubt on the appropriateness of that variable for exclusion. Johnson (2009) suggests another alternative excluded variable: The lagged value of trade partnership. This seems promising, but potential serial correlation may make it problematic to use.

2.2 Description of the Model

The HMR model starts with the decisions of firms at the micro level whether to enter the market and whether to export or not. These actions entail fixed costs that affect the firms' decisions to take them or not, but not its activity levels when it produces or exports. This feature implies that explaining whether a given country j exports to country i requires a different set of variables than those that explain the level of trade when the value is positive. Suppose that firms produce differentiated products that have constant elasticity of substitution for consumers, ε. The firms also vary by a factor, a, which affects their unit costs of production. Let

$$(1) \qquad G(a) = \frac{a^k - a_L^k}{a_H^k - a_L^k}, \qquad k > \varepsilon - 1,$$

be the time-invariant distribution of a with support $[a_L, a_H]$, where $a_H > a_L > 0$. In this situation, for country j to be exporting to country i, the most efficient firm in j ($a = a_L$) must find it profitable to sell its output to the consumers in i. Following HMR's derivations, one can show that this will be the case if[5]

$$(2) \qquad z_{jit} = \gamma_0 - \varepsilon c_{jt} + (1-\varepsilon)(\tau_{jit} + a_L - p_{it}) + y_{it} - f_{jit} + u_{jit} > 0,$$

where γ_0 is a constant, $u_{jit} \sim N(0, \sigma_u^2)$ is a random factor affecting the variable profits of exporting from j to i at time t, and the remaining variables are defined as follows:

c_{jt}: log of average unit cost of production in country j at time t,

τ_{jit}: log of unit trade costs of exporting from j to i at time t,

p_{it}: log of the average price in country i at time t,

y_{it}: log of total expenditure in country i at time t,

f_{jit}: log of the fixed costs of exporting from j to i at time t

The fixed costs have a number of components. Specifically, $f_{jit} \equiv \kappa_x\varphi_{xjt} + \kappa_m\varphi_{mit} + \kappa\varphi_{jit} - v_{jit}$, where v_{jit} is a random factor distributed as $N(0, \sigma_v^2)$, κ's are parameters, φ_{mit} is a fixed trade barrier imposed by the importing country on all exporters at time t, φ_{xjt} is a measure of fixed

[5] HMR do not specify any time dimension in their paper. Adding the time dimension, as we do here, is straightforward.

export costs common across all export destinations at time t, and φ_{jit} is a measure of any additional country-pair specific fixed trade costs. These fixed cost components may be further decomposed into time-variant and time-invariant components.

Given the above specification, the random element in (1) will be $\eta_{jit} = v_{jit} + u_{jit}$, where $\eta_{jit} \sim N(0, \sigma_\eta^2)$ and $\sigma_\eta^2 = \sigma_u^2 + \sigma_v^2$. Using T_{jit} as a dichotomous indicator of trade, the probability that country j exports to country i at time t ($T_{jit} = 1$) can be expressed as:

$$(3)\quad Pr(T_{jit}{=}1|\,observables) = \Phi[\frac{1}{\sigma_\eta}(\gamma_0 - \varepsilon c_{jt} - (\varepsilon{-}1)(\tau_{jit} + a_L - p_{it}) + y_{it} - \kappa_x\varphi_{xjt} - \kappa_m\varphi_{mit} - \kappa\varphi_{jit})],$$

where Φ is cdf of unit-normal distribution.

When exports from j to i are positive, the log of the export volume is determined by:

$$(4)\qquad x_{jit} = \beta_0 - (\varepsilon{-}1)c_{jt} + n_{jt} - (\varepsilon{-}1)(\tau_{jit} - p_{it}) + y_{it} + w_{jit} + u_{jit},$$

where n_{jt} is the log of number of firms in the exporting country and w_{jit} is related to the fraction firms that export from j to i. This is essentially the gravity equation, with the difference that it takes account of firm heterogeneity effect through w_{jit}. A key observation of HMR is that w_{jit} is a monotonic function of z_{jit}. To be specific, given the specification of $G(a)$, when $z_{jit} > 0$, $w_{jit} = \ln[\exp(\delta z_{jit}) - 1]$, where $\delta = \sigma_\eta(k - \varepsilon + 1)/(\varepsilon - 1)$. This relationship is a central part of HMR's results because it allows one to estimate w_{jit} based on the estimate of z_{jit} from equation (3), $\hat{\bar{z}}^*_{jit}$, and then correct for the firm heterogeneity effect in the gravity equation. Furthermore, the estimate of η_{jit} from (3), offers a means of standard correction for the sample selection bias à la Heckman because $E[u_{jit} \mid ., T_{jit} = 1] = \beta_{u\eta}\hat{\bar{\eta}}^*_{jit}$, where $\beta_{u\eta} \equiv \text{corr}\,(u_{jit}, u_{jit})(\sigma_u/\sigma_\eta)$ and $\hat{\bar{\eta}}^*_{jit} = E[\eta_{jit}/\sigma_\eta|\,., T_{jit} = 1]$. As a result, the gravity equation becomes:

$$(5)\qquad x_{jit} = \beta_0 - (\varepsilon - 1)c_{jt} + n_{jt} - (\varepsilon - 1)(\tau_{jit} - p_{it}) + y_{it} + \ln[\exp(\delta\,\hat{\bar{z}}^*_{jit}) - 1] + \beta_{u\eta}\hat{\bar{\eta}}^*_{jit} + e_{jit},$$

where e_{jit} is i.i.d. Note that the term containing $\hat{\bar{z}}^*_{jit}$ is nonlinear, which complicates the estimation procedure a bit. To ensure that the estimates are not sensitive to this complication, HMR also estimate (5) using a Taylor expansion of the nonlinear term and find that the results are largely unaffected.

It is worth noting that unlike many recent gravity models that follow the framework developed by Anderson and van Wincoop (2003), HMR's model does not include a single "multilateral export resistance" term. This is because HMR assume that there is no competition over resources for exporting to different countries. For every directed dyad, there is a host of firms in the exporting country distributed according to $G(a)$, independent of exports to other destinations from that country. As a result, the profitability of exports within the dyad need not be compared to an index of payoffs from exporting to alternative destinations. However, the value of such alternatives may be reflected in c_{jt} and n_{jt}, and is ultimately captured by exporter fixed effects included in the empirical estimations of (3) and (5). The "multilateral import resistance" term in Anderson and van Wincoop (2003) is the same as p_{it}, which is captured by importer fixed effects included in the empirical model.

The crucial issue in the estimation of the system of equations (3) and (5) is that except the fixed-cost factors, all the variables determining $\hat{\bar{z}}^*_{jit}$ and $\hat{\bar{\eta}}^*_{jit}$ are included on the right-hand side of (5). As a result, finding variables that represent only the fixed costs and, thus, can be excluded in (5) is crucial in making it possible to identify the heterogeneity and selection effects in the gravity equation. In the next section, we next turn to the problems with HMR's choice of such an "excluded variable" and with their dataset.

2.3 Data and Estimation Issues in HMR

The main estimation exercise of HMR uses data for dyads of 116 countries in 1986.[6] Since only one year of data is used, some of the variables in (3) and (5) become part of exporter or importer fixed effects and are not identified separately. Specifically, c_{jt}, φ_{xjt}, and n_{jt} are included in an exporter fixed effect and p_{it} and y_{it} are incorporated into an importer fixed effect. As a result, the estimation exercise becomes focused on the determinants of variable and fixed costs of bilateral trade: τ_{jit} and φ_{jit}. For τ_{jit}, the determinants consist of country-pair specific variables, particularly the distance between countries *i* and *j* and indicators of whether they share a border, the same legal system, the same colonial origin, a common dominant language. HMR also include indicators showing whether or not both countries are landlocked or islands and whether or not they are both members of the same free trade area, currency union, or the

[6] Trade data is available for 158 countries, but the regulation costs data is restricted to 116 countries.

GATT/WTO. HMR also develop a continuous variable for the extent to which religious affiliations in the two countries are shared. The definitions of these variables and their sources are summarized in Table 2.1.

For φ_{jit}, HMR start with two possible determinants derived from cost of doing business data for 1999 (Djankov et al., 2002): Regulation Costs (a binary indicator that is unity if the cost of forming a business as percent of GDP per capita is above the median in the exporting country *j* and the importing country *i*) and entry Regulation Costs Based on Days and Procedures (a binary indicator that is unity if the sum of the number of days and procedures to form a business is above the median for both the exporting country *j* and importing country *i*).

Using the dataset that HMR have made available through the Web, we reproduced the baseline results reported in Table 2 of their paper. Table 2.2 shows the results of this exercise, which yielded estimates close to those reported by HMR, but not exactly the same. This small difference is probably due to updating and changes in the dataset after the publication of the paper.[7] The key result in Table 2.2 is that Regulation Cost as percent of GDP is statistically significant in the Probit estimation of equation (3), but not in the benchmark estimate of the gravity equation (5) before corrections are made for selection and heterogeneity. (The Days and Procedures indicator of Regulation Costs is marginally significant in the benchmark regression and, therefore, is not as reliable as the other indicator.) Based on these observations, HMR proceed to derive the variables that deal with those biases in the gravity equation, treating the Regulation Cost as percent of GDP as the excluded variable and using both non-linear and polynomial versions of equation (3).[8] The results, given in the last two columns of Table 2.2,

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[7] In particular, HMR have recently corrected the religion variable that they use. (See the website of Marc Melitz at www.economics.harvard.edu/faculty/melitz/papers_melitz). Another example of a correction is the change in the data for Kiribati. In their paper, HMR include Kiribati in the list of countries that lack regulation cost data, but their dataset does include the relevant information. Also, some corrections seem to be needed for the results that they report. In particular, based on their definitions of the variables and the estimations with the dataset, the signs of island and landlocked indicators in the regressions should be positive, while the paper shows negative coefficients for both variables in all tables.

[8] The transformation of the predicted probabilities from the Probit regression into $\hat{\bar{z}}^*_{jit}$ entails a complication: For a relatively small number of country dyads for which the probability of trade is very close or equal to 1, it is not possible to make any inference on the differences in $\hat{\bar{z}}^*_{jit}$'s. HMR assign the value of $\hat{\bar{z}}^*_{jit}$ for the country dyads with an estimated probability of 0.9999999 to all $\hat{\bar{z}}^*_{jit}$ for dyads with higher probabilities. This censoring affects less than

show that the bias correction terms are both statistically significant and their inclusion tends to lower the estimated effects of distance and other bilateral factors. Furthermore, HMR decompose the effects of reduced trade costs on intensive and extensive margins and find that the firm heterogeneity effect is the dominant factor. However, the variables and the data used by HMR entail problems that cast doubt on the results.

One problem is that the Regulation Cost data are for a much later date than the trade data, raising the possibility of endogeneity of the instrument. Even if one ignores this issue, there are errors in the data that undermine the results more seriously. In particular, in many cases the distance variable in the HMR dataset does not seem to match the available measures of distance between countries. For example, the log distance indicator in their dataset is 5.50 for the Chile-New Zealand dyad and 5.26 for Norway-New Zealand dyad, while the great-circle distances of the capital cities of these country pairs are about 9,000 km and 18,000 km, respectively. Once we use the log of the great circle distance, the Regulation Cost variables become significant (at the five percent level) in the baseline estimate of the gravity model and, thus, can no longer be treated as appropriate excluded variables (see Table 2.3). The significance levels of the other variables generally stay the same, except for the common Religion measure, which also becomes highly significant in the gravity regression even after the bias correction measures are introduced. The latter change is important because HMR propose Religion as an alternative excluded variable based on its empirical properties, which cease to apply once an alternate distance variable is used.[9]

There appear to be errors in other variables in the dataset as well.[10] To deal with these data issues, we reproduced the dataset, starting from the original data sources (see Table 2.1). The results of the model's re-estimation with the revised dataset for 1986 (shown in Table 2.4)

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five percent of the country dyads included in the gravity equation. We follow the same procedure in replicating their regressions and in the estimating of our own model.

[9] Religion appears as an appropriate excluded variable based on HMR's dataset even after correction they make to the data for this variable. However, it remains significant in the trade volume regression in our regressions with the revised distance data and, thus, fails to serve the purpose.

[10] To give a few examples, in the dataset, many island countries such as Jamaica and Madagascar are not coded as such. Also, the landlocked dummy equals 1 for Syria, the common language dummy takes the value 1 for United Arab Emirates and Brazil, and the common religion variable equals 0.95 for Saudi Arabia and Norway!

strengthen our conclusion that neither the Regulation Cost indicators nor the common Religion variable work as empirically appropriate excluded variables.

Besides the empirical weaknesses of the Regulation Cost variables, there are also conceptual concerns regarding its validity for the task at hand. Unlike the other bilateral variables included in the HMR regressions which are based on factors that two countries share (such as border, language, …), the Regulation Cost variables signal the costs of entry that occur in each country separately being relatively high in both. It is not clear why such costs should affect trade in an interactive fashion as specified by HMR, rather than as an additive one. Also, there is no reason to believe that Regulation Costs in both exporting and importing country affect the fixed cost of trade the same way. In particular, the regulatory barriers in importing countries usually fall on per unit trade, while the entry barriers in exporting countries may have a bigger impact on the fixed costs of forming export activities. Testing for additive vs. interactive role of such costs and their possible asymmetry is not possible in HMR dataset because it focuses on a single-year observation of Regulation Costs, which rules out the use of any individual country characteristic once one accounts for a country fixed effect in the regression. The variable that we propose benefits from panel data availability, which allows us to examine the role of asymmetry and additive vs. interactive fixed costs of trade between trading partners.

2.4 An Alternative Determinant of Fixed Costs of Trade

We propose the indicator of risk of Contract Repudiation in ICRG dataset as a determinant of fixed costs of exporting. The variable is defined as an indicator that "addresses the possibility that foreign businesses, contractors, and consultants face the risk of a modification in a contract taking the form of a repudiation, postponement, or scaling down due to an income drop, budget cutbacks, indigenization pressure, a change in government, or a change in government economic and social priorities." Our claim is that such risks, and the efforts to overcome them, should have a major effect on the fixed costs of setting up production and arranging exports, but not necessarily the variable costs. This is, of course, a hypothesis that we try to validate empirically, using the same approach as HMR. To avoid the problems that the ordinal nature of this variable may pose for our analysis, we form a binary indicator that takes the value one if contract repudiation in a country in a given year is less than the median score of all countries in that year and equals zero otherwise. We construct this Contract Repudiation indicator separately for each country to represent φ_{xjt} and φ_{mit}. We also interact these two variables for each dyad to form a proxy for φ_{jit}, the same way that HMR handle the Regulation Cost indicators. To the extent that these variables affect only the fixed cost of trade, they should appear with significant negative coefficients in equation (3), but not in equation (5). It is, of course, possible that they may have significant coefficients in the gravity equation as well, or prove insignificant in both or have the wrong sign. These are issues that ultimately need to be settled empirically.

The dataset that we use is an unbalanced panel that covers 15,500 directed dyads involving 125 countries during 1982-1997.[11] However, due to missing data points, we end up with a total of 189,592 observations that have complete information, amounting to an average of about 12 years of data per directed dyad. Extending the data to dates before 1982 or after 1997 is difficult because of the limitations of the current versions of ICRG data. Moreover, data on bilateral trade flows after 1997 are also limited.[12]

In our baseline results, we include all the variables employed in HMR regressions other than the Regulation Cost indicators. We add another bilateral variable that shows the presence of ongoing hostility between exporting and importing countries. The reason for adding this variable is that it has significant negative correlation with the probability of trade and seems to be a natural factor to control like other bilateral variables. It also turns out to be insignificant in the gravity equation once we include the bias control terms. This feature makes Ongoing Hostility a good candidate for use as an alternative excluded variable.

To account for the changes in country conditions with respect to the number of firms and cost of production (n_{jt} and c_{jt}) in exporting countries and the distribution costs and the aggregate demand level (affecting τ_{jit}, p_{it} and y_{it}) in the importing countries, we include in the regressions the level of GDP (in US dollars) and the Rule of Law index (from ICRG dataset) for both exporter and importer in each dyad. The latter variable also captures the overall institutional

[11] This dataset does not include the countries that have broken up after 1990 and the countries that have been formed, namely the former Soviet Union and Yugoslavia.

[12] The trade dataset that contains information for flows after 1997 is not quite compatible with the previous one and lacks trade volumes when the value falls below US$100,000, a feature that complicates the estimation of the system. See Feenstra's website on "World Import and Export data" at www.internationaldata.org.

environments of the trading countries that may affect the overall costs of trade. This should help reduce the chance that such broad cost effects are picked up by the Contract Repudiation indicator, which is intended to represent a fixed cost factor.[13] We include exporter and importer fixed effects, as in HMR, to control for many unobserved fixed country characteristics. We also include a time fixed effect in the regressions to control for the role of global shocks to the trading system. The results of these regressions are presented in Table 2.5.[14]

The main new features in Table 2.5 compared with the results reported for 1986 in Table 2.4 is the use of panel data and the introduction of the Contract Repudiation indicators for exporter and importers. The exporter Contract Repudiation proves significant in determining the probability of trade, but not in the gravity equation. The opposite is true for the importer Contract Repudiation. This conforms to the conjecture made at the end of the previous section that the risks on the exporter side may largely affect fixed costs of trade, while the risks on importing side may significantly influence the variable costs.

We also ran regressions that included the interaction term of the exporter and importer Contract Repudiation indicators by itself and in conjunction with those two indicators. For the pooled panel regressions, those exercises yield results that are very similar to those shown in Table 2.4. (The estimates are not shown here to save space.) The interaction term turns out to be significant in the trade probability regression, but not in the trade volume regression. The importer Contract Repudiation, when included, remains statistically significant in both regressions, as in Table 2.5, while the exporter Contract Repudiation loses its significance in the trade probability regression. However, as we will see below, the coefficient of the interaction term is not robust and seems to owe its effect to the role of exporter Contract Repudiation. This leads us to believe that the fixed costs of initiating exports depend largely on the Contract Repudiation on the exporter side, rather than the importer side or the interaction of the two.

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[13] An alternative to the inclusion of variables such as GDP and Rule of Law is to use time varying exporter and importer fixed effects (Baldwin and Taglioni, 2007). However, this rules out the use of excluded variables that we need for addressing the selection bias in the gravity equation. Our assumption is that the basic structure of the country effects (including "multilateral resistance" terms) is stable and their variations over time are by and large captured by the country characteristics that we have included in the model.

[14] Note that the sample used in the Probit regression contains 175,309 observations. The reason is that 9 exporters export to everywhere, yielding 14,283 observations to be dropped. These observations are included in the random effect Logit regressions.

One concern over the results reported in Table 2.5 is the possibility of unobservable factors in bilateral relationships that may affect selection and heterogeneity effects. To address this concern, we introduce directed-dyad random and fixed effects in equations (3) and (5). To estimate the probability of trade with those effects, we employ Logit, which is the technique available in Stata for panel fixed effects. We also estimate the Logit version of equation (3) with pooled panel data to make it easier to assess the role of random and fixed effects. Table 2.6 shows results, which confirm the validity of exporter Contract Repudiation as an appropriate excluded variable.[15] It is notable that the coefficient estimates in the presence of random effect are larger than in the pooled panel regression (see the first two columns of Table 2.6). This is also the case for the gravity equation, except for the ongoing hostility indicator, which loses its significance, and the selection and heterogeneity terms, which have smaller coefficient. The latter outcome suggests that the biases may be smaller than those found in the pooled panel regressions. (Compare the gravity equation estimates reported in Table 2.5 and 2.6.) Indeed, the introduction of the bias correction terms in the random-effect gravity model leads to smaller changes in the coefficient estimates, when compared to the pooled regressions.

To estimate the probability of trade with directed-dyad fixed effects, again we use Stata's "xtlogit." The inclusion of dyad fixed effects obviates exporter and importer fixed effects as well as all the time-invariant bilateral variables included in earlier tables. It also reduces the size of the sample used in the estimation of equation (3) by more than half, from 189,592 to 90,356. (This is because the dyad fixed effects can fully account for the observations where the dyad has always traded or has never traded for the duration of the sample, hence the exclusion of those observations from the regression.) Nevertheless, it is useful to examine the regressions with fixed effects because they can better account for unobserved factors. Table 2.7 shows the results with different specifications regarding the interaction term for Contract Repudiation. The first column Table 2.7 indicates that the use of dyad fixed effects does not change the results for the exporter Contract Repudiation, as it retains its significance. However, the second and third columns show that the interaction term is not significant when included by itself or in combination with the exporter and importer Contract Repudiation. We thus conclude that the exporter Contract Repudiation is the main factor here that affects the fixed costs of trade. The roles of the other

[15] Note that the figures in this table are the coefficients of the variables in the exponential expression, not the marginal probabilities as in Table 2.5.

variables that remain in the regression remain largely unchanged, though their coefficients increase somewhat relative to those obtained under the random effects.

The results of using directed-dyad fixed effects in the gravity regression are shown in Table 2.8. The figures in the first column show the benchmark regression without selection and heterogeneity controls. These figures are very similar to the corresponding random effect results in the third column of Table 2.6 for the variables that the two tables have in common. To control for the selection and heterogeneity effects, we derive the necessary terms from the random effects version of equation (3) reported in the second column of Table 2.6.[16] We only estimate the polynomial version of equation (5) with fixed effects because using linear fixed effect terms in a nonlinear equation poses difficult challenges. As the second column of Table 2.8 shows, for the variables that remain in the fixed effect regression, the signs and significance levels of the coefficients are the same as those in the pooled and random-effect regressions. However, their magnitudes tend to be larger than what we found in the pooled regression (compare the second column of Table 2.8 with the last column of Table 2.5) and somewhat smaller than the results of the random-effect regression (reported in the last column of Table 2.6). To gauge the role of the time-invariant dyad variables that drop out of the fixed effect regressions, we regress the directed-dyad fixed effects on them and show the results in Table 2.9. The estimated coefficients are again generally higher than the corresponding ones in the pooled regression and lower than those in the random-effect regression. Interestingly, the extent of bias correction (differences from the corresponding benchmarks) is also in-between the pooled and random-effect regressions; typically larger than those in the random-effect approach. This suggests that the pooled regression may underestimate and the random-effect approach may overestimate the coefficients of the gravity model. The extent of bias correction, on the other hand, seems to be overestimated in the pooled regressions and underestimated in the random-effect ones.

The estimation results in Tables 2.5-2.9 provide empirical support for the exporter Contract Repudiation as a useful excluded variable. This is further confirmed by the statistical significance of the terms capturing the selection and heterogeneity effects in both the nonlinear and polynomial estimations of the gravity regression. Importantly, the results support the

[16] Using the fixed effect Logit version restricts the sample considerably without any substantive consequence for the fixed effect gravity equation. Using the pooled panel version for this purpose (first column of Table 2.5) does not change the main results in any substantive way.

theoretical insights of HMR that there are biases at the intensive and extensive margins of trade and that the latter could play a significant role. Indeed, decomposing the selection and heterogeneity biases, as in third and fourth columns of Table 2.8, shows that the main change in the estimates comes as a result of adding the heterogeneity effect term, $\hat{\bar{z}}^*_{jit}$. The same results obtain when we use pooled or random effect regressions, confirming HMR's results regarding the dominance of the firm heterogeneity effect in determining trade flows.

An important issue that HMR address based on their estimation results is the magnitude and variation of the elasticity of trade volume with respect to trade costs. They carry out an experiment by lowering distance by 10% and then measuring the elasticity for trade across three dyad types: North-North, North-South, and South-South.[17] They find that trade elasticities are generally larger than one and tend to be higher for the developing countries. We obtain somewhat lower estimates in a more compressed range by repeating the exercise using our pooled and random effect panel regressions (see Table 2.10). In particular, the range of elasticities turns out to be smaller for the South countries. These results naturally follow from the lower bias and the lower estimates that we find for the trade response to various factors when we use panel data. Inclusion of additional variables (GDP, Rule of Law, and Ongoing Hostility) has also played a role by reducing the share of variation attributable to distance.

Before closing this section, it is worth examining the consequences of using panel data and our alternative excluded variable for the indicators included in the regressions. For the bilateral variables considered by HMR, the signs and significance levels of the marginal probability effect in the Probit regression are generally similar between the pooled panel regression in Table 2.5 and those obtained for 1986 in Table 2.4. However, using the panel features of the data and adding new variables (GDP, Rule of Law, and Ongoing Hostility) tend to lower the magnitudes of the estimated marginal probabilities. As one expects, being geographically closer, having a common language, religion, legal origin, currency union, and free trade area raise the trade probability and volume (when trade is positive). The same is true for reduced hostility levels. Sharing colonial ties, border, or island status also raises trade

[17] North consists of nineteen countries: Australia, Austria, Belgium-Luxemburg, Canada, Denmark, Finland, France, Germany, Hong Kong, Iceland, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and the United States. All other countries are in the South.

volumes, but does not seem to increase the probability of positive trade. A shared border in fact seems to have the anomalous effect of lower trade probability. Sharing landlocked status also displays counterintuitive negative effects on trade probabilities and volumes.

The time-varying country variables—GDP and Rule of Law—both tend to have large and positive effects on trade probability, as expected. However, in contrast to typical gravity model estimations, the elasticity of trade with respect to GDP turns out to be much smaller than 1.

An important observation in comparing Tables 2.4 with 2.5, 2.6, or 2.8 is that the bias corrections in the gravity equation (the difference of columns 3 and 4 with column 2) tend to be notably smaller in the panel data estimates. Accounting for panel effects and adding new variables seem to indicate smaller biases than measured by HMR, though the directions and significance levels remain valid.

Finally, it is notable that all the bilateral variables included in HMR's study remain significant in the gravity equation even after we correct for selection and heterogeneity. This undermines their suggestion that variables such as common Religion and Language indicators, which lose their significance in HMR's gravity regressions, may be used as alternative excluded variables.[18] However, our study indicates that the Ongoing Hostility indicator may serve such a purpose.[19]

2.5 Conclusion

The model developed by HMR is extremely insightful about the determinants of international trade. Our aim in this paper has been to examine the empirical basis for their theoretical insights. A crucial element in such empirical analysis is identifying a variable that affects the fixed costs of exporting from one country to another, but not the variable costs ("excluded variable"). We argue that the nature of the variable that HMR had selected for this purpose and some errors in the dataset weaken their empirical case for the theoretical observations. We propose an alternative "excluded variable" that addresses those concerns. It benefits from the existence of panel data contemporaneous with the trade data and it fulfills the

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[18] HMR focus on the use of common Religion as an excluded variable. Shepotylo (2009) employs common Language for this purpose.

[19] We take advantage of such a possibility in another study of ours that focuses on energy trade.

empirical requirements for an excluded variable regardless of the model specification. The results confirm HMR's finding that firm heterogeneity plays a significant role in the response of trade volumes to trade costs. However, the magnitude of selection and heterogeneity biases in trade elasticities caused by the absence of appropriate corrections appear to be smaller than those measured by HMR. The magnitude of trade elasticities and their range variations across countries also turn out to be smaller than the levels found by HMR.

The option to use panel data with the help of the new excluded variable introduced here opens up possibilities for further research on the role of country-level variables in shaping trade patterns. We examine two such variables—GDP and Rule of Law—and find that they have tangible effects on shaping trade, though not as strong as often found in traditional gravity regressions. Our study also casts doubt on the use of some bilateral indicators, such as common Religion and Language, proposed as alternative excluded variables. Instead, it points to Ongoing Hostility among country dyads as a potential variable that can serve this purpose. These results can be very useful in future studies of trade flows and related topics.

2.6 Tables

Table 2.1 Variable Descriptions and Data Sources

Name	Description	Source
Trade $_{jit}$	Logarithm of exports from country *j* to country *i* at time *t* in thousands of constant 2000 US dollars.	Robert Feenstra, "UCD-Statistics Canada Trade Data, 1980-1997," www.internationaldata.org
Distance$_{ji}$	Logarithm of the great circle distance (in km) between exporter's *j* and importer's *i* capitals	Centre D'Etudes Prospectives et D'Informations Internationales (CEPII) http://www.cepii.fr/anglaisgraph/cepii/cepii.htm
Colonial$_{ji}$	A binary variable that is unity if exporting country *j* ever colonized importing country *i* or vice versa.	
Land Border$_{ji}$	A binary variable that is unity if exporter *j* and importer *i* share a common land border	
Island$_{ji}$	A binary variable that is unity if both exporter *j* and importer *i* are islands	CIA The World Factbook
Landlocked$_{ji}$	A binary variable that is unity if both exporting country *j* and importing country *i* have no direct access to sea	CIA The World Factbook
CU$_{ji}$	A binary variable that is unity if exporting country *j* and importing country *i* use the same currency	Rose (2000, 2004)
FTA$_{ji}$	A binary variable that is unity if exporting country *j* and importing country *i* belong to the same regional trade agreement.	Rose (2000, 2004)
Legal$_{ji}$	A binary variable that is unity if the exporting country *j* and importing country *i* share the same legal origin.	Easterly & Yu
Language$_{ji}$	A binary variable that is unity if the exporting country *j* and importing country *i* uses a common language	CIA The World Factbook
Religion$_{ji}$	(% Protestants in country *j* × % Protestants in country *i*) + (% Catholics in country *j* × %Catholics in country *i*) + (% Muslims in country *j* × %Muslims in country *i*)	Encyclopedia Britannica Book of the Year 2001
WTO$_{ji}$	A vector of two dummy variables: the first binary variable is unity if both exporting country *j* and importing country *i do not* belong to the GATT/WTO; the second binary variable is unity if both countries belong to the GATT/WTO	Rose (2004) and WTO website
Regulation Costs (Percent of GDP) $_{ji}$	A binary indicator that is unity if the relative cost (as percent of GDP per capita) of forming a business is above the median in the exporting country *j* and the importing country *i*.	Doing Business Dataset (Djankov et al., 2002)
Regulation Costs (Days & Procedures) $_{ji}$	A binary indicator that is unity if the sum of the number of days and procedures to form a business is above the median for both the exporting country *j* and importing country *i*.	Doing Business Dataset (Djankov et al., 2002)
Ongoing Hostility$_{jit}$	Dichotomous indicator of ongoing hostility between exporting country *j* and the importing country *i* .	Correlates of War Database http://www.correlatesofwar.org/
Risk of Contract Repudiation$_{jt}$	A binary variable that takes the value one if contract repudiation in country *j* is less than the median score of all countries, zero otherwise. This variable is constructed separately for both exporting country *j* and the importing country *i* . If the score of a country is less than the median it has a higher risk for repudiation of contracts.	Political Risk Services, Inc., ICGR Dataset
Rule of Law$_{jt}$	Separate for exporting country *j* and importing country *j.* It "reflects the degree to which the citizens of a country are willing to accept the established institutions to make and implement laws and adjudicate disputes." Higher scores imply better political institutions, and a strong court system	Political Risk Services, Inc., ICGR Dataset
GDP$_{jt}$	Logarithm of Gross Domestic Product in thousands of constant 2000 US dollars.	World Bank, World Development Indicators www.worldbank.org/data

Table 2.2 Baseline Results for the HMR 1986 Reduced-Sample Dataset†

Dependent Variable:	Trade Dummy, T_{ji}	Log Exports from *j* to *i*, x_{jit}		
Model	**Probit (Marginal Effects)**	**Benchmark**	**Nonlinear LS**	**Polynomial**
Distance (HMR Data)	-0.219^{**} *(0.016)*	-1.173^{**} *(0.040)*	-0.818^{**} *(0.056)*	-0.845^{**} *(0.053)*
Land Border	–0.093 *(0.072)*	0.612^{**} *(0.165)*	0.861^{**} *(0.141)*	0.841^{**} *(0.166)*
Island	0.170^{**} *(0.048)*	0.566^{*} *(0.274)*	0.442^{**} *(0.056)*	0.193 *(0.268)*
Landlocked	0.058 *(0.046)*	0.431^{*} *(0.189)*	0.849^{**} *(0.189)*	0.352^{+} *(0.187)*
Legal	0.0540^{**} *(0.019)*	0.551^{**} *(0.064)*	–0.041 *(0.074)*	0.443^{**} *(0.064)*
Language	0.0987^{**} *(0.021)*	0.126^{+} *(0.075)*	0.186 *(0.234)*	–0.032 *(0.077)*
Colonial Ties	–0.009 *(0.131)*	0.907^{**} *(0.157)*	0.335^{*} *(0.171)*	0.842^{**} *(0.148)*
Currency Union	0.222^{**} *(0.039)*	1.532^{**} *(0.334)*	1.075^{**} *(0.286)*	1.138^{**} *(0.333)*
FTA	0.357^{**} *(0.009)*	0.968^{**} *(0.246)*	0.127 *(0.240)*	0.228 *(0.198)*
Religion	0.147^{**} *(0.034)*	0.295^{*} *(0.119)*	0.121 *(0.113)*	0.137 *(0.119)*
Regulation Costs (Percent of GDP)	-0.108^{**} *(0.036)*	–0.146 *(0.100)*		
Regulation Costs (Days & Procedures)	-0.068^{*} *(0.031)*	-0.226^{+} *(0.124)*		
δ (from $\hat{\bar{w}}_{ij}^{*}$)			0.635^{**} *(0.109)*	
$\hat{\bar{\eta}}_{ij}^{*}$			0.256^{*} *(0.101)*	0.835^{**} *(0.204)*
$\hat{\bar{z}}_{ij}^{*}$				3.162^{**} *(0.519)*
$\hat{\bar{z}}_{ij}^{*2}$				-0.674^{**} *(0.161)*
$\hat{\bar{z}}_{ij}^{*3}$				0.0562^{**} *(0.016)*
Observations	12420	6645	6645	6645
R^2	.	0.693	0.700	0.701

† Regressions include exporter and importer fixed effects not shown in this table. The numbers in parentheses are standard errors.

$^{+}$ 10% significance level, * 5% significance level, ** 1% significance level

Table 2.3 Result of Estimation with HMR 1986 Reduced-Sample Dataset, Using an Alternative Distance Variable†

Dependent Variable:	Trade Dummy, T_{ji}	Log Exports from *j* to *i*, x_{jit}		
Model	**Probit (Marginal Effects)**	**Benchmark**	**Nonlinear LS**	**Polynomial**
Log of the Great Circle Distance	–0.217** *(0.017)*	–1.181** *(0.040)*	–0.828** *(0.056)*	–0.875** *(0.051)*
Land Border	–0.097 *(0.077)*	0.499** *(0.157)*	0.737** *(0.143)*	0.695** *(0.157)*
Island	0.175** *(0.047)*	0.665* *(0.271)*	0.433** *(0.056)*	0.282 *(0.261)*
Landlocked	0.052 *(0.046)*	0.422* *(0.186)*	0.872** *(0.190)*	0.366* *(0.183)*
Legal	0.0570** *(0.019)*	0.546** *(0.064)*	–0.047 *(0.075)*	0.438** *(0.064)*
Language	0.104** *(0.021)*	0.136+ *(0.076)*	0.258 *(0.235)*	–0.029 *(0.078)*
Colonial Ties	–0.022 *(0.131)*	0.909** *(0.159)*	0.342* *(0.171)*	0.855** *(0.151)*
Currency Union	0.202** *(0.044)*	1.417** *(0.337)*	0.987** *(0.286)*	1.062** *(0.338)*
FTA	0.357** *(0.009)*	1.024** *(0.243)*	0.133 *(0.244)*	0.304 *(0.198)*
Religion	0.155** *(0.034)*	0.397** *(0.119)*	0.201* *(0.113)*	0.231+ *(0.119)*
Regulation Costs (Percent of GDP)	–0.109** *(0.036)*	–0.207* *(0.100)*		
Regulation Costs (Days & Procedures)	–0.0675* *(0.031)*	–0.231+ *(0.124)*		
δ (from $\hat{\bar{w}}^*_{ij}$)			0.621** *(0.110)*	
$\hat{\bar{\eta}}^*_{ij}$			0.193* *(0.089)*	0.770** *(0.205)*
$\hat{\bar{z}}^*_{ij}$				2.935** *(0.518)*
$\hat{\bar{z}}^{*2}_{ij}$				–0.594** *(0.161)*
$\hat{\bar{z}}^{*3}_{ij}$				0.0463** *(0.016)*
Observations	12420	6645	6645	6645
R^2	.	0.693	0.699	0.700

† Regressions include exporter and importer fixed effects not shown in this table. The numbers in parentheses are standard errors.
+ 10% significance level, * 5% significance level, ** 1% significance level

Table 2.4 Estimation Results of the HMR Model with the Revised 1986 Dataset†

Dependent Variable:	**Trade Dummy, T_{ji}**	**Log Exports from *j* to *i*, x_{jit}**		
Model	**Probit (Marginal Effects)**	**Benchmark**	**Nonlinear LS**	**Polynomial**
Log of the Great Circle Distance	–0.275** *(0.014)*	–1.232** *(0.036)*	–0.796** *(0.056)*	–0.890** *(0.051)*
Land Border	–0.167** *(0.055)*	0.398** *(0.149)*	0.754** *(0.134)*	0.672** *(0.152)*
Island	0.162** *(0.041)*	0.330+ *(0.175)*	0.338** *(0.050)*	0.034 *(0.169)*
Landlocked	0.104* *(0.046)*	0.422* *(0.193)*	1.159** *(0.168)*	0.309 *(0.192)*
Legal	0.0408** *(0.016)*	0.432** *(0.056)*	0.089* *(0.066)*	0.338** *(0.056)*
Language	0.0922** *(0.019)*	0.232** *(0.068)*	0.009 *(0.158)*	0.109 *(0.069)*
Colonial Ties	–0.044 *(0.111)*	1.135** *(0.151)*	0.263* *(0.169)*	1.118** *(0.144)*
Currency Union	0.181** *(0.054)*	1.125** *(0.295)*	0.774** *(0.254)*	0.873** *(0.291)*
FTA	0.433** *(0.033)*	0.688** *(0.214)*	0.371* *(0.176)*	0.515** *(0.171)*
Religion	0.133** *(0.028)*	0.404** *(0.102)*	0.279** *(0.097)*	0.341** *(0.101)*
Regulation Costs (Percent of GDP)	–0.0814** *(0.029)*	–0.215* *(0.097)*		
Regulation Costs (Days & Procedures)	0.002 *(0.025)*	0.010 *(0.086)*		
δ (from $\hat{\bar{w}}_{ij}^*$)			*0.71*** *(0.097)*	
$\hat{\bar{\eta}}_{ij}^*$			0.256** *(0.087)*	0.903** *(0.170)*
$\hat{\bar{z}}_{ij}^*$				3.001** *(0.446)*
$\hat{\bar{z}}_{ij}^{*2}$				–0.585** *(0.140)*
$\hat{\bar{z}}_{ij}^{*3}$				0.0431** *(0.014)*
Observations	18487	8776	8776	8776
R^2	.	0.686	0.693	0.696

† Regressions include exporter and importer fixed effects not shown in this table. The numbers in parentheses are standard errors.

+ 10% significance level, * 5% significance level, ** 1% significance level

Table 2.5 Estimates of the HMR Model with Alternative Specification and Pooled Panel Data†

Dependent Variable:	Trade Dummy, T_{ji}	Log Exports from j to i, x_{jit}		
Model:	**Probit (Marginal Effects)**	**Benchmark**	**Nonlinear LS**	**Polynomial**
Log of the Great Circle Distance	–0.188** *(0.006)*	–1.358** *(0.024)*	–1.035** *(0.037)*	–1.037** *(0.039)*
Land Border	–0.176** *(0.030)*	0.356** *(0.104)*	0.640** *(0.104)*	0.622** *(0.105)*
Island	0.013 *(0.024)*	0.261+ *(0.139)*	0.227+ *(0.137)*	0.251+ *(0.136)*
Landlocked	0.0707** *(0.019)*	0.487** *(0.132)*	0.367** *(0.131)*	0.396** *(0.130)*
Legal	0.0287** *(0.007)*	0.201** *(0.036)*	0.151** *(0.036)*	0.145** *(0.036)*
Language	0.0447** *(0.008)*	0.321** *(0.049)*	0.230** *(0.050)*	0.228** *(0.050)*
Colonial Ties	0.035 *(0.039)*	0.982** *(0.123)*	0.877** *(0.118)*	0.837** *(0.117)*
Currency Union	0.107** *(0.021)*	1.044** *(0.254)*	0.795** *(0.257)*	0.792** *(0.259)*
FTA	0.158** *(0.028)*	0.534** *(0.133)*	0.460** *(0.115)*	0.568** *(0.112)*
Religion	0.160** *(0.013)*	0.572** *(0.066)*	0.316** *(0.069)*	0.323** *(0.070)*
Log of Exporter GDP	0.0444** *(0.006)*	0.483** *(0.031)*	0.396** *(0.032)*	0.390** *(0.032)*
Log of Importer GDP	0.0607** *(0.006)*	0.450** *(0.031)*	0.342** *(0.032)*	0.343** *(0.032)*
Exporter Rule of Law	0.0156** *(0.003)*	0.0555** *(0.011)*	0.023* *(0.011)*	0.0194+ *(0.011)*
Importer Rule of Law	0.004 *(0.003)*	0.0434** *(0.011)*	0.036** *(0.011)*	0.0343** *(0.011)*
Ongoing Hostility	–0.295** *(0.066)*	–0.871** *(0.213)*	–0.451* *(0.219)*	–0.470* *(0.222)*
Exporter Risk of Contract Repudiation	–0.00876* *(0.004)*	0.0066 *(0.019)*		
Importer Risk of Contract Repudiation	0.004 *(0.005)*	–0.0734** *(0.020)*	–0.0797** *(0.020)*	–0.0779** *(0.020)*
δ (from $\hat{\bar{w}}_{ij}^*$)			0.476** *(0.080)*	
$\hat{\bar{\eta}}_{ij}^*$			0.045* *(0.074)*	0.723** *(0.121)*
$\hat{\bar{z}}_{ij}^*$				3.370** *(0.319)*
$\hat{\bar{z}}_{ij}^{*2}$				–0.749** *(0.099)*
$\hat{\bar{z}}_{ij}^{*3}$				0.0615** *(0.010)*
Observations	175309	103196	103196	103196
R^2	.	0.687	0.690	0.692

† Regressions include time as well as exporter and importer fixed effects not shown in this table. The numbers in parentheses are standard errors.
+ 10% significance level * 5% significance level ** 1% significance level

Table 2.6 Panel Estimation of the Alternative Specification HMR Model with Random Effects†

Dependent Variable:	**Trade Dummy, T_{ji}**		**Log Exports from *j* to *i*, x_{jit}**	
Model:	**Pooled Panel Logit**	**Random Effect Logit**	**Benchmark**	**Polynomial**
Log of the Great Circle Distance	–1.044** *(0.0145)*	–1.335** *(0.035)*	–1.280** *(0.023)*	–1.228** *(0.023)*
Land Border	–0.866** *(0.0565)*	–1.050** *(0.137)*	0.467** *(0.096)*	0.493** *(0.094)*
Island	0.0541 *(0.0692)*	0.143 *(0.180)*	0.183 *(0.124)*	0.221+ *(0.121)*
Landlocked	0.373** *(0.0725)*	0.504** *(0.170)*	0.423** *(0.138)*	0.447** *(0.135)*
Legal	0.174** *(0.0175)*	0.199** *(0.044)*	0.194** *(0.034)*	0.168** *(0.033)*
Language	0.231** *(0.0245)*	0.363** *(0.061)*	0.309** *(0.046)*	0.304** *(0.045)*
Colonial Ties	0.162 *(0.173)*	0.474 *(0.349)*	1.127** *(0.117)*	1.017** *(0.114)*
Currency Union	0.657** *(0.0838)*	0.831** *(0.211)*	0.904** *(0.176)*	0.905** *(0.173)*
FTA	1.222** *(0.146)*	0.375 *(0.255)*	0.083+ *(0.050)*	0.167** *(0.050)*
Religion	0.833** *(0.0365)*	1.088** *(0.089)*	0.576** *(0.064)*	0.547** *(0.063)*
Log of Exporter GDP	0.244** *(0.0263)*	0.309** *(0.031)*	0.453** *(0.014)*	0.423** *(0.014)*
Log of Importer GDP	0.332** *(0.0266)*	0.418** *(0.031)*	0.491** *(0.013)*	0.457** *(0.013)*
Exporter Rule of Law	0.0813** *(0.0116)*	0.103** *(0.014)*	0.0786** *(0.005)*	0.0610** *(0.005)*
Importer Rule of Law	0.0159 *(0.0117)*	0.019 *(0.014)*	0.0634** *(0.005)*	0.0604** *(0.005)*
Ongoing Hostility	–1.402** *(0.202)*	–1.103** *(0.270)*	–0.265** *(0.009)*	0.085 *(0.112)*
Exporter Risk of Contract Repudiation	–0.0546* (0.0222)	–0.0610* *(0.026)*	–0.00048 *(0.011)*	
Importer Risk of Contract Repudiation	0.0239 (0.0227)	0.031 *(0.026)*	–0.0515** *(0.011)*	–0.0517** *(0.011)*
$\hat{\eta}_{ij}^{*}$				0.418** *(0.027)*
$\hat{z}_{ij}^{*}$				0.831** *(0.099)*
$\hat{z}_{ij}^{*2}$				–0.171** *(0.032)*
$\hat{z}_{ij}^{*3}$				0.0159** (0.003)
Observations	175309	189592	117479	117479
R^2		.	.	.

† Regressions include time as well as exporter and importer fixed effects not shown in this table. The numbers in parentheses are standard errors.

+ 10% significance level * 5% significance level ** 1% significance level

Table 2.7 Fixed-Effect Panel Estimates of the Probability of Trade Equation[†]

Dependent Variable:	Trade Dummy, T_{ji}		
Method:	**Fixed Effect Logit**	**Fixed Effect Logit**	**Fixed Effect Logit**
Log of Exporter GDP	0.319** *(0.031)*	0.318** *(0.031)*	0.325*** *(0.031)*
Log of Importer GDP	0.422** *(0.031)*	0.422** *(0.031)*	0.415*** *(0.031)*
Exporter Rule of Law	0.105** *(0.014)*	0.105** *(0.014)*	0.110*** *(0.013)*
Importer Rule of Law	0.021 *(0.014)*	0.020 *(0.014)*	0.013 *(0.013)*
Ongoing Hostility	–0.922** *(0.313)*	–0.920** *(0.313)*	–0.920*** *(0.313)*
Exporter Risk of Contract Repudiation	–0.0560* *(0.026)*	–0.028 *(0.033)*	
Importer Risk of Contract Repudiation	0.028 *(0.026)*	0.0586+ *(0.034)*	
Interaction of Exporter/Importer Risk of Contract Repudiation		–0.056 *(0.041)*	–0.037 *(0.027)*
Observations	90356	90356	90356
Number of directed dyads			

[†] Regressions include time and dyad fixed effects not shown in this table. The numbers in parentheses are standard errors.
[+] 10% significance level, [*] 5% significance level, [**] 1% significance level

Table 2.8 1982-1997 Fixed-Effect Panel Estimates†

Dependent Variable:	Log Exports from *j* of *i*, x_{jit}			
Model:	**Benchmark**	**Polynomial**	**Firm Heterogeneity**	**Heckman Selection**
Log of Exporter GDP	0.450** *(0.028)*	0.350** *(0.039)*	0.303** *(0.017)*	0.429** *(0.014)*
Log of Importer GDP	0.494** *(0.025)*	0.371** *(0.049)*	0.330** *(0.018)*	0.496** *(0.014)*
Exporter Rule of Law	0.0821** *(0.009)*	0.0494** *(0.014)*	0.0509** *(0.006)*	0.0945** *(0.005)*
Importer Rule of Law	0.0661** *(0.009)*	0.0637** *(0.006)*	0.0640** *(0.006)*	0.0715** *(0.006)*
Ongoing Hostility	–0.253* *(0.119)*	0.072 *(0.153)*	0.162+ *(0.095)*	–0.272** *(0.090)*
Exporter Risk of Contract Repudiation	–0.00002 *(0.017)*			
Importer Risk of Contract Repudiation	–0.0467** *(0.016)*	–0.0495** *(0.012)*	–0.0532** *(0.011)*	–0.0411** *(0.011)*
$\hat{\eta}^{*}_{ij}$		0.199+ *(0.116)*		0.407** *(0.028)*
$\hat{z}^{*}_{ij}$		0.480** *(0.115)*	0.392** *(0.027)*	
$\hat{z}^{*2}_{ij}$		–0.0159** *(0.002)*		
$\hat{z}^{*3}_{ij}$		0.000236** *(0.000)*		
Observations	117479	117479	117479	117479
R^2	0.124	0.127	0.126	0.126

† Regressions include time and dyad fixed effects not shown in this table. The numbers in parentheses are standard errors.
+ 10% significance level, * 5% significance level, ** 1% significance level

Table 2.9 Determinants of Directed-Dyad Fixed Effects in Gravity Equation†

Dependent Variable:	Directed-Dyad Fixed Effect, X_{ji} Benchmark		Directed-Dyad Fixed Effect, X_{ji} Polynomial	
Model:	**OLS**	**OLS**	**OLS**	**OLS**
Log of the Great Circle Distance	–1.292**	–1.290**	–1.008**	–1.003**
	(0.0257)	*(0.0260)*	(0.0256)	(0.0259)
Land Border	0.523**	0.513**	0.705**	0.695**
	(0.115)	*(0.113)*	(0.114)	(0.113)
Island	0.158	0.161	0.177	0.178
	(0.121)	*(0.122)*	(0.119)	(0.120)
Landlocked	0.390**	0.417**	0.353**	0.375**
	(0.127)	*(0.126)*	(0.128)	(0.128)
Legal	0.189**	0.187**	0.120**	0.118**
	(0.0363)	*(0.0363)*	(0.0358)	(0.0358)
Language	0.344**	0.308**	0.314**	0.283**
	(0.0490)	*(0.0490)*	(0.0481)	(0.0480)
Colonial Ties	1.105**	1.125**	0.922**	0.942**
	(0.108)	*(0.108)*	(0.109)	(0.110)
Currency Union††		1.056**		0.922**
		(0.220)		(0.225)
FTA††		–0.304		–0.187
		(0.194)		(0.188)
Religion	0.551**	0.574**	0.375**	0.395**
	(0.0659)	*(0.0658)*	(0.0650)	(0.0650)
Observations	11833	11833	11833	11833
R^2	0.634	0.635	0.487	0.488

† The numbers in parentheses are standard errors.
†† These variables are set equal to 1 if the exporter and importer belong to the FTA or Currency Union for at least 5 years in the 1980s.
+ 10% significance level, * 5% significance level, ** 1% significance level

Table 2.10 Trade Elasticity Responses to Distance Reduction Across Country Dyads

Country pairs group	Number of Country Dyads	Elasticity of Trade with Respect to Distance: Mean	S.D.	Min	Max
		Pooled Panel Regressions			
North-North	2141	1.184	0.205	1.037	2.324
North-South	32799	1.531	0.328	1.037	2.644
South-South	68256	1.985	0.365	1.037	2.717
Overall	103196	1.824	0.420	1.037	2.717
		Random Effect Regressions			
North-North	4283	1.237	0.059	1.228	1.973
North-South	44940	1.340	0.199	1.228	2.219
South-South	68256	1.685	0.283	1.228	2.246
Overall	117479	1.537	0.305	1.228	2.246

`

CHAPTER 3

HOW THE OIL FLOWS

3.1 Introduction

Oil prices play a major role in the world economy. In particular, fluctuations in oil prices in the past four decades have contributed to significant economic instability in many countries. It is well understood that these fluctuations depend on the elasticities of oil demand in importing countries and on the behavior of oil exporting countries (Hamilton, 2008 and 2009). However, far less attention has been paid to factors that determine oil trade, which also influence the cost of oil for each country. Such costs and their variability in turn influence the policies in countries toward domestic energy prices as well as the efforts to develop alternative sources of energy. This paper makes an effort to fill the gap in research on oil trade patterns around the world. We use the approach developed Helpman, Melitz and Rubinstein (2008), HMR hereafter, to specify and estimate a model of bilateral oil trade. We employ the estimation results to analyze the role of various factors in the formation of partnerships and bilateral flows in oil trade. We examine how these factors affect the cost of oil for each country and their ultimate impact on world prices and trade pattern.

The HMR approach addresses a number of important concerns in estimating the equation for bilateral trade flows often encountered in the standard gravity framework. One such concern is the large number of zeros among country dyads. Focusing on the sample of bilateral relationships with positive trade poses a selection problem. In addition, the elasticity of oil supply with respect to various factors depends on how oil producers respond as the prices they face change. Oil exporting countries with very heterogeneous oil sources may face rapidly rising costs if they try to expand production and exports, while those with more homogenous oil sources may be able to respond with larger changes in trade volumes. The HMR framework allows us to deal with both selection and heterogeneity issues and explain both partnerships as well as trade flows.

HMR develop a theoretical model of international trade with heterogeneous firms from which they derive two equations: one determining the formation of partnerships and the other trade volumes for the formed partnerships. Their empirical results show that ignoring the unobserved firm heterogeneity and selection effects causes an upward bias in standard estimations of gravity model. The results we obtain by estimating the equation with dyadic panel data of oil trade flows for 1980-2000 also provide support for their argument in the case of international oil market. We observe that ignoring the selection and heterogeneity effects in oil trade causes significant biases in the estimated trade elasticities.

Oil well productivity varies greatly among and within countries. Table 3.1 illustrates the heterogeneity of oil fields throughout the world and also shows the diverse nature of oil fields within each country and even region (Simmons, 2002). Top 250 most productive wells in Utah and the amount they produce are shown in Figure 3.1 and Figure 3.2. They illustrate that even within the boundaries of a state, oil wells can be quite heterogeneous with significantly different productivities. Although there is no full dataset for the productivity of all oil wells at country level, these figures and tables give a glimpse of the extent of heterogeneity within one country. The extent of such heterogeneity determines the elasticity of supply from each oil-exporting country. Even though we don't have data across countries to directly measure variations in heterogeneity, HMR method offers an indirect way of gauging heterogeneity of productivity of sources within each country.

The selection effect is more closely tied to the average productivity of oil wells in each country. An oil producing country can end up exporting oil if the productivity of some of its oil fields is large enough to overcome the costs of trade. The higher the average productivity, the greater is the number of fields that can potentially export. A simple corroboration of this point can be seen in Table 3.2, which shows the average oil well productivity in some of the oil producing countries along with the corresponding number of oil wells and export/production data. The highest productive oil wells are located in Saudi Arabia followed by Norway. Among the major oil producing countries the lowest well productivity can be found in USA with the highest number of oil wells by far. Since the total production of oil is found by multiplying oil well productivity by the number of oil wells, higher production does not necessarily mean that country is more productive in producing oil. In fact, the correlation of oil production and oil well productivity is 0.49. For example, United States is ranked as 3rd in total oil production and but is ranked as 40th in average oil well productivity. Venezuela is ranked as 7th in oil production but is ranked as 21th in average well productivity. More systematic support for this point comes from the regression of oil exports on total production and average oil well productivity across oil exporting countries. (See Table 3.3.) Both variables prove statistically and economically significant, jointly explaining 82 percent of the variation in oil export. Notably, they display equal explanatory powers, indicating that oil well productivity is as important as total production in explaining exports. If in a country total production is kept constant and 10 percent more oil is produced out of 10 percent fewer wells, exports goes up by 6.3 percent at the mean, very close to the increase in exports if total production goes up 10 percent through expansion in the number of wells. This result is in line with Melitz (2003) model of trade with heterogeneous firms in which he associates the exports of a country with the productivity of its firms. This same effect is present in HMR: the more productive the firms in a country, the more likely that they are able to cover the fixed costs of exporting. With firm heterogeneity the model can explain zero and asymmetric trade flows between countries.

A critical aspect of HMR structural model is that its estimation requires a variable that affects the probability of trade but is uncorrelated with the residual of the trade volume equation. Factors that affect fixed costs of trade but have no impact on variable trade costs satisfy this exclusion restriction. For our estimation, we need a valid excluded variable that works in a panel setting. In an earlier study of trade flow for all products (Ergul and Esfahani, 2010), we find that Ongoing Hostility between an exporting and importing country serve such a purpose, affecting fixed costs, but not variable costs, both on theoretical and empirical grounds. In this study, we show that this variable plays a similar role in crude oil trade. As an additional support for our argument, we also present the results obtained by using an alternative and valid excluded variable, Contract Repudiation Index. The two methods yield very similar results. Moreover, we carry out the *chi*-squared test for overidentification and conclude that both excluded variables are uncorrelated with second stage residuals. [1]

We use the econometric estimation results to simulate a model of global oil trade and explore the outcome of possible scenarios of conflicts and a war-like situation which causes higher transportation costs for the oil exporters of Middle East. One of our experiments is increasing the hostilities between Iran and a group of countries which result in a change in trade

[1] We obtain 1.506 as our test statistic with a probability value of 0.22. So, we don't reject the hypothesis that both variables are uncorrelated with second stage residuals.

patterns of some of the countries in the group as they stop trading with Iran. A more radical one is putting an embargo against Iranian oil by the same group of countries, which has more severe impact on oil prices in the world. If Iran retaliates by blocking the oil routes around the Persian Gulf that would cause an increase in transportation costs of the oil export out of that region and the situation would deteriorate more. In each situation we try to identify the emerging trade patterns and the way the added conflicts affects the crude oil prices and oil expenditures of importing countries. Finally, we use our model to make projections for ten year ahead, from year 1997 to 2007, and compare our projections with the actual change in world crude oil prices in that time frame. The results confirm that our model is able to predict actual values quite well.

In section 3.2 we present a modified version of the HMR model, which we employ in our estimation. We then describe the data and discuss the regression results in sections 3.3 and 3.4, respectively. In section 3.5, we present our simulation experiments. Section 3.6 concludes the paper.

3.2 Description of the Model

For estimating the elasticities of oil trade, we rely on the HMR model. For our purposes, it is sufficient to describe the main equations determining trade probabilities and trade flows, adapted to a panel setting. HMR show that the probability of formation of a partnership between exporter j and importer i is related to

(1) $$z_{jit} = \gamma_0 - \varepsilon c_{jt} + (1-\varepsilon)(\tau_{jit} + a_L - p_{it}) + y_{it} - f_{jit} + u_{jit} \,,$$

where γ_0 is a constant and $u_{jit} \sim N(0, \sigma_u^2)$ is a random factor affecting the profits of exporting from j to i at time t. The other variables are defined as follows:

ε: the elasticity of substitution among oil varieties (oil from different sources),

c_{jt}: log of average unit cost of production of oil in country j at time t,

τ_{jit}: log of unit trade costs of exporting oil from j to i at time t,

a_L: productivity of the most efficient production station,

p_{it}: log of the average price of oil in country i at time t,

y_{it}: log of total expenditure on oil in country i at time t,

f_{jit}: log of the fixed costs of exporting oil from j to i at time t.

The fixed costs have a number of components. Specifically, $f_{jit} \equiv \kappa_x\varphi_{xjt} + \kappa_m\varphi_{mit} + \kappa\varphi_{jit} - v_{jit}$, where v_{jit} is a random factor distributed as $N(0, \sigma_v^2)$, κ's are parameters, φ_{mit} is a fixed trade barrier imposed by the oil importing country on all oil exporters at time t, φ_{xjt} is a measure of fixed export costs common across all export destinations at time t, and φ_{jit} is a measure of any additional country-pair specific fixed trade costs. These fixed cost components may be further decomposed into time-variant and time-invariant components.

Given the above specification, the composite random element in (1) will be $\eta_{jit} = v_{jit} + u_{jit}$, where $\eta_{jit} \sim N(0, \sigma_\eta^2)$ and $\sigma_\eta^2 = \sigma_u^2 + \sigma_v^2$. Using T_{jit} as a dichotomous indicator of trade, the probability that country j exports to country i at time t ($T_{jit} = 1$) can be expressed as:

$$(2)\quad Pr(T_{jit}=1|\ observables) = \Phi[\frac{1}{\sigma_\eta}(\gamma_0 - \varepsilon c_{jt} - (\varepsilon-1)(\tau_{jit} + a_L - p_{it}) + y_{it} - \kappa_x\varphi_{xjt} - \kappa_m\varphi_{mit} - \kappa\varphi_{jit})],$$

where Φ is cdf of unit-normal distribution.

The volume of exports from country j to country i when there is a partnership forms a gravity-type equation, which can be expressed in log-linear form as:

$$(3)\qquad x_{jit} = \beta_0 - (\varepsilon-1)c_{jt} + n_{jt} - (\varepsilon-1)(\tau_{jit} - p_{it}) + y_{it} + w_{jit} + u_{jit},$$

where β_0 is a constant, n_{jt} is the log of number of oil production stations in the exporting country, and w_{jit} is the heterogeneity factor of oil production stations that export from j to i. The key difference between this equation and the standard gravity model is the heterogeneity effect of oil production stations, w_{jit}. This term need not be symmetric with respect to the direction of trade. Its value is determined by the marginal profitability of exporting from j to i. Since the determinants of volume of trade are also related to marginal profitability, their coefficients are likely to be biased if w_{jit} is left out. Another source of bias is the selection problem due to higher values of u_{jit} among dyads that become trade partners, which causes a correlation between this term and the factors affecting profitability of trade included on the right-hand side of the equation (Heckman 1979).

HMR show that w_{jit} can be derived as a monotonic function of z_{jit}: When $z_{jit} > 0$, $w_{jit} = \ln[\exp(\delta z_{jit}) -1]$, where δ is a positive parameter. This relationship provides a means of estimating w_{jit} based on the estimate of z_{jit} from equation (2), $\hat{\bar{z}}^*_{jit}$. Equation (2) also offers a way of dealing with the selection bias caused by the fact that u_{jit} is truncated. Given the estimate of η_{jit} from (2), we have $E[u_{jit} \mid ., T_{jit} = 1] = \beta_{u\eta} \hat{\bar{\eta}}^*_{jit}$, where $\beta_{u\eta} \equiv$ corr $(u_{jit}, u_{jit})(\sigma_u/\sigma_\eta)$ and $\hat{\bar{\eta}}^*_{jit} = E[\eta_{jit}/\sigma_\eta| ., T_{jit} = 1]$. With these considerations in mind, the trade volume equation becomes:

(4) $$x_{jit} = \beta_0 - (\varepsilon - 1)c_{jt} + n_{jt} - (\varepsilon - 1)(\tau_{jit} - p_{it}) + y_{it} + \ln[\exp(\delta\, \hat{\bar{z}}^*_{jit}) - 1] + \beta_{u\eta} \hat{\bar{\eta}}^*_{jit} + e_{jit},$$

where e_{jit} is i.i.d. Note that the term containing $\hat{\bar{z}}^*_{jit}$ is nonlinear, which complicates the estimation procedure a bit. To facilitate estimation, HMR use a Taylor expansion of the nonlinear term and find that the results are largely unaffected. We follow their procedure and replace the nonlinear term with a quadratic polynomial of $\hat{\bar{z}}^*_{jit}$.

The crucial issue in the estimation of the system of equations (2) and (4) is that except the fixed-cost factors, all the variables determining $\hat{\bar{z}}^*_{jit}$ and $\hat{\bar{\eta}}^*_{jit}$ are included on the right-hand side of (4). As a result, finding variables that represent only the fixed costs and, thus, can be excluded from (4) is crucial in making it possible to identify the heterogeneity and selection effects in the trade volume equation. In the next section, we discuss this choice along with the description of our data.

3.3 Data

The dataset that we use is an unbalanced panel that covers 26,082 directed dyads involving 162 countries during 1980-2000. However, due to missing data points, we end up with a total of 278,761 observations that have complete information, amounting to an average of about 11 years of data per directed dyad. Since about 37 percent of the countries in our dataset do not export any oil, we end up with 175,206 observations that can be used in estimations. The data sources and the variables used in our empirical analysis are described in Table 3.4.

In our regressions, we include the log of oil production (in US dollars) for exporting countries to account for the number of production units and their average productivity, serving as a proxy for $n_{jt} - (\varepsilon - 1)c_{jt}$. We also include the log of oil expenditure (in US dollars) for importing countries as a measure of y_{it}. Since there may be concerns about endogeneity of these variables, we use their lagged values as instruments. As indicators of trade costs, τ_{jit}, we use Distance, Contiguity, shared Legal system, Colonial ties, shared Religions, shared dominant Language, and Ongoing Hostility. Since the contemporaneous value of Ongoing Hostility may be affected by the trade relations, we use its lagged value as an explanatory variable. Following HMR, we also include indicators showing whether or not both countries are Landlocked or Islands.[2] We employ *time* fixed effects to take account of global shocks and exporter and importer fixed effects to account for the time invariant unobserved country characteristics.

In order to take account of the selection and heterogeneity effects, we use Ongoing Hostility between a dyad as the excluded variable. High levels of hostility between two countries certainly discourage trade between them. However, once the countries overcome their hostility barrier and begin to trade, the level of hostility may not have a major effect on the volume of trade. We have found empirical support for this claim in our study of aggregate trade partnerships and flows (Ergul and Esfahani, 2010). Our estimation results here for the oil market again confirm that Ongoing Hostility significantly and negatively affects the probability of partnership formation in oil trade, but once a partnership forms, the role of hostility proves insignificant in determining the volume of trade. We repeat this estimation with an alternative excluded variable, Contract Repudiation Index, which should theoretically be a valid one, as we argue and empirically support it in Ergul and Esfahani (2010). This index is constructed by Stephen Knack and Philip Keefer (1995), using International Country Risk Guide (ICRG) dataset of the Political Risk Services, Inc., defined as an indicator that "addresses the possibility that foreign businesses, contractors, and consultants face the risk of a modification in a contract taking the form of a repudiation, postponement, or scaling down due to an income drop, budget cutbacks, indigenization pressure, a change in government, or a change in government economic and social priorities." Such risks, and the efforts to overcome them, should have a major effect on the fixed costs of setting up production and arranging exports, but not necessarily the variable costs. Since Contract Repudiation is country specific, rather being dyad specific, we include the indicators for the exporter and importer separately in the equation. These could be viewed as representing φ_{xjt} and φ_{mit}. We also interact these two variables for each dyad to form a proxy for φ_{jit}, the same way that HMR handle the Regulation Cost indicators. To the extent that these

[2] We also experimented with many other variables that are commonly employed as determinants of trade costs in gravity models (e.g., such as common membership in a free trade area, currency union, or the GATT/WTO). These variables did not prove significant in our regressions.

variables affect only the fixed cost of trade, they should appear with significant negative coefficients in equation (2), but not in equation (4). It is, of course, possible that they may have significant coefficients in the gravity equation as well, or prove insignificant in both or have the wrong signs. These are issues that ultimately need to be settled empirically.

For estimation with Contract Repudiation, the total number of observations drops to 105,932 due to limited availability of ICRG data, which only covers 15,500 directed dyads involving 125 countries during 1982-1997.

3.4 Estimation Results

We start with the regressions that use the Contract Repudiation indices for the exporter and the importer as potential excluded variables (see Table 3.5). The first column shows the estimates for the probability of trade equation. The second column is the benchmark estimate for the trade volume equation, without controls for selection and heterogeneity. The third column is the estimate of the polynomial version of equation (4). First, note that the importer Contract Repudiation is a significant variable in determining the probability of trade, but is not significantly associated with the volume of trade shown in column 2. This indicates that the importer Contract Repudiation tends to impose a fixed cost on selling oil in a country, but once the importer overcomes the hurdle, that institutional weakness has little tangible effect on the marginal cost of imports. As a result, this variable can serve as an excluded variable with reasonable theoretical and empirical backing. The exporter Contract Repudiation turns out to be insignificant in all regressions. This is in contrast with our finding in Ergul and Esfahani (2010) regarding the role of this variable in aggregate trade. This contrasting outcome in the case of oil trade seems sensible because oil exporting firms are typically owned by governments that internalize the costs of contract repudiation and try to mitigate its impact on their oil exports. In contrast, the import side is dominated by foreign or private domestic companies that face fixed costs affected by reliability problems at wholesale or distribution outlets.

Next, note that all three regressions yield significant coefficient estimate for most variables with reasonable signs. Oil production of the exporting country, oil expenditure of the importing country, Distance between the two countries, Common Religion, Legal System, and Colonial Ties are significant at reasonable levels with expected signs and magnitudes compared to other gravity studies. Furthermore, the selection and heterogeneity terms all display high levels of significance. These estimates show that the regressions are meaningful and can produce useful results.

A particularly notable result in Table 3.5 is that Ongoing Hostility within the dyad is significant in the trade partnership equation with expected signs, but proves insignificant in the benchmark equation and remains so when we control for biases using importer Contract Repudiation as the excluded variable. This result conform with Morrow's (1999) conclusion that the probability of conflict may impose a fixed costs on trade within the dyad, but once that cost is paid, there is not any additional cost of conflict affecting the volume of trade. These observations suggest that Ongoing Hostility may serve as an alternative excluded variables. Table 3.6 shows the results of pursuing this idea.

Using Ongoing Hostility alone as a determinant of fixed cost of trade and the excluded variable in the trade volume equation allows us to work with approximately 75 percent more observations (see Table 3.6). The coefficients are similar to those obtained in Table 3.5, but they are estimated more accurately. Therefore, in the rest of this paper we will focus on these results and discuss their implications.

The elasticity of trade volume with respect to production is marginally smaller than one, indicating that a large part of increased production gets exported to existing customers, with a smaller part being either exported to new customers or consumed domestically. The domestic use of the additional production may be because of increased consumption induced by higher incomes from oil. Expenditure elasticity in importing countries is more visibly less than one, suggesting that importers try to diversify their sources and possibly raise domestic production as their consumption rises. These elasticity estimates are very close to income elasticity estimates 0.8-0.9 of Rose (2000 and 2004) using product of two trading partners' GDP's. Our results are also in the range of estimates of Feenstra, Markusen and Rose (2001). Their income elasticity estimate for exporting country is in the range of 0.44-1.15 and 0.62-0.86 for importing country depending on whether the good is differentiated or homogenous.

The absolute value of the elasticity of trade with respect to distance turns out to be somewhat greater than one. This is again quite close to Rose's (2000 and 2004) estimates for the distance elasticity of aggregate trade, which is in the range of -1.09 to -1.31. Similarly, Glick and Taylor (2010) obtain -1.2. HMR find a lower elasticity, -0.847, after correcting for selection and heterogeneity biases. Comparing this result with our estimate for oil trade, we conclude that Distance may be playing a relatively more important role in the oil market than in the typical traded product. This highlights the important role of distance and helps explain why most countries tend to buy oil from nearby sources.

We also compare our results to Helmers and Pasteels (2005) since they estimate a gravity model with disaggregated trade flows one of which is petroleum industry. Their right hand side variables include neither production and expenditure nor controls for income of trading partners. Instead they use exporting and importing country fixed effects and with cross section data fixed effects absorb the effect of those variables. Their distance coefficient turns out to be very close to ours. But they find significant effect of conflict on trade levels.

Nugent and Yousef (2005) disaggregate data into energy (oil-gas) and non-energy sub-groups. Their distance elasticity of oil and gas flows is at odds with existing literature. It display high significance but with a positive coefficient, which is found to be 2.01. They add squared distance to their estimates which is negative, significant and quite small, -0.097. Their income elasticity estimates using product of two trading partners' GDP's ranges between 0.337-0.454. Similar to our results, Common Language is insignificant and Colonial Ties is significant in explaining oil and gas trade though with a much greater coefficient estimate than ours and the existing literature.

One important question regarding the results is the magnitude and direction of bias due to selection and heterogeneity effects. Table 3.7 presents the results of introducing the variables representing the two effects separately, along with the benchmark and full model estimates. Note that in the absence of any type of bias correction, the estimated coefficients of oil production, oil expenditure and distance are 0.697, 0.560 and –1.066, respectively. They go down sharply when only heterogeneity bias is corrected, and they go up sharply when only the selection bias is corrected. When both corrections are made, the estimated coefficients end up at 0.902, 0.834, and –1.244 respectively. A similar pattern can be seen in the coefficients of other significant variables. These observations suggest that in the absence of corrections, selection causes a downward bias and heterogeneity causes an upward bias in the coefficients.

The direction of the selection bias is easy to understand: Many unobserved factors that make it more profitable for trade partnerships to form help add some observations to the trade volume sample that would not otherwise be present based on their observed characteristics. As a result, the effects of the observed characteristics appear as weaker than they actually are; i.e., their coefficient estimates are downward biased. In the case of oil trade such biases seem to be quite strong for most of the variables included in the regression (compare the first and last columns of Table 3.7). To understand the role of heterogeneity in biasing the standard gravity regressions, note that when the productivities of oil production stations are very diverse, it is more likely that there are some with export potential. Such units will have lower marginal cost of production and, therefore, are likely to export large amounts as trade costs decline. Without appropriate controls for heterogeneity, the entire response of trade may be attributed to factors included in the regression, thus over-estimating their impact on trade. This can account for the sharp drop in elasticities when we control for heterogeneity. Our results show that both biases are large. However, the overall downward bias indicates that the selection bias strongly dominates the heterogeneity effect of oil production stations.

3.5 Simulations

3.5.1 The Setup

In order to assess the performance of our model and to demonstrate the usefulness of the results, we carry out a number of simulations by placing the estimated equations in a global equilibrium context. We use our empirical results and HMR's theoretical model to calculate probabilities of trade partnership, trade volumes, prices, and production and consumption levels for all dyads with available data. For our base period, we focus on the average of the data over the 1995-1997 period. We allow the average cost of oil production in a country, c_{jt}, to adjust and shifts its export prices up and down to equilibrate total demand for the country's oil with its production. This is done by adjusting the exporter fixed effects. The aggregate effect of price increases for oil from different sources (derived from a Dixit-Stigliz model of differentiated products) can then be turned into an adjustment term in the importer fixed effect in the probability of trade equation, $-(1-\varepsilon)p_{it}/\sigma_\eta$. We assume that the elasticity of substitution among oil varieties is high and set $\varepsilon = 11$, which is in range often found in the study of substitution elasticities among varieties of the same product. (The results are not very sensitive to changes in ε within a reasonable range around this value.) As an estimate of σ_η, we use the inverse of the coefficient of log of expenditure in the Probit regression, $\sigma_\eta = 1/0.0838$.

Building a simulation model based on the regression results poses a number of additional challenges and requires important assumptions and modeling choices. The first problem to address is the calculation of own use of oil for oil-producing countries. The estimation results provide us with trade relationships, but not with own use of oil. We assume that own use is basically trade with the country itself and form the bilateral coefficients and measure trade volume accordingly. However, own trade may entail effects not captured in bilateral trade models. For this purpose, we calculate own-use fixed effects as an adjustment to the price for domestic use such that for each oil producer, the volume of internal trade derived from the model becomes equal to the actual use in the base period.

The second challenge is to deal with the missing values. There is inadequate data for 37 out of 162 countries. Fortunately, these are all relatively small countries with very small potential production or consumption compared to the rest of the world. For the remaining 125, there are some missing expenditure and fixed effect data. In particular, we do not obtain importer fixed effects for oil exporters that do not import from any other country. Since it is theoretically possible that these countries may start importing from other countries under some scenarios, we need their importer fixed effects for the simulation exercise. We address this problem by regressing the available fixed effects on country characteristics such as GDP, population, and oil exports and use the results to predict fixed effects for the cases with missing data. The total number of such cases is less than 10 percent of importer and exporters, the most important ones being transition countries that export oil, but have limited data for estimation, especially before 1995. Excluding such countries from the simulation exercises does not change the main results. But, we decided to include them to ensure that the exercises are more comprehensive.

Another aspect of missing data challenge is that production and uses do not balance for many countries because of their dealings with the countries left out of the simulation exercise. We address this problem by taking the shares of all such transactions as given. So, the equilibrium of the exercises is derived with the remaining shares of production and expenditure being balanced through price adjustments.

The fourth challenge is modeling overall supply and demand elasticity for each country. We assume that the aggregate expenditure is a constant elasticity function of the aggregate price of imports and own oil in each country. We obtain short and long run elasticities of oil demand from Cooper (2003) and Altinay (2007) for 24 developed countries. For the rest, we use Krichene's (2005) estimated price elasticity of demand for the world, which equals -0.06 in the short run and -0.26 in the long run. [3] We follow a different procedure for obtaining supply elasticity. We could not find supply elasticity estimates for individual countries. However, Krichene (2002) offers a long run price elasticity of 0.10 for the supply of crude oil in the world, with the short sun elasticity being negative, though small and statistically not different from zero. We augment this result by using the estimate of the heterogeneity factors for each supplier, w_{jit}, as a relative supply elasticity indicator. We scale these indicators such that the weighted supply elasticity of world production of oil equals 0.1 in the long run. The weights that we use are the shares of directed dyad exports in total world exports. For the short run, we assume that supply elasticity is 0 for all oil producers. We should add that these estimates are quite imprecise and seem to be only marginally different from zero.

The fifth challenge is to translate the simulated partnership probabilities into an actual trade/no-trade outcome. For this purpose, once we calculate the probabilities of trade between directed dyads from equation (2) given the dyad's characteristics, we employ the following rule for determining the existence of trade, indicated by T_{ji}, which equals 1 in case of trade in the directed dyad *ji* and equals 0 in the absence of trade. We first check whether T_{ji} is equal to 1 or 0 originally in actual data. If initially $T_{ji} = 1$ and the updated probability of trade is greater than or equal to 0.5, then the updated T_{ji} is set to 1, otherwise $T_{ji} = 0$ if the probability of trade drops by more than a tolerance level, *t*. When the initially $T_{ji} = 0$, we set the updated $T_{ji} = 0$ as long as the updated probability derived from the model is less than or equal to 0.5, otherwise we set the updated $T_{ji} = 1$ if the probability has risen by more than *t*. The role of *t* is to deal with unobserved factors that create partnerships or prevent a dyad from trading. A higher *t* means that trade partnerships do not form or fall apart with small changes in our measured probability of trade. Lower values of *t* discount the role of factors that may account for persistence in trade partnerships or lack thereof, but are not captured in our model. For our experiments, we set $t = 0.1$, but our sensitivity analysis suggests that higher values of *t* do not change the results much.

[3] These estimates are obtained with cointegration method. For the same time period, when they use vector error correction method they obtain -0.12 for the long run price elasticity and -0.01 for the short run price elasticity of demand.

However, lower values of *t* do cause shifts in trade patterns, though still with limited impact on aggregate price changes.

Our final challenge is to deal possible multiplicity or non-existence of equilibria. This is a problem in our model because in the absence of exports from country *j* to country *i*, the price in *j* may drop and the price in *i* may rise so much that makes trade between them profitable, while in the presence of trade prices become such that the trade probability equation negates such trade. Such fluctuations also affect aggregate prices and each country's choices regarding their other partners, potentially giving rise to multiple equilibria and non-existence. Such situations are uncommon, but there are few dyads in some simulations that display such problems and prevent the convergence of our numerical solution algorithm. We address this concern by assuming that if, after for allowing for the tolerance level, a dyad finds it profitable to trade in the absence of initial trade, it will choose to trade even if profitability of trade may come into question once prices change as a result of trade.

3.5.2 Oil Prices and Economic Growth

Our first experiment with the model is to see if it can reproduce the fast growth of international oil prices during 1997-2007, when the average price of crude oil increased from $19 per barrel in 1997 to $72 in 2007, or given the 30 percent CPI rise during the same period, a real increase of 190 percent in ten years. We focus the decade before 2008 to avoid complications that the crisis of 2008-2009 may have introduced, when the price of oil first rose sharply and then dropped precipitously. We calculate the oil expenditure increase of each country by using its GDP growth rates given in World Development Indicators of World Bank and multiplying it by the income elasticities of oil use estimated by Gately and Huntington (2002). The first row of Table 3.8 shows the result of the simulation for four different combinations of demand and supply elasticities. It is clear from the table that if we take the long run elasticities, the sharp rise in oil prices cannot be explained by the demand and supply changes in world markets. However, if the actual elasticities are closer to their short run estimates then the model produces average world prices for oil close to the actual outcome. The role that demand price elasticity plays in this outcome is particularly important in this. Given the imprecise estimation of long run price elasticities, it is possible that indeed the elasticities over the decade are closer to the short run ones and the model can account for a good part of the rise in prices during the decade. [4]

The rise in oil prices is often attributed to the increase in the demand from two fast growth giant economies, China and India. We explore this issue by recalculating the equilibrium under different elasticity estimates, lowering the growth rates of these two countries by half. The second row of Table 3.8 shows these results, which indicate that about one fifth of the growth induced rise in oil prices could be attributed to the fast growth of these two economies. By way of comparison, we carry out two similar simulations, separately cutting the growth rates of OECD and transition countries in half. The first experiment, reported in the third row of Table 3.8, shows that the fast growth in transition countries accounts for a part of world oil price increase that is very similar to the one caused by China and India. The second experiment reported in the last row of Table 3.8 points to the fact that fast growth in OECD countries may have been a more significant contributory factor, accounting for about one fourth of the growth-induced oil price rise between 1997 and 2007.

3.5.3 The Impact of International Conflict: Confrontation between Iran and the West

We now use our model to examine the consequences of one of the most important conflicts of recent years, the confrontation between Iran and Western countries, which is closely related to the decision of Iranian government to pursue uranium enrichment. International community has a serious concern over Iran's disputed nuclear program because it can be used to make nuclear weapons. United States and Western countries have been constantly pressuring the United Nations to put sanctions on Iran. We examine the consequences of possible actions that might be taken against Iran and possible retaliation by Iran, such as reducing its oil supply or creating a war-like situation around the Persian Gulf, which could result in higher transportation costs for the oil-exporting countries of the region. Since Iran’s role in oil market is non-negligible, one might expect non-trivial changes in world oil price and oil trade partnerships following these actions.

Our first experiment is to increase the Ongoing Hostility between Iran and a group of countries.[5] We then recalculate the probabilities of trade and find out whether higher hostilities

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[4] Krichene (2002) estimates the long run price elasticity of crude oil as -0.0005 for 1973-1999.

change the oil trade partnership structure in the world. We also compare the initial and posterior share of purchases of this group of countries with Iran. Our results are presented in Table 3.9. According to our results, twelve countries stop trading with Iran due to high hostility, and eight countries keep trading. Moreover, the share of Iranian oil in the purchases of those who did not stop trading with Iran drop only trivially. This result again confirms that hostility is not significant in explaining the amount of trade once there is an existing trade partnership.

We are also interested in learning the impact of higher hostility levels with Iran on the other oil exporters. Does it create more opportunities for them to sell their oil? How much more would they expect to sell? In order to understand the consequences further, we list the top oil supplier of each country in the hostile group and then compare their initial and posterior share. We also identify the oil exporting country that faces the biggest change in the share of the hostile countries' oil exports. We present our results in Table 3.10. The trading partners of twelve countries which stop trading with Iran observe a much higher demand for their oil. The average increase of the purchases of hostile countries from their top supplier is about 7 percent. Not surprisingly, the countries that keep trading with Iran, despite the hostility, increase their purchases from their top oil suppliers very modestly. The oil exporting country that has the biggest change in share is Iran when a hostile country stops trading. Higher hostility with Iran hit the Bulgaria the most since Iran is its top supplier of oil; 41 percent of its oil purchases comes from Iran. Finally, Iran observes a slight increase in the share of hostile countries who continue to trade (see Table 3.11).

Next we work on a situation resulted from a more radical decision taken by the group of countries we listed above. Suppose that they decide to put an embargo on Iranian oil. So, the probability of trade between a dyad will not be determined endogenously in the model unlike the hostility experiment, but is set equal to zero for Iran and the group of countries that decide to put an embargo to Iranian oil. In this scenario the outcome is more severe and the world weighted average of buyer price goes up by 1.76 percent and the world weighted average of seller price goes down by 0.91 percent. It has also considerable effect on Iran as its supplier price drops

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[5] Canada, USA, Israel, Japan, Cyprus, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, UK, Austria, Finland, Iceland, Norway, Sweden, Switzerland, Gibraltar, Malta, Albania, Bulgaria, Belarus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation, Ukraine, Bosnia & Herzegovina, Croatia, Slovenia, TFYR Macedonia, Yugoslavia, Australia, New Zealand.

sharply by 23 percent. Because of the embargo if the production of Iran drops by 20 percent then the increase on average buyer price would be 4.61 percent and each additional 20 percent drop in supply would further increase the world weighted average of buyer price by 1.6 - 2.4 percent. On the other hand, the impact on the world weighted average of seller price would be higher; each extra 20 percent cut in Iranian supply would increase the seller price by 1.9 - 2.4 percent (see Table 3.12).

The impact of embargo on Iranian oil on the trade relationship with other oil exporters is summarized in Table 3.13. Since embargo dictates all countries in the hostile group to stop trading with Iran the impact is bigger compared to previous experiment. All countries previously trading with Iran, except Canada, start buying from their top suppliers about 2 to 10 percent more.

Suppose that Iran retaliate by sinking the oil tankers and blocking the Strait of Hormuz to disrupt oil delivery. This would turn into higher transportation costs for the oil exporting countries located in Persian Gulf region, Saudi Arabia, Iraq, United Arab Emirates, Kuwait, Bahrain, and Qatar, the major oil producers of Middle East. If the current routes become insecure those countries would have to divert oil to Red Sea to safely transfer the oil. In order to simulate this situation we hypothetically increase the actual distance from these oil exporting countries to all possible destination countries by 50 percent. The trade partnership structure and import prices change dramatically. The increase in world weighted average of buyer price would be 8.91 percent after the retaliation of Iran. The hostile group of countries would experience 4 to 10 percent increase in their import prices, and Asian countries about 7 to 9 percent.

3.6 Conclusion

In this paper, we have estimated a model of bilateral oil trade, controlling for the role of selection in partnership formation and source heterogeneity in the flow of oil among countries. The model displays a good fit and offers important insights into the working of the global oil market. The results show that ignoring these controls introduces significant biases in the estimation of the elasticities of oil trade with respect to its determinants.

We use the model to carry out a series of global equilibrium simulation exercises to demonstrate the usefulness of the model. In particular, we show that for the rise in oil prices during 1997-2007 to have been caused by economic growth around the world, the demand and supply price elasticities must have been closer to their short run estimates found in the literature. Moreover, relatively high growth in OECD countries followed by rapid growth in transition countries and India and China account for the bulk of the rise in global oil prices. We also show that the model can be used to explore various scenarios of oil price responses to international security issues, especially the conflicts of Iran with the West.

3.7. Tables and Figures

Table 3.1 List of the World's Giant Oilfields

Country	Field Name	Date Of Discovery	2000 Production ('000/Day)
Saudi Arabia	Ghawar	1948	4,500[1]
Mexico	Cantarell	1976	1,211
Kuwait	Burgan	1938	1,200[1]
China	Daquig	1959	1,108
Iraq	Kirkuk	1927	900
Iraq	Rumailia North	1958	700[1]
Saudi Arabia	Abqaiq	1940	600[1]
Saudi Arabia	Shayba	1975[1]	600[1]
U.S.A.	Prudhoe Bay	1968	550
China	Shengli	1962	547
Brazil	Marlim	1985	530[1]
Iraq	Rumailia South	1953	500[1]
Saudi Arabia	Safaniyah	1951	500[1]
Saudi Arabia	Zuluf	1965	500[1]
Abu Dhabi	Bu Hasa	1962	450[1]
Abu Dhabi	Zakum – Lower	1963	400[1]
Abu Dhabi	Zakum – Upper	1963	400[1]
Saudi Arabia	Berri	1964	400[1]
Russia	Samotlor	1961	320[1]
Norway	Ekofisk	1971	310
Columbia	Cusiana	1988	300[1]
Iran	Gachsaran	1937	300[1]
Iran	Ahwaz Bangestan	1958	300[1]
Neutral Zone	Khafji	1961	300[1]
Russia	Romashkino	1948	300[1]
Venezuela	Cabimas	1917	300[1]
China	Liaohe	1964	291
Qatar	Dukhan	1940	282
Abu Dhabi	Bab	1958	260[1]
Norway	Troll (I & II)	1979	260
Venezuela	Bachaquero	1930	260[1]
Mexico	Ku	1979	255
Malaysia	Tapis	1975	250[1]
Saudi Arabia	Marjan	1967	250[1]
Norway	Snorre	1979	240
Abu Dhabi	Asab	1965	230
U.S.A.	Kuparuk River	1969	220
Norway	Draugen	1984	215
Khazakastan	Tengiz	1979	214
India	Bombay High	1974	210
Abu Dhabi	Umm-Shaif	1958	210[1]
Norway	Oseberg	1979	205
Brazil	Roncador	1996	200[1]
Indonesia	Duri	1941	200[1]
Indonesia	Minas	1944	200[1]
Iran	Agha Jari	1936	200[1]
Iran	Marun	1963	200[1]
Iraq	Bai Hassan	1953	200[1]
Kuwait	Raudhatain	1955	200[1]
Libya	Sarir	1961	200[1]
Russia	Tevlin-Russkin	1971[1]	200[1]
Russia	Vatyegan	1970[1]	200[1]
Venezuela	Lagunillas	1925	200[1]
Venezuela	Santa Barbara	1941	200[1]
Venezuela	Mulata	1942	200[1]
Mexico	Caan	1985	185
Norway	Gullfaks	1978	185
Algeria	Hassi Messaud - South	1956	182
China	Xinjiang	1993[1]	181

[1] Estimate.

Table 3.1 (cont.)

Country	Field Name	Date Of Discovery	2000 Production (000/Day)
Egypt	Belayim	1953	181
Iran	Karanj	1961	180[1]
Norway	Statfjord	1974	175
Norway	Heidrun	1985	170
Brazil	Albacora	1986	160[1]
Russia	Lyantor	1966[1]	160[1]
Yemen	Camaal	1991	160[1]
Dubai	Fatih	1966	150
Iran	Salman	1964	150[1]
Iraq	Al-Zubair	1938	150[1]
Kuwait	Sabriya	1957	150[1]
Malaysia	Guntong	1978	150[1]
Norway	Norne	1992	150
Russia	Fedorov	1971[1]	150[1]
U.S.A.	Ursa	1991	150
Yemen	Alif	1984	149
Algeria	Hassi Messaud - North	1956	148
Mexico	Chuc	1985	146
Iraq	West Qurna	1974	140[1]
U.S.A.	Mars	1989	140
Equatorial Guinea	Zafiro	1995	135
Libya	El Shaharal	1988	135
Angola	Takula	1971	131
Canada	Hibernia	1978	130
Iran	Doroud	1961	130[1]
Iran	Faroozan	1966	130[1]
Mexico	Abkatun	1978	126[1]
Russia	Mamontov	1965[1]	125[1]
Iran	Bibi Hakimeh	1961	120[1]
Venezuela	Petrozuata	1991	120
Oman	Nimr	1980	111
Azerbaijan	Chiraq	1990[1]	110[1]
Oman	Yibal	1963	110
Libya	Bu Attifel	1968	108
Qatar	Al-Shaheen	1994	107
Venezuela	Cerro Negro	1980	105
Mexico	Pol	1979	104
Qatar	Idd Ed Shardi	1960	104
Angola	Chinkuito	1998	100
Denmark	Dan	1983	100
Egypt	October	1978	100[1]
Iran	Mansuri	1963	100[1]
Libya	Defa-waha	1959	100[1]
Libya	Nasser	1959	100[1]
Libya	Gialo	1961	100[1]
Libya	Messia	1971	100[1]
Russia	Urdaneta Oest	1955	100[1]
Russia	Sutormin	1975[1]	100[1]
Russia	Povkhov	1975	100[1]
U.S.A.	Kern River	1899	100[1]
U.S.A.	Belridge South	1911	100[1]
U.S.A.	Midway-Sunset	1884	100[1]
U.S.A.	Auger	1996	100
U.S.A.	Alpine	1999	100
Venezuela	Tia Juana	1926	100[1]
Venezuela	Lamar	1958	100[1]
Venezuela	El Furrial	1986	100[1]
Total Production			32,361

[1] Estimate.

Table 3.2 Oil Well Productivity and Number of Oil Wells in Oil Producing Countries

Country	Oil Well Productivity (barrel/well/day)	Number of Oil Wells	Oil Exports (US $)	Oil Production (barrel/day)
Australia	447	1417	1366979	633000
Austria	19	950	10124.5	18400
Azerbaijan	143	2102	4822	300000
Canada	41	54061	7419122	2216501
China	47	72255	2865583	3400000
Crotia	29	723	34374	21000
Denmark	1714	213	839095.7	365000
France	57	463	8452	26200
Georgia	7	281	15434	2000
Germany	72	991	195996.3	71700
Greece	320	10	70477	3200
Hungary	23	944	4456	21700
India	201	3300	8492	663000
Indonesia	134	8373	5639051	1120000
Iran	3080	1120	1.52E+07	3450000
Iraq	1205	1685	1563402	2030000
Israel	14	7	3809.667	100
Italy	418	208	90288.66	87000
Japan	76	157	11835	12000
Kazakhstan	69	11676	1445372	800000
Kuwait	2025	790	8184348	1600000
Malaysia	964	788	2702659	760000
Netherlands	207	203	3550546	42000
New Zealand	466	73	190953	34000
Norway	3782	833	1.99E+07	3150000

Table 3.2 (cont.)

Country	Oil Well Productivity (barrel/well/day)	Number of Oil Wells	Oil Exports (US $)	Oil Production (barrel/day)
Pakistan	240	250	46654	60000
Papua New Guinea	1179	39	670643	46000
Phillippines	1750	8	11205	14000
Poland	12	1404	926	16500
Romania	20	6000	7	118000
Russia	179	41192	1.72E+07	7385000
Saudi Arabia	4730	1560	4.19E+07	7378800
Spain	310	21	4772	6500
Taiwan	11	73	95724	800
Thailand	174	749	151376.3	130000
Turkey	56	846	70897	47000
Turkmenistan	73	2460	14575	180000
UK	1622	1387	1.03E+07	2250000
Ukraine	58	1353	51244.33	78000
U.S.	11	521070	479276.7	5731770
Uzbekistan	68	2190	6746.333	150000
Venezuela	157	15395	1.14E+07	2417015

Source: Oil & Gas Journal, 2010.

Table 3.3 Estimates of Oil Exports with Oil Production and Oil Well Productivity by OLS †

Dependent Variable:	**Oil Exports**		
Oil Production	2.198** *(0.316)*	3.26** *(0.399)*	
Oil Well Productivity	3800** *(560.736)*		5739** *(718.946)*
Observations	42	42	42
R^2	0.82	0.63	0.61

† The numbers in parentheses are standard errors.
+ 10% significance level
* 5% significance level
** 1% significance level

Table 3.4 Variable Descriptions and Data Sources

Name	Description	Source
Trade $_{jit}$	Logarithm of crude oil exports from country *j* to country *i* at time *t* (SITC4 level, code 3330) in thousands of constant 2000 US dollars.	Robert Feenstra, "“World Trade Flows (WTO), 1962–2000." www.internationaldata.org
Oil Production $_{jt}$	Logarithm of crude oil production in exporting country *j* at time *t* in thousands of constant 2000 US dollars.	Energy Information Administration (EIA) & International Energy Agency (IEA)
Oil Expenditure $_{it}$	Logarithm of crude oil expenditure in importing country *i* at time *t* in thousands of constant 2000 US dollars.	EIA, IEA and WTO
Distance$_{ji}$	Logarithm of the great circle distance (in km) between exporter's *j* and importer's *i* capitals	Centre D'Etudes Prospectives et D'Informations Internationales (CEPII) http://www.cepii.fr/anglaisgraph/cepii/cepii.htm
Colonial$_{ji}$	A binary variable that is unity if exporting country *j* ever colonized importing country *i* or vice versa.	
Land Border$_{ji}$	A binary variable that is unity if exporter *j* and importer *i* share a common land border	
Contiguity$_{ji}$	Dichotomous indicator that shows direct contiguity of exporter *j* and importer *i* (1 = Land Border, 2 = 1-12 miles water, 3 = 13-24, 4= 25-150 , 5 = 151-400, 6= not)	Correlates of War Database http://www.correlatesofwar.org/
Island$_{ji}$	A binary variable that is unity if both exporter *j* and importer *i* are islands	CIA The World Factbook
Landlocked$_{ji}$	A binary variable that is unity if both exporting country *j* and importing country *i* have no direct access to sea	CIA The World Factbook
Legal$_{ji}$	A binary variable that is unity if the exporting country *j* and importing country *i* share the same legal origin.	Easterly & Yu
Language$_{ji}$	A binary variable that is unity if the exporting country *j* and importing country *i* uses a common language	CIA The World Factbook
Religion$_{ji}$	(% Protestants in country *j* × % Protestants in country *i*) + (% Catholics in country *j* × %Catholics in country *i*) + (% Muslims in country *j* × %Muslims in country *i*)	Encyclopedia Britannica Book of the Year 2001
Ongoing Hostility$_{jit}$	Dichotomous indicator of ongoing hostility between exporting country *j* and the importing country *i* .	Correlates of War Database http://www.correlatesofwar.org/
Risk of Contract Repudiation$_{jt}$	A binary variable that takes the value one if contract repudiation in country *j* is less than the median score of all countries, zero otherwise. This variable is constructed separately for both exporting country *j* and the importing country *i* . If the score of a country is less than the median it has a higher risk for repudiation of contracts.	Political Risk Services, Inc., ICGR Dataset
GDP$_{jt}$	Logarithm of Gross Domestic Product in thousands of constant 2000 US dollars.	World Bank, World Development Indicators www.worldbank.org/data

Table 3.5 Estimates of the Oil Trade Equations Using Contract Repudiation as Excluded Variable[†]

Pooled Panel of Directed Dyads with Instrumental Variables for Production and Expenditure, 1982-1997

Dependent Variable:	**Trade Dummy, T_{ij}**	**Log of Exports of j to i, x_{ji}**	
Model:	**Probit**[‡]	**Benchmark IVREG**	**Polynomial IVREG**
Log of Oil Production by Exporter, Lagged	0.139** *(0.0230)*	0.645** *(0.129)*	0.823** *(0.226)*
Log of Oil Expenditure by Importer, Lagged	0.0529** *(0.0111)*	0.522** *(0.146)*	0.766** *(0.171)*
Log of Distance	-1.078** *(0.0445)*	-1.020** *(0.101)*	-1.168** *(0.327)*
Contiguity	0.108** *(0.0238)*	0.0981* *(0.0484)*	0.121* *(0.0521)*
Island	-0.251 *(0.208)*	-0.533 *(0.531)*	-0.572 *(0.535)*
Landlocked	0.457 *(0.315)*	0.775 *(0.601)*	1.266* *(0.602)*
Legal	0.229** *(0.0518)*	0.305** *(0.106)*	0.321* *(0.126)*
Language	-0.0312 *(0.0753)*	-0.150 *(0.138)*	-0.0926 *(0.136)*
Colonial Ties	0.340** *(0.127)*	0.432+ *(0.230)*	0.428+ *(0.249)*
Religion	0.267* *(0.123)*	0.318 *(0.249)*	0.611* *(0.273)*
Ongoing Hostility, Lagged	-0.958** *(0.210)*	0.782 (2.809)	-0.301 (0.329)
Exporter Risk of Contract Repudiation	0.0101 *(0.0272)*	-0.0145 *(0.0483)*	0.0266 *(0.0506)*
Importer Risk of Contract Repudiation	-0.0943* *(0.0385)*	-0.0431 *(0.0820)*	
$\hat{\eta}^*_{ij}$			1.210** (0.374)
$\hat{z}^*_{ij}$			2.803** (0.855)
$\hat{z}^{*2}_{ij}$			-0.604* (0.244)
Observations	105932	7529	7529
R^2	.	0.551	0.560

[†] The numbers in parentheses are standard errors.
[‡] Marginal effects on probability of partnership at sample mean.
[+] 10% significance level
[*] 5% significance level
[**] 1% significance level

Table 3.6 Estimates of Oil Trade with Ongoing Hostility as Excluded Variable†

Pooled Panel of Directed Dyads with Instrumental Variables for Production and Expenditure, 1980-2000

Dependent Variable:	**Trade Dummy, T_{ij}**	**Log of Exports of *j* to *i*, x_{ji}**	
Model:	**Probit‡**	**Benchmark IVREG**	**Polynomial IVREG**
Log of Oil Production by Exporter, Lagged	0.159** *(0.0234)*	0.697** *(0.117)*	0.902** *(0.244)*
Log of Oil Expenditure by Importer, Lagged	0.0838** *(0.00936)*	0.560** *(0.106)*	0.834** *(0.191)*
Log of Distance	-0.970** *(0.0377)*	-1.066** *(0.0916)*	-1.244** *(0.374)*
Contiguity	0.0949** *(0.0210)*	0.117* *(0.0464)*	0.146** *(0.0553)*
Island	-0.231 *(0.176)*	-0.983+ *(0.513)*	-0.957+ *(0.527)*
Landlocked	0.502 *(0.307)*	0.210 *(0.750)*	0.802 *(0.769)*
Legal	0.220** *(0.0441)*	0.250** *(0.0969)*	0.278* *(0.129)*
Language	-0.0648 *(0.0632)*	-0.194 *(0.125)*	-0.153 *(0.124)*
Colonial Ties	0.397** *(0.111)*	0.475* *(0.211)*	0.481+ *(0.260)*
Religion	0.199+ *(0.105)*	0.453* *(0.225)*	0.768** *(0.245)*
Ongoing Hostility, Lagged	-0.683** *(0.156)*	0.0655 *(0.893)*	
$\hat{\bar{\eta}}^*_{ij}$			1.239** *(0.431)*
$\hat{\bar{z}}^*_{ij}$			2.852** *(0.958)*
$\hat{\bar{z}}^{*2}_{ij}$			-0.621* *(0.286)*
Observations	175206	10589	10589
R^2	.	0.546	0.552

† The numbers in parentheses are standard errors.
‡ Marginal effects on probability of partnership at sample mean.
+ 10% significance level
* 5% significance level
** 1% significance level

Table 3.7 Estimates of Oil Trade with Ongoing Hostility as Excluded Variable, 1980-2000†

Decomposition of Bias Effects

Dependent Variable:	**Log of Exports of *j* to *i*, x_{ji}**			
Model:	**Benchmark IVREG**	**Polynomial IVREG**	**Heterogeneity Correction IVREG**	**Selection Correction IVREG**
Log of Oil Production by Exporter, Lagged	0.697**	0.902**	0.453**	1.305**
	(0.117)	*(0.244)*	*(0.123)*	*(0.187)*
Log of Oil Expenditure by Importer, Lagged	0.560**	0.834**	0.431**	1.125**
	(0.106)	*(0.191)*	*(0.102)*	*(0.155)*
Log of Distance	-1.066**	-1.244**	-0.401**	-2.053**
	(0.0916)	*(0.374)*	*(0.135)*	*(0.211)*
Contiguity	0.117*	0.146**	0.0680	0.235**
	(0.0464)	*(0.0553)*	*(0.0465)*	*(0.0488)*
Island	-0.983+	-0.957+	-0.840	-1.162*
	(0.513)	*(0.527)*	*(0.514)*	*(0.531)*
Landlocked	0.210	0.802	0.150	1.273+
	(0.750)	*(0.769)*	*(0.771)*	*(0.699)*
Legal	0.250**	0.278*	0.0856	0.481**
	(0.0969)	*(0.129)*	*(0.101)*	*(0.104)*
Language	-0.194	-0.153	-0.0966	-0.205+
	(0.125)	*(0.124)*	*(0.122)*	*(0.124)*
Colonial Ties	0.475*	0.481+	0.148	0.835**
	(0.211)	*(0.260)*	*(0.216)*	*(0.217)*
Religion	0.453*	0.768**	0.587**	0.939**
	(0.225)	*(0.245)*	*(0.221)*	*(0.240)*
Ongoing Hostility, Lagged	0.0655			
	(0.893)			
$\hat{\eta}^*_{ij}$		1.239**		1.671**
		(0.431)		*(0.298)*
$\hat{\bar{z}}^*_{ij}$		2.852**	1.748**	
		(0.958)	*(0.315)*	
$\hat{\bar{z}}^{*2}_{ij}$		-0.621*		
		(0.286)		
Observations	10589	10589	10589	10589
R^2	0.546	0.552	0.555	0.538

† The numbers in parentheses are standard errors.
‡ Marginal effects on probability of partnership at sample mean.
+ 10% significance level
* 5% significance level
** 1% significance level

Table 3.8 Percent Change in World Weighted Average of Seller Price of Oil Induced by GDP Growth During 1997-2007†

	Long Run Demand and Supply Elasticities	Long Run Demand Elasticities, Short Run Supply Elasticities	Short Run Demand Elasticities, Long Run Supply Elasticities	Short Run Demand and Supply Elasticities
Scenario 1: Actual GDP Growth	53.3	71.1	123.8	260.3
Scenario 2: Halved Growth in India and China	44.4	58.9	97.8	205.7
Scenario 3: Halved Growth in Transition Countries	45.2	60.3	99.1	206.5
Scenario 4: Halved Growth in OECD Countries	43.5	57.1	95.2	195.5

† Oil production in each country is used as a weight for the role of its supply price in the aggregate world price index.

Table 3.9 The Impact of Increased Hostility with Iran on the Trade Relationship with Iran

Countries with Increased Hostility	Initial Probability	Posterior Probability	Countries Stop Trading	Initial Share of Purchases	Posterior Share Of Purchases
Canada	0.675	0.407	X	1.90	0.00
USA	0.964	0.864		0.00	0.00
Israel	0.478	0.228		0.00	0.00
Japan	0.877	0.681		13.06	12.14
Cyprus	0.242	0.240		0.00	0.00
Belgium	0.772	0.521		7.97	7.44
Denmark	0.401	0.173		0.00	0.00
France	0.897	0.717		7.43	6.95
Germany	0.903	0.729		7.07	6.62
Greece	0.730	0.476	X	20.04	0.00
Ireland	0.128	0.034		0.00	0.00
Italy	0.919	0.761		8.41	7.91
Netherlands	0.865	0.660		8.01	7.48
Portugal	0.647	0.380	X	7.70	0.00
Spain	0.870	0.668		7.60	7.11
UK	0.795	0.552		1.67	1.55
Austria	0.705	0.444	X	12.59	0.00
Finland	0.494	0.240		0.00	0.00
Norway	0.394	0.168		0.00	0.00
Sweden	0.699	0.434	X	3.45	0.00
Switzerland	0.446	0.206	X	7.87	0.00
Malta	0.040	0.007		0.00	0.00
Albania	0.005	0.001		0.00	0.00
Bulgaria	0.274	0.106	X	41.79	0.00
Belarus	0.996	0.973		0.00	0.00
Czech Rep.	0.279	0.104	X	18.39	0.00
Estonia	0.985	0.930		0.00	0.00
Hungary	0.458	0.213		0.00	0.00
Poland	0.567	0.306	X	17.52	0.00
Romania	0.470	0.231	X	14.35	0.00
Russian Fed	0.205	0.065		0.00	0.00
Slovakia	0.994	0.966		0.00	0.00
Ukraine	0.998	0.984		0.00	0.00
Croatia	0.993	0.960		0.00	0.00
Slovenia	0.989	0.944		0.00	0.00
Yugoslavia	0.481	0.239	X	12.05	0.00
Australia	0.604	0.334		0.00	0.00
New Zealand	0.398	0.172	X	3.75	0.00

Table 3.10 The Impact of Increased Hostility with Iran on the Trade Relationship with Oil Exporters

Countries with Increased Hostility	Country they import from the most	Initial percentage of purchases	Posterior percentage of purchases	Country that has biggest change in share	The amount of change in percentage
Canada	Saudi Arabia	9.66	9.92	Iran	-1.90
USA	Saudi Arabia	9.59	9.55	Venezuela	0.05
Israel	Egypt	64.68	64.87	Russian Fed.	-0.46
Japan	Saudi Arabia	35.31	35.68	Iran	-0.92
Cyprus	Russian Fed	72.35	71.69	Russian Fed.	-0.66
Belgium	UK	46.90	47.34	Iran	-0.54
Denmark	Norway	47.81	47.78	Russian Fed.	-0.08
France	UK	23.00	23.25	Iran	-0.49
Germany	Norway	33.19	33.35	Iran	-0.45
Greece	Saudi Arabia	38.35	48.85	Iran	-20.04
Ireland	UK	66.59	66.96	UK	0.36
Italy	Libya	35.87	35.68	Iran	-0.50
Netherlands	UK	31.85	32.16	Iran	-0.54
Portugal	Algeria	25.17	27.09	Iran	-7.70
Spain	Algeria	23.09	23.06	Iran	-0.49
UK	Norway	7.76	7.62	Iran	-0.12
Austria	Saudi Arabia	32.09	37.92	Iran	-12.59
Finland	Norway	47.06	47.81	Russian Fed.	-0.94
Norway	UK	1.85	1.86	Russian Fed.	-0.04
Sweden	Norway	75.87	78.68	Iran	-3.45
Switzerland	UK	23.11	25.19	Iran	-7.87
Malta	Algeria	58.22	57.79	Nigeria	-0.43
Bulgaria	Iran	41.79	0.00	Iran	-41.79
Belarus	Russian Fed	69.47	69.40	Russian Fed.	-0.07
Czech Rep.	Russian Fed	38.60	46.83	Iran	-18.39
Estonia	Russian Fed	53.83	53.72	Russian Fed.	-0.11
Hungary	Russian Fed	35.74	35.29	Russian Fed.	-0.45
Poland	Norway	33.01	40.76	Iran	-17.52
Romania	Russian Fed	18.81	27.73	Iran	-14.35
Russian Fed	China	0.81	0.85	China	0.04
Slovakia	Russian Fed	96.56	96.69	Czech Rep.	-0.14
Ukraine	Russian Fed	52.52	52.40	Russian Fed.	-0.12
Croatia	Norway	9.67	9.74	Russian Fed.	-0.23
Slovenia	Libya	31.71	31.67	Russian Fed.	-0.55
Yugoslavia	Russian Fed	14.55	20.52	Iran	-12.05
Australia	Saudi Arabia	17.44	17.44	New Zealand	-0.03
New Zealand	Australia	25.91	27.23	Iran	-3.75

Table 3.11 The Impact of Increased Hostility with Iran on the Share of Iran's Trade Partners

Iran's Trade Partners	Percentage share in Iran's exports before hostility increase	Percentage share in Iran's exports after hostility increase
Japan†	12.84	13.29
Korea Rep.	5.64	5.85
Germany†	4.44	4.63
Italy†	3.45	3.61
France†	3.16	3.29
India	2.34	2.43
Taiwan	1.97	2.04
Spain†	1.86	1.94
China	1.85	1.91
Netherlands†	1.67	1.74
Turkey	1.62	1.70
Belgium†	1.16	1.21
Greece†	1.13	0.00
UK†	1.08	1.11
Poland†	1.06	0.00
Romania†	1.01	0.00
Canada†	0.77	0.00
Bulgaria†	0.69	0.00
Austria†	0.53	0.00
Czech Rep†	0.51	0.00
Portugal†	0.41	0.00
Sweden†	0.37	0.00
Switzerland†	0.19	0.00
Yugoslavia†	0.11	0.00
New Zealand†	0.08	0.00
USA†	0.00	0.00
Israel†	0.00	0.00
Denmark†	0.00	0.00
Ireland†	0.00	0.00
Finland†	0.00	0.00
Iceland†	0.00	0.00
Norway†	0.00	0.00
Russian Fed†	0.00	0.00
Australia†	0.00	0.00

† Countries with increased hostility level

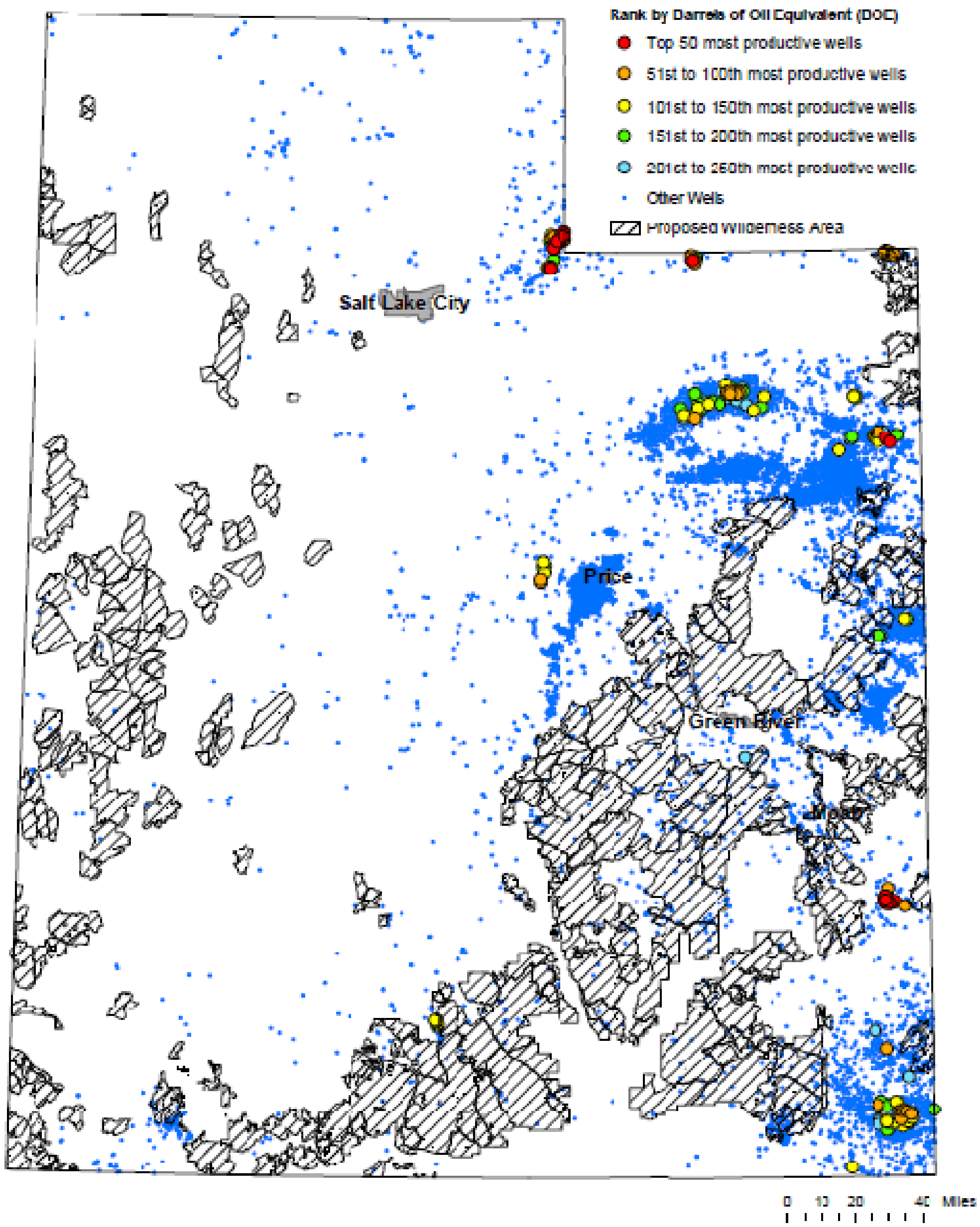
Table 3.12 Change in World Weighted Average of Buyer and Seller Price of Oil Due to Heightened Conflict between Iran and the West

	Percentage Change in Average weighted buyer price	Percentage Change in Average weighted seller price
Due to Increased Hostility with Iran	0.48	-0.005
Due to Embargo on Iranian Oil	1.76	-0.91
Iran's production drops by 20%	4.61	3.34
Iran's production drops by 40%	6.22	5.21
Iran's production drops by 60%	8.65	7.62
Iran attacks Persian Gulf	8.91	7.50

Table 3.13 The Impact of Embargo on Iranian Oil on the Trade Relationship with Oil Exporters

Countries Put an Embargo on Iranian Oil	Country they import from the most	Initial percentage of purchases	Posterior percentage of purchases	Country that has biggest change in share	The amount of change in percentage
Canada	Saudi Arabia	9.66	9.19	Iran	-1.90
USA	Saudi Arabia	9.59	9.06	Saudi Arabia	-0.53
Israel	Egypt	64.68	64.56	Mexico	0.22
Japan	Saudi Arabia	35.31	41.23	Iran	-13.06
Cyprus	Russian Fed	72.35	72.44	Algeria	-0.13
Belgium	UK	46.90	50.91	Iran	-7.97
Denmark	Norway	47.81	47.96	Norway	0.15
France	UK	23.00	24.81	Iran	-7.43
Germany	Norway	33.19	35.88	Iran	-7.07
Greece	Saudi Arabia	38.35	48.62	Iran	-20.04
Ireland	UK	66.59	66.65	Norway	0.17
Italy	Libya	35.87	38.53	Iran	-8.41
Netherlands	UK	31.85	34.30	Iran	-8.01
Portugal	Algeria	25.17	26.65	Iran	-7.70
Spain	Algeria	23.09	24.53	Iran	-7.60
UK	Norway	7.76	7.82	Iran	-1.67
Austria	Saudi Arabia	32.09	37.55	Iran	-12.59
Finland	Norway	47.06	47.39	Russian Fed	-0.41
Norway	UK	1.85	1.84	Russian Fed	-0.02
Sweden	Norway	75.87	78.67	Iran	-3.45
Switzerland	UK	23.11	25.05	Iran	-7.87
Malta	Algeria	58.22	57.01	Nigeria	1.21
Bulgaria	Iran	41.79	0.00	Iran	-41.79
Belarus	Russian Fed	69.47	69.68	Russian Fed	0.21
Czech Rep.	Russian Fed	38.60	47.47	Iran	-18.39
Estonia	Russian Fed	53.83	54.14	Russian Fed	0.31
Hungary	Russian Fed	35.74	35.68	Libya	-0.24
Poland	Norway	33.01	40.61	Iran	-17.52
Romania	Russian Fed	18.81	27.92	Iran	-14.35
Russian Fed	China	0.81	0.74	China	-0.07
Slovakia	Russian Fed	96.56	96.68	Czech Rep.	-0.14
Ukraine	Russian Fed	52.52	52.82	Russian Fed	0.32
Croatia	Norway	9.67	9.69	Russian Fed	-0.16
Slovenia	Libya	31.71	32.24	Libya	0.53
Yugoslavia	Russian Fed	14.55	20.76	Iran	-12.05
Australia	Saudi Arabia	17.44	17.49	Kuwait	0.15
New Zealand	Australia	25.91	27.08	Iran	-3.75

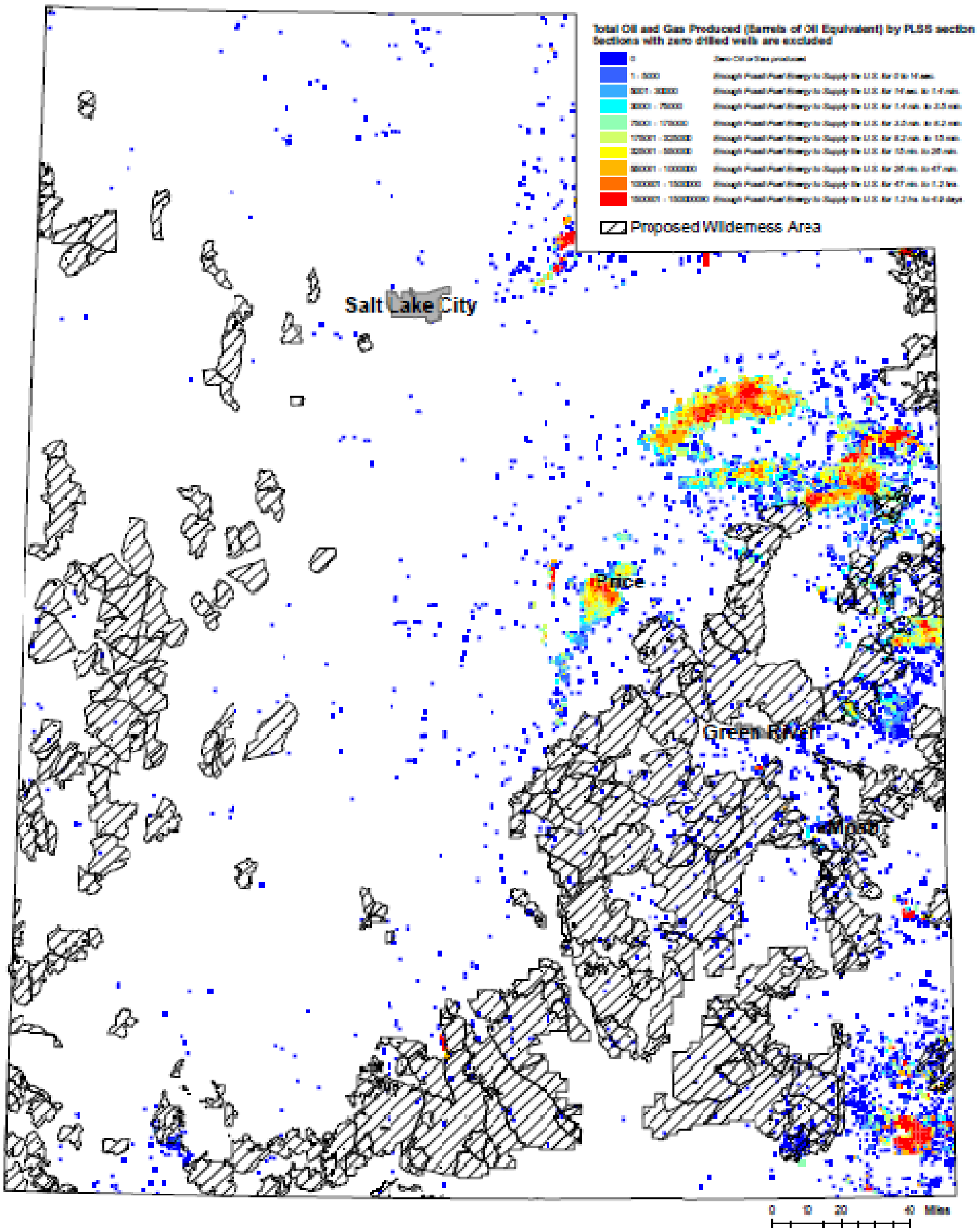
Figure 3.1 Map of All Drilled Wells in Utah



The top 250 wells make up less than 2% of the more than 13,500 wells in Utah, yet have produce more than 45% of Utah Oil and Gas

Source: Utah Division of Oil, Gas and Mining Database (10/2003)

Figure 3.2 Utah Oil and Gas Production to Date



Statewide cumulative production of oil and gas is 2.60 billion barrels of oil equivalent (BBOE): enough to supply the United States' fossil-fuel energy needs for 2.8 months

Sources: Utah Division of Oil, Gas and Mining Database (10/2003) and Energy Information Administration

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CHAPTER 4

NON-OIL ENERGY TRADE:

THE ROLE OF GEOGRAPHY AND HETEROGENEITY OF SOURCES

4.1 Introduction

The need for finding energy sources alternative to oil has been growing due to oil price hikes and dramatic growth in developing countries in recent years. Tight oil markets and instability in oil exporting countries have added to the urgency of expanding the substitutes for oil. One of the most common substitutes for oil is natural gas, which has been used in some countries for many years. In addition to natural gas, coal is viewed as a close substitute, sometimes serving as a direct replacement for oil through the coal-to-liquids method. Bio-fuels are also being strongly encouraged and gaining popularity in many countries.

Based on International Energy Agency (IEA) data, world price of oil has increased by 278 percent during 1997-2007, much faster than the rise in consumer price of 30 percent during the same period. The corresponding increase in the price of natural gas was 126 percent, and for coal was 62 percent. During this period, according to the Statistical Review of World Energy 2009 published by British Petroleum, global oil production had increased by 13 percent, while production of natural gas had grown by 32.5 percent and coal by 37.2 percent. China doubled its demand and production of coal in the last decade, with a share of 42 percent in world total. Hence, with the growing energy consumption and heightened energy prices, demand has shifted away from oil, the energy source with the greatest price increase, and towards gas and especially coal, the source with the smallest price increase so far.

In this paper, we try to understand the trade patterns of oil's substitutes around the world and how it links with the crude oil trade. We construct price and quantity indices for three forms of energy—natural gas, coal and electricity (GCE)—that are substitutes for each other and oil. We use the approach developed by Helpman, Melitz and Rubinstein (2008), HMR hereafter, to specify and estimate a model of bilateral trade in GCE forms of energy. We employ the estimation results to analyze the role of various factors in the formation of partnerships and bilateral flows in GCE trade. We also examine how these factors affect the cost of GCE for each country and ultimately shape world prices and trade patterns.

The HMR approach addresses a number of important concerns in estimating the equation for bilateral trade flows often encountered in the standard gravity framework. One such concern is the large number of zeros among country dyads. Including these observations in the regressions biases the coefficient estimates downward due to truncation. On the other hand, focusing on the sample of bilateral relationships with positive trade poses a selection problem. In addition, the elasticities of energy supply with respect to various factors depend on how production within each country responds to changes in those factors. Exporting countries with very heterogeneous sources may face rapidly rising costs if they try to expand production and exports, while those with more homogenous sources may be able to respond with larger changes in trade volumes. Ignoring the role of these effects in the formation of trade partnerships and volume of trade is another source of bias in standard gravity estimations. The HMR framework allows us to deal with both selection and heterogeneity issues and explain both partnerships as well as trade flows.

HMR develop a theoretical model of international trade with heterogeneous firms from which they derive two equations: one determining the formation of partnerships and the other trade volumes for the formed partnerships. Their empirical results for trade flow across all products show that ignoring the unobserved firm heterogeneity and selection effects causes upward bias in trade elasticity estimates based on the standard gravity model. Our estimates for the model of GCE trade using dyadic panel data for 1982-1997 confirm the existence of such biases in energy trade elasticities.

A critical aspect of HMR structural model is that its estimation requires a variable that affects the probability of trade but is uncorrelated with the residual of the trade volume equation. Factors that affect fixed costs of trade but have no impact on variable trade costs satisfy this exclusion restriction. For our estimation, we need a valid excluded variable that works in a panel setting. In an earlier study of trade flow for all products (Ergul and Esfahani, 2010), we find that Contract Repudiation Index of a country serve such a purpose, affecting fixed costs, but not variable costs, both on theoretical and empirical grounds. In this study, we show that this variable plays a similar role in energy trade.

We use the econometric estimation results to simulate a model of global GCE trade. We also compare the projections of the model for 1997-2007 with the actual outcomes to assess the performance of the model and the required assumption for reproducing actual trends. The results confirm that our model is able to predict actual values quite well under reasonable assumptions. We finally highlight the potential applications of the model by examining the outcome of a conflict scenario between Russia and Europe over gas supply.

In section 4.2 we present a modified version of the HMR model, which we employ in our estimation. We describe the data and discuss the regression results in sections 4.3 and 4.4, respectively. In section 4.5, we present our simulation experiments. Section 4.6 concludes the paper.

4.2 Description of the Model

In order to estimate the elasticities of GCE trade, we use HMR model. For our purposes, it is sufficient to describe the main equations determining trade probabilities and trade flows, adapted to a panel setting. HMR show that the probability of formation of a partnership between exporter *j* and importer *i* is related to

(1) $$z_{jit} = \gamma_0 - \varepsilon c_{jt} + (1-\varepsilon)(\tau_{jit} + a_L - p_{it}) + y_{it} - f_{jit} + u_{jit}\ ,$$

where γ_0 is a constant and $u_{jit} \sim N(0, \sigma_u^2)$ is a random factor affecting the profits of exporting from *j* to *i* at time *t*. The other variables are defined as follows:

ε: the elasticity of substitution among GCE varieties (GCE from different sources),

c_{jt}: log of average unit cost of production of GCE in country *j* at time *t*,

τ_{jit}: log of unit trade costs of exporting GCE from *j* to *i* at time *t*,

a_L: productivity of the most efficient production station,

p_{it}: log of the average price of GCE in country *i* at time *t*,

y_{it}: log of total expenditure on GCE in country *i* at time *t*,

f_{jit}: log of the fixed costs of exporting GCE from *j* to *i* at time *t*.

The fixed costs have a number of components. Specifically, $f_{jit} \equiv \kappa_x\varphi_{xjt} + \kappa_m\varphi_{mit} + \kappa\varphi_{jit} - v_{jit}$, where v_{jit} is a random factor distributed as $N(0, \sigma_v^2)$, κ's are parameters, φ_{mit} is a fixed trade barrier imposed by importing country on all exporters at time t, φ_{xjt} is a measure of fixed export costs common across all export destinations at time t, and φ_{jit} is a measure of any additional country-pair specific fixed trade costs. These fixed cost components may be further decomposed into time-variant and time-invariant components.

Given the above specification, the composite random element in (1) will be $\eta_{jit} = v_{jit} + u_{jit}$, where $\eta_{jit} \sim N(0, \sigma_\eta^2)$ and $\sigma_\eta^2 = \sigma_u^2 + \sigma_v^2$. Using T_{jit} as a dichotomous indicator of trade, the probability that country j exports to country i at time t ($T_{jit} = 1$) can be expressed as:

$$(2)\quad Pr(T_{jit}=1|\, observables) = \Phi[\frac{1}{\sigma_\eta}(\gamma_0 - \varepsilon c_{jt} - (\varepsilon-1)(\tau_{jit} + a_L - p_{it}) + y_{it} - \kappa_x\varphi_{xjt} - \kappa_m\varphi_{mit} - \kappa\varphi_{jit})],$$

where Φ is cdf of unit-normal distribution.

The volume of exports from country j to country i when there is a partnership forms a gravity-type equation, which can be expressed in log-linear form as:

$$(3)\qquad x_{jit} = \beta_0 - (\varepsilon-1)c_{jt} + n_{jt} - (\varepsilon-1)(\tau_{jit} - p_{it}) + y_{it} + w_{jit} + u_{jit},$$

where β_0 is a constant, n_{jt} is the log of number of production stations in the exporting country, and w_{jit} is the heterogeneity factor of production stations that export from j to i. The key difference between this equation and the standard gravity model is the heterogeneity effect of production stations, w_{jit}. This term need not be symmetric with respect to the direction of trade. Its value is determined by the marginal profitability of exporting from j to i. Since the determinants of volume of trade are also related to marginal profitability, their coefficients are likely to be biased if w_{jit} is left out. Another source of bias is the selection problem due to higher values of u_{jit} among dyads that become trade partners, which causes a correlation between this term and the factors affecting profitability of trade included on the right-hand side of the equation (Heckman 1979).

HMR show that w_{jit} can be derived as a monotonic function of z_{jit}: When $z_{jit} > 0$, $w_{jit} = \ln[\exp(\delta z_{jit}) - 1]$, where δ is a positive parameter. This relationship provides a means of estimating w_{jit} based on the estimate of z_{jit} from equation (2), $\hat{z}^*_{jit}$. Equation (2) also offers a way of dealing with the selection bias caused by the fact that u_{jit} is truncated. Given the estimate of

η_{jit} from (2), we have $E[u_{jit} \mid ., T_{jit} = 1] = \beta_{u\eta}\hat{\bar{\eta}}^*_{jit}$, where $\beta_{u\eta} \equiv$ corr $(u_{jit}, u_{jit})(\sigma_u/\sigma_\eta)$ and $\hat{\bar{\eta}}^*_{jit} = E[\eta_{jit}/\sigma_\eta| ., T_{jit} = 1]$. With these considerations in mind, the trade volume equation becomes:

$$(4) \qquad x_{jit} = \beta_0 - (\varepsilon - 1)c_{jt} + n_{jt} - (\varepsilon - 1)(\tau_{jit} - p_{it}) + y_{it} + \ln[\exp(\delta\hat{\bar{z}}^*_{jit}) - 1] + \beta_{u\eta}\hat{\bar{\eta}}^*_{jit} + e_{jit},$$

where e_{jit} is i.i.d. Note that the term containing $\hat{\bar{z}}^*_{jit}$ is nonlinear, which complicates the estimation procedure a bit. To facilitate estimation, HMR use a Taylor expansion of the nonlinear term and find that the results are largely unaffected. We follow their procedure and replace the nonlinear term with a quadratic polynomial of $\hat{\bar{z}}^*_{jit}$.

The crucial issue in the estimation of the system of equations (2) and (4) is that except the fixed-cost factors, all the variables determining $\hat{\bar{z}}^*_{jit}$ and $\hat{\bar{\eta}}^*_{jit}$ are included on the right-hand side of (4). As a result, finding variables that represent only the fixed costs and, thus, can be excluded from (4) is crucial in making it possible to identify the heterogeneity and selection effects in the trade volume equation. In the next section, we discuss this choice along with the description of our data.

4.3 Data

The dataset that we use is an unbalanced panel that covers 15,500 directed dyads involving 125 countries during 1982-1997. However, due to missing data points, we end up with a total of 181,799 observations that have complete information, amounting to an average of about 12 years of data per directed dyad.

The data sources and the variables used in our empirical analysis are described in Table 4.1. We define our dependent variable as GCE exports from country *j* to country *i*. It is composed of three sub-categories of energy—gas, coal, and electricity. At the aggregate level, the share of natural gas in total trade value is approximately 63 percent, coal 30 percent, and electricity less than 7 percent.

In our regressions we include the log of value of GCE production by adding the sum of production in three energy categories (in US dollars) for exporting countries to account for the number of production units and their average productivity, serving as a proxy for $n_{jt} - (\varepsilon - 1)c_{jt}$. We also include the log of GCE expenditure (in US dollars) for importing countries as a measure of y_{it}. Since these variables are likely to be endogenous, we use their lagged values as instruments. As indicators of trade costs, τ_{jit}, we use Distance, shared Border, shared Legal system, Colonial Ties, shared Religions, shared dominant Language, and Ongoing Hostility. Since the contemporaneous value of Ongoing Hostility may be affected by the trade relations, we use its lagged value as an explanatory variable. Following HMR, we also include indicators showing whether or not both countries are Landlocked or Islands. We employ *time* fixed effects to take account of global shocks and exporter and importer fixed effects to account for the time invariant unobserved country characteristics.

In order to take account of the selection and heterogeneity effects, we use Contract Repudiation Index as the excluded variable, which should theoretically be a valid one, as we argue and empirically support it in Ergul and Esfahani (2010). This index is constructed by Stephen Knack and Philip Keefer (1995), using International Country Risk Guide (ICRG) dataset of the Political Risk Services, Inc. It is defined as an indicator that "addresses the possibility that foreign businesses, contractors, and consultants face the risk of a modification in a contract taking the form of a repudiation, postponement, or scaling down due to an income drop, budget cutbacks, indigenization pressure, a change in government, or a change in government economic and social priorities." Such risks, and the efforts to overcome them, should have a major effect on the fixed costs of setting up production and arranging exports, but not necessarily the variable costs. Since Contract Repudiation is country specific, rather being dyad specific, we include the indicators for the exporter and importer separately in the equation. These could be viewed as representing φ_{xjt} and φ_{mit}. To the extent that these variables affect only the fixed cost of trade, they should appear with significant negative coefficients in equation (2), but not in equation (4).

4.4 Estimation Results

Table 4.2 presents our main estimation results. The first column shows the estimates for the probability of trade equation. The second column is the benchmark estimate for the trade volume equation, without controls for selection or heterogeneity effects. Note that both exporter and importer Contract Repudiation indicators are highly significant in the equation for trade partnership probability, while lacking significance in the benchmark model. This supports our claim that policy risks largely affect the fixed costs of GCE trade, but not its variable costs. Using these indicators as excluded variables along with the measures of selection and heterogeneity derived from the first column, the third column shows the estimates of the polynomial version of equation (4). The selection and heterogeneity terms are all significant and their inclusion has a non-trivial impact on the elasticity coefficients.

In the estimation results reported in columns 1 and 2 of Table 4.2, GCE production in the exporting country, total GCE expenditure in the importing country, Distance between the two countries, existence of shared Border, Colonial Ties, and Ongoing Hostility emerge with high statistical significance levels and reasonable signs and magnitudes in both equations. Indicators of shared Legal System and Landlocked status prove significant in the probability of trade equation, but not in the level of trade. This could be because, like Contract Repudiation, they mainly influence the fixed costs of trade. The positive sign of the Landlocked indicator needs a bit of explanation. The increase in the probability of GCE trade partnerships is essentially due to added border and neighborhood effects in central Africa and central Europe, where there are clusters of landlocked countries that find trade among themselves relatively less costly than trade with others. Sharing the Island status seems to have the opposite effect and shows a negative effect on the variable costs of trade with a marginal level of significance. The presence of a Common Language or Common Religion does not seem to matter for GCE trade.

As the third column of Table 4.2 shows, the elasticity of trade with respect to production proves to be rather large, but still smaller than one, suggesting that while most of increased production is exported to existing customers, a small part gets exported to new customers or goes toward increased domestic consumption. Expenditure elasticity in the importing country turns out to be much lower than one, suggesting that importers try to diversify their sources and possibly raise domestic production as their consumptions rise. The absolute value of the elasticity of trade with respect to distance is found to be greater than one. This, along with the large coefficient of the Border variable, highlights the important role of distance in GCE trade and helps explain why most countries tend to provide their demands for these types of energy from nearby sources.

An important issue in assessing the results is the magnitude and direction of bias due to selection and heterogeneity effects. Table 4.3 presents the results of introducing the variables representing the two effects separately, along with the benchmark and full model estimates. Almost all the estimated elasticities go down sharply when only the heterogeneity bias is corrected, and they go up sharply when only the selection bias is corrected. The direction of the selection bias is easy to understand: Many unobserved factors that make it more profitable for trade partnerships to form help add some observations to the trade volume sample that would not otherwise be present based on their observed characteristics. As a result, the effects of the observed characteristics appear as weaker than they actually are; i.e., their coefficient estimates are downward biased. In the case of GCE trade such biases seem to be quite strong for most of the variables included in the regression (compare the first and last columns of Table 4.3). To understand the role of heterogeneity in biasing the standard gravity regressions, note that when the productivities of GCE production units are very diverse, it is more likely that there are some with export potential. Such units will have lower marginal cost of production and, therefore, are likely to export large amounts as trade costs decline. Without appropriate controls for heterogeneity, the entire response of trade may be attributed to factors included in the regression, thus over-estimating their impact on trade. This can account for the sharp drop in elasticities when we control for heterogeneity. When corrections are made for both selection and heterogeneity, for most right-hand side variables the selection effect turns out to dominate, raising the estimated elasticities above the benchmark. In particular, the benchmark estimates for the coefficients of GCE production, GCE expenditure, and distance are 0.585, 0.257 and -0.870, respectively (see column 1 of Table 4.3). After correction for the biases, they reach 0.761, 0.368, and -1.190, respectively (see column 2 of Table 4.3). Similar changes in net effects materialize in the case of Ongoing Hostility, shared Language and Landlocked status. Border and Island status are the only variables for which the absolute magnitude of the estimated coefficient decline somewhat when both corrections are made. However, in these cases, the estimates are rather imprecise. Therefore, on the whole, we can conclude that there are overall downward biases in the estimated elasticities of the standard regressions, with the selection and heterogeneity biases working in opposite directions and the former dominating.

4.5 Simulations

4.5.1 The Setup

In order to assess the performance of our model and to demonstrate the usefulness of the results, we carry out a number of simulations by placing the estimated equations in a global market equilibrium context. We use our empirical results and HMR's theoretical model to calculate probabilities of trade partnership, trade volumes, prices, and production and consumption levels for all dyads with available data. For our base period, we focus on the average of the data over the 1995-1997 period. We allow the average cost of GCE production in a country, c_{jt}, to adjust and shifts its export prices up and down to equilibrate total demand for the country's GCE with its production. This is done by adjusting the exporter fixed effects. The aggregate effect of price increases for GCE from different sources (derived from a Dixit-Stigliz model of differentiated products) can then be turned into an adjustment term in the importer fixed effect in the probability of trade equation, $-(1-\varepsilon)p_{it}/\sigma_\eta$. We assume that the elasticity of substitution among GCE varieties is high and set $\varepsilon = 11$, which is in range often found in the study of substitution elasticities among varieties of the same product. (The results are not very sensitive to changes in ε within a reasonable range around this value.) As an estimate of σ_η, we use the inverse of the coefficient of log of expenditure in the Probit regression, $\sigma_\eta = 1/0.114$.

Building a simulation model based on the regression results poses a number of additional challenges and requires important assumptions and modeling choices. The first problem to address is the calculation of own use of GCE for countries. The estimation results provide us with trade relationships, but not with own use of energy. We assume that own use is basically trade with the country itself and form the bilateral coefficients and measure trade volume accordingly. However, own trade may entail effects not captured in bilateral trade models. For this purpose, we calculate own-use fixed effects as an adjustment to the price for domestic use such that for each producer country, the volume of internal trade derived from the model becomes equal to the actual use in the base period.

The second challenge is to deal with the missing values, especially fixed effect data are missing for some countries. In particular, we do not obtain importer fixed effects if a country does not import from any other country. Since it is theoretically possible that these countries may start importing from other countries under some scenarios, we need their importer fixed effects for the simulation exercise. We address this problem by regressing the available fixed effects on country characteristics such as GDP, population, and GCE exports and use the results to predict fixed effects for the cases with missing data. The total number of such cases is less than 10 percent of importer and exporters, the most important ones being transition countries that export GCE forms, but have limited data for estimation, especially before 1995. Excluding such countries from the simulation exercises does not change the main results. But, we decided to include them to ensure that the exercises are more comprehensive.

Another aspect of missing data challenge is that production and uses do not balance for many countries because of their dealings with the countries left out of the simulation exercise. We address this problem by taking the shares of all such transactions as given. So, the equilibrium of the exercises is derived with the remaining shares of production and expenditure being balanced through price adjustments.

The fourth challenge is modeling overall supply and demand elasticity for each country. We assume that the aggregate expenditure is a constant elasticity function of the aggregate price of imports and own energy in each country. We obtain long run elasticities of energy demand (excluding oil) from Gately and Huntington (2002) which equals -0.24 for OECD and -0.16 for non-OECD countries. We could not find supply elasticity estimates for GCE forms of energy. So, we decided to use a rough estimate based on the supply increase given the 53 percent real increase in the GCE price rise during 1997-2007.[1] Given the average increase of about 30 percent in total supply, this implies an elasticity of about 0.6. We also simulate the model with lower elasticities (0.1 and 0.3) for short run and medium runs. We augment our estimates by using the estimate of the heterogeneity factors for each supplier, w_{jit}, as a relative supply elasticity indicator. We scale these indicators such that in the base case, the weighted supply elasticity of world production of GCE equals 0.6 in the long run. The weights that we use are the shares of directed dyad exports in total world exports. We repeat the exercise by changing the scaling factor for the world supply elasticity of 0.1 and 0.3.

The fifth challenge is to translate the simulated partnership probabilities into an actual trade/no-trade outcome. For this purpose, once we calculate the probabilities of trade between directed dyads from equation (2) given the dyad's characteristics, we employ the following rule for determining the existence of trade, indicated by T_{ji}, which equals 1 in case of trade in the directed dyad *ji* and equals 0 in the absence of trade. We first check whether T_{ji} is equal to 1 or 0 originally in actual data. If initially $T_{ji} = 1$ and the updated probability of trade is greater than or equal to 0.5, then the updated T_{ji} is set to 1, otherwise $T_{ji} = 0$ if the probability of trade drops by more than a tolerance level, *t*. When the initially $T_{ji} = 0$, we set the updated $T_{ji} = 0$ as long as the

[1] The real price increase is based on 100 percent nominal increase less 30 percent CPI increase, or 2/1.3 − 1 = 0.53.

updated probability derived from the model is less than or equal to 0.5, otherwise we set the updated T_{ji} = 1 if the probability has risen by more than *t*. The role of *t* is to deal with unobserved factors that create partnerships or prevent a dyad from trading. A higher *t* means that trade partnerships do not form or fall apart with small changes in our measured probability of trade. Lower values of *t* discount the role of factors that may account for persistence in trade partnerships or lack thereof, but are not captured in our model. For our experiments, we set *t* = 0.1, but our sensitivity analysis suggests that higher values of *t* do not change the results much. However, lower values of *t* do cause shifts in trade patterns, though still with limited impact on aggregate price changes.

Our final challenge is to deal possible multiplicity or non-existence of equilibria. This is a problem in our model because in the absence of exports from country *j* to country *i*, the price in *j* may drop and the price in *i* may rise so much that makes trade between them profitable, while in the presence of trade prices become such that the trade probability equation negates such trade. Such fluctuations also affect aggregate prices and each country's choices regarding their other partners, potentially giving rise to multiple equilibria and non-existence. Such situations are uncommon, but there are few dyads in some simulations that display such problems and prevent the convergence of our numerical solution algorithm. We address this concern by assuming that if, after for allowing for the tolerance level, a dyad finds it profitable to trade in the absence of initial trade, it will choose to trade even if profitability of trade may come into question once prices change as a result of trade.

4.5.2 Energy Prices and Economic Growth

Our first experiment with the model is to see if it can reproduce the growth of international energy prices during 1997-2007, when the average price of natural gas increased from \$142 per barrel in 1997 to \$321 in 2007, coal from \$42 in 1997 to \$68 in 2007, and electricity from \$0.0648 in 1997 and \$ 0.0879 in 2007 (IEA, 2010). The combined increase in price index amounts to an increase of 100 percent in ten years. We calculate the energy expenditure increase of each country by using its GDP growth rates given in World Development Indicators of World Bank and multiplying it by the income elasticities of energy use estimated by Gately and Huntington (2002). The first row of Table 4.4 shows the result of the simulation for three different levels of long run supply elasticities.

It is clear from the table that our estimate of the long run price elasticity of GCE supply give rise to average world prices for GCE that are somewhat lower than the world price rise of 53 percent. To match the actual price rise, the average supply price elasticity must be about 0.4. However, the actual price increase also reflects the cross-price elasticity from the oil market that is not captured in this simulation. Assuming a long run cross-price elasticity of 0.02 (one fifth of the long run own price elasticity of oil), which raises GCE expenditures by about 3.8 percent over the 10 year period given the 190 percent real increase in oil prices, is adequate to reproduce the actual outcome.

The rise in oil prices is often attributed to the increase in the demand from two fast growth giant economies, China and India. We explore this issue by recalculating the equilibrium lowering the growth rates of these two countries by half. The second row of Table 4.4 shows these results, which indicate that about 23 percent of the growth-induced rise in energy prices could be attributed to the fast growth of these two economies. By way of comparison, we carry out two similar simulations, separately cutting the growth rates of OECD and transition countries in half. The first experiment, reported in the third row of Table 4.4, shows that the fast growth in transition countries accounts only for 10.9 percent of price increase. The second experiment reported in the last row of Table 4.4 points to the fact that the growth in OECD countries may have been a more significant contributory factor, accounting for about 18.4 percent of the growth-induced GCE price rise between 1997 and 2007.

4.5.3 The Impact of International Conflict: Confrontation between Russia and the West

Beginning of 2009 Russia started cutting supply to Ukraine. As Ukraine is playing a key role in energy transit this was also seen as a signal from Russia to Europe that it can use energy as a weapon for political reasons. We use our model to examine the consequences of a possible embargo of Russia on Europe. We set the probability of trade between Russia and Europe to zero and recalculate the equilibrium. The world weighted average of buyer price goes up by 1.5 percent, while the world weighted average of seller price does not change significantly. There is a 20 percent drop in the supplier price of Russia but increases in other supplier prices balance out. We summarize the impact of embargo on the trade relationship of Europe with other exporters in Table 4.5. Countries that rely on Russian exports increase their purchases from other sources up to 10 percent. The price increase for individual countries has a wide range; for some countries the increase in price is as low as half percent, for some countries price increases sharply, up to 9 percent. These figures suggest that the impact of such an embargo may be far greater on Russia than on Europe, casting some doubt on the credibility of Russian threats.

4.6 Conclusion

In this paper, we have estimated a model of bilateral trade of natural gas, coal, and electricity (GCE), controlling for the role of selection in partnership formation and source heterogeneity in the flow of oil among countries. The model displays a good fit and offers important insights into the working of the global GCE market. The results show that ignoring these controls introduces significant biases in the estimation of the elasticities of GCE trade with respect to its determinants.

We use the model to carry out a series of global equilibrium simulation exercises to demonstrate the usefulness of the model. In particular, we show that the rise in GCE prices during 1997-2007 may be explained by economic growth around the world, with an estimated long-run price elasticity of world supply of GCE which is around 0.60. Moreover, high growth in China and India followed by rapid growth in transition countries and OECD countries account for the bulk of the rise in global GCE prices. We also show that the model can be used to explore various scenarios of GCE price responses to international conflict issues, especially the conflicts of Russia with Europe.

4.7 Tables

Table 4.1 Variable Descriptions and Data Sources

Name	Description	Source
$Trade_{jit}$	Logarithm of the sum of natural gas, coal and electricity exports from country *j* to country *i* at time *t* in thousands of constant 2000 US dollars.	Robert Feenstra, "“World Trade Flows (WTO), 1962–2000." www.internationaldata.org
GCE $Production_{jt}$	Logarithm of the sum of natural gas, coal and electricity production in exporting country *j* at time *t* in thousands of constant 2000 US dollars.	Energy Information Administration (EIA) & International Energy Agency (IEA)
GCE $Expenditure_{it}$	Logarithm of the sum of natural gas, coal and electricity expenditure in importing country *i* at time *t* in thousands of constant 2000 US dollars.	EIA, IEA and WTO
$Distance_{ji}$	Logarithm of the great circle distance (in km) between exporter's *j* and importer's *i* capitals	Centre D'Etudes Prospectives et D'Informations Internationales (CEPII) http://www.cepii.fr/anglaisgraph/cepii/cepii.htm
$Colonial_{ji}$	A binary variable that is unity if exporting country *j* ever colonized importing country *i* or vice versa.	
Land $Border_{ji}$	A binary variable that is unity if exporter *j* and importer *i* share a common land border	
$Contiguity_{ji}$	Dichotomous indicator that shows direct contiguity of exporter *j* and importer *i* (1 = Land Border, 2 = 1-12 miles water, 3 = 13-24, 4= 25-150 , 5 = 151-400, 6= not)	Correlates of War Database http://www.correlatesofwar.org/
$Island_{ji}$	A binary variable that is unity if both exporter *j* and importer *i* are islands	CIA The World Factbook
$Landlocked_{ji}$	A binary variable that is unity if both exporting country *j* and importing country *i* have no direct access to sea	CIA The World Factbook
$Legal_{ji}$	A binary variable that is unity if the exporting country *j* and importing country *i* share the same legal origin.	Easterly & Yu
$Language_{ji}$	A binary variable that is unity if the exporting country *j* and importing country *i* uses a common language	CIA The World Factbook
$Religion_{ji}$	(% Protestants in country *j* × % Protestants in country *i*) + (% Catholics in country *j* × %Catholics in country *i*) + (% Muslims in country *j* × %Muslims in country *i*)	Encyclopedia Britannica Book of the Year 2001
Ongoing $Hostility_{jit}$	Dichotomous indicator of ongoing hostility between exporting country *j* and the importing country *i* .	Correlates of War Database http://www.correlatesofwar.org/
Risk of Contract $Repudiation_{jt}$	A binary variable that takes the value one if contract repudiation in country *j* is less than the median score of all countries, zero otherwise. This variable is constructed separately for both exporting country *j* and the importing country *i* . If the score of a country is less than the median it has a higher risk for repudiation of contracts.	Political Risk Services, Inc., ICGR Dataset
GDP_{jt}	The logarithm of Gross Domestic Product in thousands of constant 2000 US dollars.	World Bank, World Development Indicators www.worldbank.org/data

Table 4.2 Estimates of the GCE Trade Equations with Contract Repudiation as Excluded Variable†

Pooled Panel of Directed Dyads with Instrumental Variables for Production and Expenditure, 1982-1997

Dependent Variable:	**Trade Dummy, T_{ij}**	**Log of Exports of *j* to *i*, x_{ji}**	
Model:	**Probit‡**	**Benchmark IVREG**	**Polynomial IVREG**
Log of GCE Production by Exporter, Lagged	0.197** *(0.040)*	0.585** *(0.141)*	0.761** *(0.169)*
Log of GCE Expenditure by Importer, Lagged	0.114** *(0.040)*	0.257+ *(0.135)*	0.368* *(0.154)*
Log of Distance	-0.865** *(0.025)*	-0.870** *(0.0640)*	-1.190** *(0.408)*
Border	0.287** *(0.085)*	1.127** *(0.176)*	0.992** *(0.216)*
Island	0.117 *(0.131)*	-0.820* *(0.335)*	-0.543+ *(0.326)*
Landlocked	0.912** *(0.228)*	0.565 *(0.504)*	1.021+ *(0.618)*
Legal	0.251** *(0.039)*	0.0323 *(0.100)*	0.130 *(0.150)*
Language	0.019 *(0.058)*	-0.137 *(0.138)*	-0.116 *(0.133)*
Colonial ties	0.370** *(0.086)*	0.434* *(0.186)*	0.609* *(0.257)*
Religion	-0.106 *(0.079)*	0.00415 *(0.191)*	-0.0941 *(0.194)*
Ongoing Hostility, Lagged	-1.151** *(0.166)*	-2.487** (0.939)	-4.790+ *(2.838)*
Exporter Risk of Contract Repudiation	0.023** *(0.008)*	0.0191 *(0.0237)*	
Importer Risk of Contract Repudiation	0.040** *(0.009)*	-0.00256 *(0.0254)*	
$\hat{\bar{\eta}}^*_{ij}$			2.015** *(0.476)*
$\hat{\bar{z}}^*_{ij}$			3.053** *(0.622)*
$\hat{\bar{z}}^{*2}_{ij}$			-0.547** *(0.103)*
Observations	181799	12019	12019
R^2	.	0.541	0.568

† The numbers in parentheses are standard errors.
‡ Marginal effects on probability of partnership at sample mean.
+ 10% significance level, * 5% significance level, ** 1% significance level

Table 4.3 Estimates of GCE Trade with Contract Repudiation as Excluded Variable, 1982-1997†
Decomposition of Bias Effects

Dependent Variable:	Log of Exports of *j* to *i*, x_{ji}			
Model:	**Benchmark IVREG**	**Polynomial IVREG**	**Firm Heterogeneity IVREG**	**Heckman Selection IVREG**
Log of GCE Production by Exporter, Lagged	0.585**	0.761**	0.249*	0.972**
	(0.141)	*(0.169)*	*(0.126)*	*(0.126)*
Log of GCE Expenditure by Importer, Lagged	0.257+	0.368*	0.0385	0.506**
	(0.135)	*(0.154)*	*(0.126)*	*(0.130)*
Log of Distance	-0.870**	-1.190**	-0.497**	-1.891**
	(0.0640)	*(0.408)*	*(0.117)*	*(0.118)*
Border	1.127**	0.992**	0.425*	1.199**
	(0.176)	*(0.216)*	*(0.175)*	*(0.166)*
Island	-0.820*	-0.543+	-0.722*	-0.525
	(0.335)	*(0.326)*	*(0.318)*	*(0.323)*
Landlocked	0.565	1.021+	-0.735	1.803**
	(0.504)	*(0.618)*	*(0.462)*	*(0.489)*
Legal	0.0323	0.130	-0.341**	0.342**
	(0.100)	*(0.150)*	*(0.0976)*	*(0.0980)*
Language	-0.137	-0.116	-0.134	-0.174
	(0.138)	*(0.133)*	*(0.133)*	*(0.134)*
Colonial ties	0.434*	0.609*	-0.179	0.896**
	(0.186)	*(0.257)*	*(0.179)*	*(0.198)*
Religion	0.00415	-0.0941	-0.0886	0.124
	(0.191)	*(0.194)*	*(0.187)*	*(0.188)*
Ongoing Hostility, Lagged	-2.487**	-4.790+	2.425	-7.832**
	(0.939)	*(2.838)*	(1.669)	(2.339)
Exporter Risk of Contract Repudiation	0.0191			
	(0.0237)			
Importer Risk of Contract Repudiation	-0.00256			
	(0.0254)			
$\hat{\eta}^*_{ij}$		2.015**		2.181**
		(0.476)		(0.192)
$\hat{z}^*_{ij}$		3.053**	4.710**	
		(0.622)	(0.536)	
$\hat{z}^{*2}_{ij}$		-0.547**		
		(0.103)		
Observations	12019	12019	12019	12019
R^2	0.541	0.568	0.548	0.572

† The numbers in parentheses are standard errors.
+ 10% significance level
* 5% significance level
** 1% significance level

Table 4.4 Percent Change in World Weighted Average of Seller Price of GCE Induced by GDP Growth During 1997-2007[†]

	Supply Elasticity=0.1[††]	**Supply Elasticity=0.3**	**Supply Elasticity=0.6**
Scenario 1: Actual GDP Growth	97.8	59.8	42.5
Scenario 2: Halved Growth in India and China	69.8	43.2	30.3
Scenario 3: Halved Growth in Transition Countries	84.1	51.9	36.5
Scenario 4: Halved Growth in OECD Countries	75.1	47.9	33.6

[†] GCE production in each country is used as a weight for the role of its supply price in the aggregate world price index.
[††] Long run supply elasticity of crude oil

Table 4.5 The Impact of Disruption of GCE Trade between Russia and Europe

Countries that are Embargoed by Russia	Initial share of Russia	Country they import from the most	Initial percentage of purchases	Posterior percentage of purchases
Belgium	0.41	Netherlands	8.55	8.65
Denmark	0.03	Germany	0.65	0.69
France	0.26	Algeria	1.91	2.02
Germany	0.19	Poland	1.50	1.61
Greece	0.08	USA	0.16	0.18
Ireland	0.07	UK	7.07	7.10
Italy	0.14	France	0.69	0.71
Netherlands	0.17	Belgium	1.98	1.99
Portugal	0.15	US	2.29	2.44
Spain	0.12	Algeria	2.77	2.81
UK	0.07	US	1.10	1.20
Austria	0.20	Germany	7.58	7.92
Finland	11.74	Russia	11.74	0.00
Iceland	0.00	US	1.87	1.89
Norway	0.32	Poland	0.81	0.90
Sweden	0.36	Norway	2.57	2.73
Switzerland	0.07	France	2.37	2.38
Gibraltar	0.00	South Africa	15.89	16.41
Malta	0.00	Algeria	4.11	4.17
Albania	0.25	Russia	0.25	0.00
Bulgaria	0.87	Poland	2.14	2.94
Belarus	0.70	Poland	0.85	0.86
Czech Rep.	0.64	Poland	6.88	6.98
Estonia	1.52	Russia	1.52	0.00
Hungary	2.74	Poland	5.64	6.09
Latvia	11.90	Russia	11.90	0.00
Lithuania	3.60	Poland	6.63	9.10
Moldova	21.24	Russia	21.24	0.00
Poland	1.90	Russia	1.90	0.00
Romania	4.75	Russia	4.75	0.00
Slovakia	1.39	Poland	13.26	14.10
Ukraine	6.00	Russia	6.00	0.00
Bosnia Herzegovina	0.85	Russia	0.85	0.00
Croatia	0.79	Slovenia	6.39	6.53
Slovenia	0.53	Crotia	3.81	3.86
Macedonia	28.27	Poland	41.25	51.71
Yugoslavia	0.07	Poland	0.32	0.33

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