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Destinations of Irish Exports: A Gravity Model Approach

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***Abstract*:** This paper uses a gravity model approach in order to analyse the geographical patterns of Irish exports. The gravity model in international trade has been demonstrated to be an extremely robust empirical method. The gravity model is first applied to aggregate Irish exports from 1980 to 2007. Distance is found to have a strong negative effect on exports. On the other hand, exports are positively related to sharing a common language and when communications infrastructure is well developed. The gravity model is shown to fit the data extremely well. We then use firm-level data on indigenous Irish exporters to divide the effects of trade costs into how they influence the number of firms exporting to each market and the average exports per firm. Finally, the firm data is divided into four broad sectors to examine if there is any sectoral variation in the standard results.

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1. INTRODUCTION

A high level of openness to trade is one of the hallmarks of the Irish economy. The patterns of these exports and the influence of trade costs on export sales are therefore topics that are of perennial interest to economists and policymakers in such a small and open economy. This paper looks at these issues from two different angles - the "big picture" of where in the world Irish exports are sold and the more micro question of how trade costs and barriers influence the number of firms exporting to different markets and the firms' average sales in each market.

This paper uses a gravity model approach in order to analyse the geographical patterns of Irish exports. The gravity model in international trade has been demonstrated to be an extremely robust empirical method. The objective of this method is to link trade between country pairs to the factors that work either to attract or to restrict trade. The fundamental factors are the size of the economies (capturing supply and demand) and the distance between them (as a broad proxy for transport costs).

In addition to these basic elements, the literature on gravity models has identified a large number of proxies for trade costs in addition to distance. This paper thus adds variables such as common language, influences of internal geography, and infrastructure. Furthermore, I use new data from the World Bank on the costs associated with importing procedures (Djankov, Freund and Pham, 2010). These include financial costs coming from customs and port fees as well as less tangible costs such as the length of time it takes for imports to be processed and the complexity of the importing procedure, measured by the number of documents that have to be completed for each container-load.

In the first part of this paper, I apply the gravity model to aggregate Irish exports from 1980 to 2007. This was a period in which exports grew dramatically, particularly during the 1990s Celtic Tiger period, and when the geographic patterns of Irish trade also underwent a transformation. The reliance on the UK market declined significantly, with a growing proportion of exports going to Europe and the USA. In common with the stylised

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facts of the gravity regression, distance is found to have a strong negative effect on exports. On the other hand, exports are positively related to sharing a common language and when communications infrastructure is well developed. The gravity model is shown to fit the data extremely well.

The second part of the paper uses firm-level data on indigenous Irish exporters to divide the effects of trade costs into how they influence the number of firms exporting to each market and the average exports per firm. This split into extensive and intensive margins enables us to discuss trade costs in terms of barriers to entry (or fixed costs) and variable costs of trade. Lawless (2008) showed how the Melitz (2003) model predicts that the extensive margin is negatively affected by both fixed and variable trade costs, but that there is no such clear prediction for the intensive margin. This is because an increase in variable costs will reduce the sales of all firms exporting to a given country, but may also result in some of the lowest sales firms exiting the market, thus resulting in an ambiguous effect for *average* sales per firm.

The results from the Irish firm-level data corroborate those from the US data used in Lawless (2008). Most of the trade cost variables affect exports largely through their influence on the extensive margin. Distance has a negative effect on both margins, but the magnitude of the coefficient is considerably larger for the extensive margin. All of the variables capturing language, internal geography, and import cost barriers have significant and appropriately signed effects on the extensive margin. However, almost none of these variables are found to have a statistically significant relationship with the intensive margin.

The final section of the paper divides the firm-level data into four broad sectors to examine if there is any sectoral variation in the standard results. Distance is found to have a particularly strong effect on traditional manufacturing compared to more high technology sectors. The finding that the distance effect works primarily through the extensive margin holds across all sectors. The coefficient for English is highest in the traded services sector, where one would imagine communications to be especially relevant.

The paper is organised as follows. Section 2 discusses the background to the gravity model, its earlier applications to Irish data and how it might be decomposed into firm numbers and average exports components. Section 3 describes the data. Section 4 presents the gravity results for aggregate exports. Section 5 uses the firm level data to examine the relative effects of the gravity explanatory variables on the extensive and intensive margins of trade. Section 6 looks at how these intensive and extensive margin effects differ across sectors. Section 7 concludes.

2. GRAVITY MODEL

The empirical basis for the analysis is the gravity model, which relates trade flows between countries to the size of their markets and the cost of moving goods between them. The gravity approach to modeling trade has a long history, being first used in the 1960s by Tinbergen (1962) and Linnemann (1966). The technique acquired its name from the parallel with the physical force of gravity determined by the combined mass of two bodies and the (inverse square) of the distance between them.

In economics, the gravity approach was initially essentially atheoretical but proved extremely successful empirically in explaining a large proportion of trade flows. The method was also used to explain other types of international flows, most notably migration. The gravity approach was placed on a firmer theoretical basis by Anderson (1979) and Bergstrand (1985). These derivations of the gravity model demonstrate that it is not merely an *ad hoc* data method but is a reduced-form version of a theoretical representation of world trade.
The gravity equation to be estimated for aggregate export sales *S* to country *j* is:

$$\ln(S_j) = \beta_0 + \beta_1 \ln(GDP_j) + \beta_2 \ln(Distance_j) + \beta_X \ln(TradeCosts_j) + u_j$$

The fundamental components of the gravity model are the variables GDP, which captures demand in the destination market, and distance, which provides a broad proxy for the transportation and other costs involved in exporting to country *j*. Gravity models using bilateral data also typically include the GDP of the source country to capture export supply - as we focus on exports for Ireland, the constant term and year dummies capture changes in domestic production. The final term in the equation above, $\beta_X \ln(TradeCosts_j)$, is a vector of coefficients for other trade cost variables. All of these variables will be described in more detail in the data section below. The error term is u_j. The empirical specification is in logs, which results in the coefficients being interpreted as elasticities.

2.1 Previous Gravity Model Research for Ireland

In the first gravity study of Irish trade, Fitzpatrick (1984) notes that the geographical pattern of trade has a number of important implications, such as "determin[ing] the extent to which economic and other developments in individual overseas countries affect the Irish economy. Similarly it will affect the impact on the Irish economy of changes in exchange rates, in international trade regulations, and in international transport costs."

Fitzpatrick used cross-sectional Irish trade data for 1977, with GNP of the trading partner and distance as his main explanatory variables. The paper then focused on the effects of a number of dummy variables representing geographical regions. In particular, membership of the (then) EEC was examined and found to have a strong positive effect on both exports and imports.

More recent research on Irish trade based on the gravity model approach has been to examine if trade with individual partner countries are at, or below, the levels predicted by this regression framework. Two papers have used this method to examine trade flows between the Republic of Ireland and Northern Ireland. Fitzsimons, Hogan and Neary (1999) found that aggregate trade between the two countries was at approximately the level predicted by the model. Morgenroth (2009) replicated their approach using sectoral data and adding a number of additional explanatory factors, including dummy variables for political developments. The results were quite different from those of Fitzsimons, Hogan and Neary, with trade flows estimated as being approximately 80% of the level predicted by the model.

Brühart and Kelly (1999) also used the gravity model to examine if Irish trade was at its predicted level, in this case the partner countries of interest were five Central and Eastern European countries negotiating accession to the European Union.[2] They found that exports from Ireland to these partner countries in 1994 were close to the level predicted, but that imports were less than half of the expected level.

A well-known paper in the gravity literature by Rose (2000) found that membership of a currency union could double the trade volume between two countries. Thom and Walsh (2002) examined if the reverse would hold by examining the Irish break with sterling in 1979. They found no evidence from a gravity analysis or from time-series regressions that the exchange rate change had any appreciable effect on trade between Ireland and the UK. They argue that this result was because, unlike many of the currency unions examined by Rose, both countries were developed and stable and the exchange rate break was not accompanied by any change in free trade arrangements between the two countries.

2.2 Gravity and Firm Export Margins

Almost all of the previous research on the gravity relationship in international trade has focused on aggregated data, which sum up bilateral exports over sectors or whole economies. One reason for this limited focus is that, until recently, researchers have not had access to firm-level data reporting both the quantity and the destination of each firm's exports. However, papers such as Eaton, Kortum, and Kramarz (2004), Bernard, Jensen, Redding and Schott (2007) and Lawless (2008, 2009) have shown how such data can generate substantial insights into the processes underlying international trade.

Eaton, Kortum, and Kramarz (2004) do not explicitly discuss the effect of distance on the pattern of trade, but they report results that indicate the traditional approach to the gravity relationship, based on homogeneous firms within each country, is incorrect. Using a cross-sectional sample of French firms from 1986, they show that the so-called extensive margin of trade (variations in the number of firms that serve export markets) appears to be more important than the intensive margin (variations in average export sales per firm).

Lawless (2008) uses a variant of the Melitz (2003) model to get expressions for the factors that determine the two margins. The model predicts that the extensive margin is negatively affected by both fixed and variable trade costs. There is no such clear prediction for the intensive margin however. For example, an increase in variable costs will reduce the sales of all firms exporting to a given country, but may also result in some of the lowest sales firms exiting the market, thus leaving an ambiguous effect on *average* sales per firm. In addition, the model predicts that sales per firm should be *positively* related to fixed trade costs. Thus, the model predicts that variables such as GDP, which might be expected to be correlated with fixed trade costs, should have a positive effect on sales per firm, while those variables that impact on variable trade costs should show up having

[2] The countries analysed were Poland, Hungary, Czech Republic, Estonia and Slovenia, all of whom have since joined the EU.

a clear effect on the extensive margin (number of firms) and perhaps have little effect on the intensive margin (sales per firm).
These results show how the combination of fixed costs and firm heterogeneity can lead to somewhat counter-intuitive results for the effects of trade costs on the extensive and intensive margins seen in the data, i.e the number of exporting firms and average sales of these firms. The number of firms selling to a market is negatively related to both fixed and variable trade costs, as would be expected. However the same is not true for the average sales per firm. Intuitively, this result can be explained as follows. First consider the effects of variable trade costs. For each individual firm, an increase in variable costs reduces the exports they can sell if they continue to export to market *j*. However, this increase also eliminates some marginal low-sales firms from the market and these two counteracting forces offset each other. As a result, variable trade costs have a much smaller (and under some assumptions, have no effect) on average exports per firm. In contrast, fixed trade costs have no effect on sales of individual firms (once a firm has decided to supply that market) but an increase in these costs removes some marginal firms with low sales from the market. For this reason, average exports per firm depend positively on fixed costs.

The empirical results from US data used in the Lawless (2008) paper largely confirm this prediction. Most of the variables affected exports largely through their influence on the extensive margin. Distance has a negative effect on both margins, but the magnitude of the coefficient is considerably larger for the extensive margin. All of the variables capturing language, internal geography, and import cost barriers have significant and appropriately signed effects on the extensive margin. However, almost none of these variables are found to have a statistically significant relationship with the intensive margin. Of the variables that have a significant effect on the intensive margin, the proxies for communications infrastructure initially appear to have the wrong sign, although this counterintuitive result is in fact in keeping with the ambiguous predictions of the model for the influence of trade costs on average sales. The results show that the only factor to consistently affect the intensive margin is the size of the market.

3. DATA

3.1 Aggregate Exports

The data on aggregate Irish exports comes from the IMF Direction of Trade Statistics (DOTS) and covers exports from Ireland to 137 destination countries from 1980 to 2007. Table 1 shows the breakdown by region of aggregate Irish exports and how they have evolved from 1980 to 2007. The most striking aspect of these figures is the relative decline in the importance of the UK as a destination market. Exports to the UK made up 46.3% of total Irish exports in 1980, but this share fell rapidly over the following two decades. By 2001, the UK accounted for 24.5% of Irish exports. The share of exports to the UK market then steadied somewhat with the relative contribution still declining but at a much slower pace so that by 2007 UK sales made up 22.3% of total exports.

To a large extent, the UK was replaced over this period as the dominant market by the US, whose share of Irish exports rose from 7.1% in 1980 to 21.2% in 2007. Most of this growth in the share of the US market was concentrated in the 1995-2001 export boom period, when the US share almost doubled (from 10% in 1995 to 19.2% in 2001). The share of Irish exports going to the EU-15 (excluding the UK) grew strongly in the 1980s and early 1990s (from 33.3% in 1980 to 46.3% in 1995). However, much of this increase was later reversed and by 2007 the EU-15 accounted for 34% of Irish exports, not substantially different from the position of the early 1980s. The share of Irish exports to the new member states of the EU (the EU-10) doubled between 2001 and 2007, although these countries still account for a very small percentage of total exports (1.4% in 2007).

The share of Irish exports to South America and Africa declined over this period and the share to the Middle East region was broadly unchanged. The strong economic growth in Asian countries throughout the 1990s is reflected in the increased share of Irish exports being sold in that region. The share of exports to Asia increased from 1.5% in 1980 to 9.3% in 2001, with this latter share staying relatively constant for the remainder of the 2000s.

3.2 Firm Exports

The micro-level firm data used in this paper come from a survey of Irish firms undertaken by Enterprise Ireland and Forfás, previously used in Lawless (2009).[3] The focus of the survey is on Irish-owned and predominantly exporting firms and it records detailed information on exports to over fifty individual markets from 2000 to

[3] This is the Irish national policy advisory board for enterprise, trade and technology, which operates under the Government Department of Enterprise, Trade and Employment.

2004. This paper aggregates this data over the 53 countries to get a series for number of exporters and average exports per firm for each country in each year.
Comparing the total exports of the firms covered by this survey to the census totals from the Irish Central Statistics Office (2000-2004), our data cover approximately two-thirds of exports from Irish-owned firms. This was a period during which exports did not change much: The aggregate data show export growth of 3% in 2000-2001, followed by a significant decline over the next three years, falling by over 10% in 2001-2002 for example. The survey data used in this paper follow a similar but slightly less extreme pattern, the decline in 2001-2002 is 5% and a return to positive growth is observed by the end of the sample (see Table 1). This difference is likely due to a slight under-representation of small firms in our sample. The export participation patterns of these firms tend to be more volatile.[4]

That the firms are Irish-owned is an aspect of the sample selection that must be emphasised, as foreign-owned firms dominate aggregate Irish exports; this is primarily due to a history of economic policy focused on encouraging export platform foreign direct investment (FDI) to the country. In 2004, foreign owned companies accounted for just over 90 per cent of the country's manufacturing exports (Central Statistics Office, 2004). Therefore, although the current sample can be considered representative of indigenous Irish exporting firms, this constitutes only a small proportion of overall Irish exports. Although having similar data on foreign-owned exporters would extend the scope of the analysis, the Irish experience of FDI-dominated exports is far from being a common occurrence. So, it is probably fair to conclude that understanding the export decisions and patterns of indigenous Irish firms is more likely to yield conclusions that apply more broadly across countries.

3.3 Destination Variables

The explanatory variables at the country level come from a number of sources. Data on GDP is taken from the Penn World Tables (Heston, Summers and Aten, 2006), and distance between capital cities comes from Jon Haveman's website, a standard source of gravity data.[5] The GDP of the importing country is a key trade-creating variable in the gravity model, indicating the total demand in that country and is, therefore, expected to have a positive effect on trade. The geographical distance between the importing and exporting countries can be thought of as a proxy for transport costs, a significant factor in inhibiting trade flows. As such, this variable is expected to be negatively signed.

Ability to communicate in a common language is predicted to reduce the costs of trade. We use two measures for English as a common language. The first is the formulation generally used in the gravity literature, that is a dummy variable for English as (one of the) official language(s) in the destination market. We also use a more detailed measure to capture the extent to which English is spoken as a second language, regardless of its official status. Jacques Melitz (2008) demonstrates how important ability to communicate is to trade and how this is underestimated by the use of a binary official language variable. He uses a range of measures of linguistic diversity to capture this effect. The measure I use is much simpler, as the data originate from a single English-speaking source country and data is more readily available on the extent of usage of English as a first or second language. The data used comes from a variety of sources, compiled by the on-line encyclopaedia Wikipedia.[6]

Distance is the main indicator of transport costs used in the gravity model. Even if the assumption that transport costs are an increasing function of distance holds (which seems reasonable), there is still the problem that countries are not "dimensionless points" (Schumacher, 1997). Transport costs also exist within countries, particularly in large ones or those with poor infrastructure. To capture effects of internal geography and level of development, we use a number of infrastructural and access variables from World Bank World Development Indicators. To augment the market size variable, we use two additional measures to capture how easily the exporting firm can gain access to this market. The physical size of the country (area in square kilometres) is used to proxy for internal transportation costs. The share of population in urban areas is also used as an indicator of internal geography that might make it easier for the exporter to reach a large proportion of the market without having to set up a very large distribution network. In terms of communications infrastructure, access to information on the market can make it easier for a firm to investigate the market and to conduct business (Anderson and van Wincoop, 2003 and 2004). We use the extent of telephone and computer usage to proxy for the ease of information gathering and running a business abroad.

[4] Gleeson and Ruane (2006) discuss the contribution by firm size in their decomposition of export participations and growth of Irish firms.
[5] http://www.macalester.edu/research/economics/PAGE/HAVEMAN/Trade.Resources/Data/Gravity/dist.txt
[6] From http://en.wikipedia.org/wiki/List_of_countries_where_English_is_an_official_language and http://en.wikipedia.org/wiki/List_of_countries_by_English-speaking_population.

Data on administrative costs of international trade come from the Doing Business Survey, undertaken by the World Bank in 2005 (for a detailed description see Djankov, Freund and Pham, 2008). The costs detailed in this data source relate to customs inspections, storage and handling at the port and documentation required in the importing country. The costs are compiled on the basis of a homogeneous import good; specifically, the cost is that of processing a dry-cargo, 20-foot container requiring no special treatment such as refrigeration or environmental safety standards. Three variables are used to capture the administrative costs of trade: The first is the number of documents that must be filled to import the container into the country, the second is the average length of time in days it takes for all the technical and customs procedures to be completed and the third is the cost of all the fees associated with customs clearance and handling at the port (but does not include taxes or tariffs). The importance of time delays in trading and the associated costs of storage and depreciation (particularly of time-sensitive products such as fresh produce) has been examined by Hummels (2001), who estimated that each day saved in transporting manufactured goods is worth 0.8 percent ad-valorem.

Finally, although there has been a recent move towards including country fixed effects in gravity regressions, we do not do so here. As the data is based on a single source country, the use of fixed effects would mean excluding all other fixed variables (e.g. distance) and would result in a considerable loss of information on these variables.

4. GRAVITY MODEL OF TOTAL EXPORTS

Table 2 presents the gravity results for total Irish exports to 137 destination markets over the period 1980 to 2007. The dependent variable in each specification is the log of export sales from Ireland to the individual destination (j) in each year X_{jt}. The first specification includes destination GDP, distance to the foreign market and a dummy variable for English as an official language. Year dummies are included in all specifications. The results in the first column are as predicted - market size has a significantly positive effect on export flows and distance has a strong negative effect. The empirical attraction of the gravity model can be seen in Figure 1, which demonstrates the high fit of the model by plotting the actual export values for each destination in 2007 against the linear predictions from the basic gravity specification. The correlation coefficient for the two series is 0.88.

One interesting question that could be asked at this stage is how much the distance effect has changed over time. We ran the benchmark gravity regression separately for each of the years 1980 to 2007 and plot the distance coefficients in Figure 2. The coefficients fluctuate from year to year but most values are within two standard deviations and the coefficients do not show any particularly strong trend, certainly not one that would be indicative of "death of distance."

Sharing a common language appears to ease the process of conducting business across international borders with a significant positive impact on exports. The fit of this very reduced form model, with just three explanatory variables, is extremely good with a R^2 of 0.79. The second column of Table 2 uses a more refined language measure to capture the fact that English is widely spoken even if it is not an official language of a country. Using the percentage of English speakers we find an elasticity of 0.2. This measure also increases the model's R^2 to 0.86. However, data on the percentage of English speakers was available for only about half of the countries in the sample so the number of observations is much lower.

The second panel of Table 2 looks at the effects of adding variables to capture internal transport costs of the destination market, to supplement the standard transport cost proxy of distance to the capital city. The physical area (square kilometres) of the destination market is used as an indicator of these additional transport costs. We find that they are negatively associated with exporting, although to a lesser degree than the distance to the country. The area of the country, therefore, adds to the costs of exporting, but this might be mitigated if a large proportion of the population are concentrated in cities. A high urban population would enable the firm to access a large proportion of the market with lower transportation costs (although other costs of doing business in cities could be higher than in rural areas). The finding of the gravity model is that a high percentage urban population has a positive effect on exports, perhaps indicating that the reduction in transport costs dominate.

The next panel adds two different proxies for communications infrastructure - the numbers of phones and computers per 100 people. Both of these measures have positive and significant coefficients for their relationship with export sales. In terms of the model's fit, the computer variable is one of the most successful, with an R^2 of 0.83.

The final panel of Table 2 includes the measures of import costs in each destination country from the World Bank Doing Business Survey. As discussed in the Data section earlier, there are three measures collected for the costs of processing imports at the country level. The first is the number of documents that have to be completed before the container can be released from the port of arrival. This indicator of the level of bureaucracy associated with exporting has a significantly negative effect on the level of exports. The amount of time that the importing process takes also has an inhibiting effect on trade. The third measure from the Doing Business survey is how much it costs to process each container of goods being imported and has the expected negative sign.

5. FIRM-LEVEL EXPORTS

The distribution of the number of export markets is shown in Figure 3. Consistent with the findings of Eaton, Kortum and Kramarz (2004) for France and of Bernard, Jensen and Schott (2009) for US firms, the distribution across markets is very skewed. Most firms export to only a small number of markets, with over one-third exporting to a single market. The average number of markets exported to over the five-year period was 5.9, with a median of 2.8 (see also Lawless, 2009). The average number of destination markets per firm is higher than was found by Bernard, Jensen and Schott (2009). The firms in their analysis exported to 3.3 markets in 2000. The highly skewed nature of the distribution is common across the Irish, French and US firms. Only 17% of the firms in this paper export to more than 10 markets and just 3% to more than 25. Eaton, Kortum and Kramarz (2004) found approximately 20% of firms exporting to more than 10 markets and reported 1.5% exporting to over 50.

In further comparisons of exporting firms in Table 3, we find some consistent differences in the characteristics of firms selling in many markets relative to those in a small number of markets. Firms with greater market coverage tend to be larger in terms of employment and there is some evidence suggesting they are more productive. Firms selling in multiple markets have a fairly similar level of exports per market as those in only one or two markets. This result initially appears counterintuitive given that these firms with many markets are larger and export much more in total. The apparent puzzle is resolved when exports to a particular market are compared. Taking the UK as an example because it is the market most firms export to, firms with more export markets export much more to the UK than do firms with few export markets. The measurement of exports per market for firms with many markets is reduced because they also export to some small markets. This denotes a pattern of firm export growth in which firms both increase exports to their existing markets and expand their portfolio of markets into new destinations.

The number of firms exporting to individual markets is shown in Table 4. Unsurprisingly, given its proximity and historical links, the UK is the predominant export destination for Irish exporters. The 584 firms who sell at least some of their exports to this market represent 94% of the sample. The second largest market (the USA) has less than half of the number of firms exporting to it than the UK. With the exception of the US, the top ten markets for Irish firms are all located in Western Europe, an ordering very much in keeping with the predictions of a standard gravity model. Figure 4 plots the relationship between the (log) number of firms and average exports per firm by destination. The strong positive correlation is in agreement with the predictions of the model, where a number of factors such as productivity and variable trade costs have similar effects on both margins.

5.1 Gravity Model of Intensive and Extensive Margins

This section presents the results of the gravity model for total trade and separates the effects into those coming from the number of firms exporting and the average exports per firm. As in Bernard, Jensen, Redding and Schott (2007), the aggregate export sales S to country j are decomposed into the number of firms exporting to the destination, N_j and the average exports per firm S/N. This decomposition can be expressed in log form as:

$$\ln S_j = \ln N_j + \ln(S_j/N_j)$$

Each of the three components (total exports, number of firms and average exports) are regressed on a range of variables that might be expected to have an effect on the costs of trading internationally:

$$\ln Z_j = \alpha + \beta \ln D_j + \gamma \ln GDP_j + \delta X_j + \varepsilon_j$$

where Z represents either total sales, number of exporters or average exporters, D is bilateral distance, GDP is destination GDP and X is a range of other factors proxying for trade costs. Finally, ε is a stochastic error term. The gravity model generally includes both importer and exporter income as explanatory variables: however, as

we use data on exporting from a single source country, its income level will be picked up in the regression constant. As is standard in the gravity literature, all the variables are expressed in logs, allowing us to interpret the coefficients as elasticities. Using OLS means that the coefficients on number of firms and average sales will sum to give the coefficient on total exports.

The first subsection reports the results of the basic gravity formulation, using market size, distance and common language. The second subsection then augments the model by adding further variables that may influence the costs of exporting, such as infrastructure indicators and bureaucracy measures.

5.2 Basic Gravity Results

The benchmark gravity model, using just GDP and distance as explanatory variables, is presented in Table 5. The results for total exports show, as expected, a significant negative relationship between trade and distance and a significant positive coefficient on destination GDP. The distance coefficient on total trade is -0.71. This is slightly lower than the average distance elasticity of -0.9 found by Disdier and Head (2008) in a meta-analysis of 103 gravity model papers. They found that 90% of estimates were between -0.28 and -1.55, so our result is well within the standard range.

Splitting the total trade into the number of firms and average exports shows that most of the distance effect is working through inhibiting entry: the coefficient on the extensive margin is -0.53, almost three-quarters of the total effect. The effect on average exports is also negative but is considerably smaller and significant only at the 10% level. As predicted by the theory, the effect of trade costs on average exports has off-setting effects by changing the threshold for entry as well as the total sales. As distance is a proxy for these trade costs, it should be expected that its effect on the intensive margin therefore appears weaker than on the extensive margin, where trade costs work in a single direction.

The decomposition of the GDP effect is more equal across the two margins: the total effect of 0.83 is made up of a coefficient of 0.39 on the extensive margin and 0.44 on the intensive margin. Regarding the fit of the model, a feature of all our specifications is that the R^2 is always higher, sometimes almost double, for number of firms compared to average exports. Again this is probably due to the offsetting effects trade costs can have on average sales, the extent of which can vary across countries.

Comparing these to results for US exports in Lawless (2008), the coefficient on distance for the Irish data of -0.71 is quite a bit lower than the finding for the US of -1.32. As Ireland is a much smaller and more open economy than the US, it is not particularly surprising that these coefficients are dissimilar. Interestingly, however, the relative contributions of the extensive and intensive margins to the total effect are very close: 75% of the effect for Ireland is through the number of firms and this margin accounts for 80% of the effect of distance for the US. The effect of GDP is more comparable across the two countries (0.83 in Ireland and 0.94 in the US), with the importance of the number of firms margin being stronger in the US in this case. The GDP effect for Irish exports works almost equally through both margins.

Table 6 adds the alternative measures of common language to the basic gravity specification. Both the dummy variable for English as an official language and the percentage of the population who speak English is positively related to total trade. This effect works entirely through the extensive margin. Regardless of how it is measured, the common language variable has no significant impact on average sales.

5.3 Infrastructure Variables

This section augments the gravity model by including additional variables that might be expected to affect the costs of trading internationally. The distance coefficient captures the costs of transportation to the foreign market. Further costs of transportation are likely to be incurred within the country and Table 7 presents results for two proxies of internal geography that may influence these costs. The first is the physical area of the country, which should increase the costs of supplying that market and, as one would expect, it has a negative coefficient on total trade. This is not a perfect measure of course, as population is rarely evenly distributed within a country. For that reason, we also add a measure of population concentration, in this case the percentage of the population living in urban areas.[7]

The urban share of population has a positive effect on total exports and when this factor is added to the regression, the area measure becomes insignificant. Thus, one could say that markets where consumers are

[7] Population density would be an alternative but can be misleading, particularly in countries that have relatively large areas that are uninhabited.

relatively highly concentrated are more accessible for exporters. A reasonable assumption would be that this concentration reduces the costs, not just of transportation, but possibly also of marketing and administration in general. The division of the effects of these internal geography measures show that both work entirely through the extensive margin of trade. Once again, we also find that we are able to explain much more of the variation in the extensive margin than we are of the intensive margin, as evidenced by the differences in the R^2 (0.65 for the extensive margin in the second panel of Table 5 compared to 0.38 for the intensive margin).

The effect of a country's size on trade costs depends to a large extent on the quality of infrastructure. Communications infrastructure is likely to be especially important in facilitating trade across countries. Table 8 presents results including measures of the extent of telephone and computer networks, as indicators both of the ease of transacting business for firms in the market and also for accessing information prior to an entry decision. Both of the measures have positive and significant effects on total trade, with the number of computers per thousand performing somewhat better in terms of model fit. Our main finding of trade costs working mainly through the number of firms margin finds further support, with no significant effect on average sales detected. A further interesting finding is that distance, the foundation variable for the gravity model, is not significant for average export sales when the communications variables are included (although it should be noted that distance was only just significant at the 10% level in the other specifications).

5.4 Business Costs

The Doing Business Survey, conducted by the World Bank, provides the measures for costs of import processing in the destination country, both financial and in terms of the burden of paperwork and time. As the measures are all relatively highly correlated, they are entered into the specification separately, the results of which are presented in Table 9. The administrative complexity of the importing process, as measured by the number of documents that need to be completed, is negatively associated with total trade and with the number of firms exporting to the market. The length of time required to fulfil all the necessary requirements has a similar effect. The financial cost is negative, albeit not statistically significant, in terms of its effect on total trade but does have a significant negative relationship with the number of exporters. None of these trade costs measures have any noticeable impact on average sales.

Drawing all of the elements together, Table 10 presents results for an extended gravity model that includes a range of trade cost variables in addition to the standard elements of GDP and distance. The results remain comparable to when the costs are entered separately, with statistically significant coefficients for the variables' effects on number of firms and not on average exports. The exception is the percentage of the population in urban areas, which is now significant in the average exports regression. The fit of this extended model is considerably higher relative to the benchmark model containing just GDP and distance. The R^2 for the total trade column has increased from 0.50 to 0.62. The extra trade cost variables do particularly well in explaining the variation in number of firms; the R^2 of the extended model is 0.78 compared to 0.50 for the benchmark. On the other hand, there is very little improvement in the fit of the average firm exports regression (0.39 in the extended model compared to 0.35 in the benchmark). The lack of improvement in fit and the generally insignificant coefficients for the average exports regressions are consistent with the predictions of the model, because the impact of trade costs were shown to have an ambiguous effect on this intensive margin.

6. SECTOR DIFFERENCES IN GRAVITY EFFECTS

This section divides the data on Irish exporters into broad sectors to examine if there are any sectoral differences in sensitivity to the main explanatory variables of the gravity model. Four broad sector categories are used - Food and Drink; Traditional Manufacturing; High-Tech Manufacturing; and, Internationally Traded Services.

6.1 Sector Export Characteristics

Table 11 presents some summary statistics on export firms across these four sectors. As we saw for all firms in Figure 3, the distribution of number of export markets is very skewed and in each of the sectors the median number of markets is considerably lower than the average. There is considerable variation across the sectors in the number of markets exported to. Firms in high-tech manufacturing export to the most markets, with 9.7 destinations on average and a median of 6. In contrast, the traditional manufacturing sector exports to an average of 3.5 markets with the median being a single destination. The food and drink sector and internationally traded services both export to an average of between 5 and 6 markets.

Although the food and drink and traded services sectors have similar current levels of export destinations, a look at the average entry and exit rates over the five years of data show them moving in different directions. The firms in the food and drink sector have an average addition of 0.42 markets annually and exit from -0.44,

resulting in a net reduction of -0.02 in the average market coverage per year. Traded services has an average market entry rate of 0.55 and an exit rate of -0.45, thus expanding market coverage at a rate of 0.1 markets annually. The export market expansion of high-tech manufacturing is even more rapid, with an entry rate of 0.78 markets whilst exiting an average of -0.54 markets. Traditional manufacturing has expanded its average number of markets over the period, but at the considerably slower pace of just 0.02 markets per year.

The importance of the UK as an export destination also varies significantly across sectors, in general being inversely related to the average number of export markets. Traditional manufacturing remains the most reliant on the UK, with 58% of exports being sold there. In traded services, on the other hand, the UK accounts for 25% of exports and in high-tech manufacturing the UK market accounts for 36%.

6.2 Sector Gravity Results

Table 12 replicates the first panel of Table 6 separately for each of the four broad sectors. Once again, there are three dependent variables (total sector exports, number of exporting firms and average firm exports) and the explanatory variables used are GDP, distance and a dummy for English as an official language. There are sizable differences in the effects of these explanatory variables across the sectors, which we will compare for each of the variables.

We look first at the effect of distance and recall from Table 6 that the aggregate coefficient was -0.87 with a standard error of 0.15. Of the four sectors, three come within one standard error of this aggregate coefficient. Traditional manufacturing is the exception; with a distance coefficient of -1.54 it is almost 50 per cent more sensitive to distance than the other sectors. The higher coefficient on distance for traditional manufacturing, which would frequently (although not exclusively of course) include bulky or heavy goods with higher transport costs seems fairly intuitive.

More surprising is that the coefficient for the distance effect on internationally traded services is -1.03, higher than the value for total trade. Intuitively, one would expect services to be less sensitive to distance than goods as transport costs are not as applicable. However, the results in the literature on services exports find very mixed results on the effect of distance, with most finding a similar effect to that of total trade but others finding no significant effect at all (see Walsh, 2006, for a review).

Next we decompose the distance coefficients into their component effects on numbers of exporting firms and average exports per firm. We find that the effect on firm export participation is the stronger effect in three of the sectors, with the exception of high-tech manufacturing where the distance effect appears to operate almost equally on both margins. The GDP coefficients vary very little across sectors for total exports, and the relative effects on number of firms and average sales are also broadly similar in each sector. High-tech manufacturing is something of an exception once again, with the destination GDP having a particularly strong effect on average sales (0.60 out of a total export effect of 0.85).

The English dummy coefficients are almost twice as high for traditional manufacturing and services as they are in the other two sectors. For traditional manufacturing, the dominance of the UK as a destination is the most likely explanation. The strong effect of language on services exports is perhaps determined more by the nature of the products for which ease of communication is a key consideration.

7. CONCLUSIONS

The gravity model relating trade flows to GDP and proxies for trade costs is one of the most empirically successful in international economics. This paper uses the gravity methodology to analyse the patterns of Irish exports, both at the aggregate level and, more innovatively, at the firm and sector level.

The gravity model is first applied to aggregate Irish exports from 1980 to 2007. In common with the stylised facts of the gravity regression, distance is found to have a strong negative effect on exports. In addition to the standard gravity variables of size and distance, we add factors such as common language, internal geography and communications infrastructure. Furthermore, we use new data from the World Bank on the costs associated with importing procedures, including both financial costs coming from customs and port fees, the length of time it takes for imports to be processed and the complexity of the importing procedure. Exports are found to be strongly positively related to sharing a common language and when communications infrastructure is well developed.

This paper expands on the traditional gravity approach by using a unique survey of Irish firms over a five-year period, which contains detailed information on exports to over fifty markets. This firm level data is used to decompose the gravity model into an extensive (number of firms) and intensive (average export sales per firm) margin.

Theoretical predictions suggest that the extensive margin is negatively affected by both fixed and variable trade costs, but the prediction for the intensive margin contains counteracting terms whose overall sign is unclear. Consistent with the theory, all of the variables capturing language, internal geography, and import cost barriers have significant and appropriately signed effects on the extensive margin. However, almost none of these variables are found to have a statistically significant relationship with the intensive margin.
The final section of the paper divides the firm-level data into four broad sectors to examine if there is any sectoral variation in the standard results. Distance is found to have a particularly strong effect on traditional manufacturing compared to more high technology sectors. The finding that the distance effect works primarily through the extensive margin holds across all sectors. The coefficient for English is highest in the traded services sector.

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Table 1. Destinations of Aggregate Irish Exports
(Percentage of Current Value)

	1980	1987	1995	2001	2007
UK	46.3	36.6	27.8	24.5	22.3
EU-15 (excl. UK)	33.3	40.5	46.3	36.6	34
EU-10	0.6	0.3	0.6	0.7	1.4
Other Europe	1.7	3.2	3.7	4.6	5.8
North America	7.1	9.5	10	19.2	21.2
South America	2.2	1.3	1.1	1.4	1.6
Middle East	1.6	1.8	1.6	1.4	1.6
Oceania	0.7	1.1	0.7	1.1	1.3
Africa	5.0	2.5	1.7	1.2	1.5
Asia	1.5	3.2	6.4	9.3	9.2

Table 2. Gravity Model of Total Irish Exports

Ln Distance	-1.13***	-0.68***	-0.92***	-0.86***	-0.85***	-0.81***	-0.81***	-0.80***	-0.99***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Ln GDP	1.02***	0.92***	1.11***	0.94***	0.91***	0.92***	0.98***	0.92***	0.99***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
English dummy	0.76***								
	(0.05)								
Ln % English		0.22***							
		(0.02)							
Ln Area			-0.19***						
			(0.01)						
Ln Urban Pop.				0.82***					
				(0.05)					
Ln Phones					0.39***				
					(0.02)				
Ln Computers						0.46***			
						(0.02)			
Ln Import Docs							-1.60***		
							(0.08)		
Ln Import Time								-0.95***	
								(0.04)	
Ln Import Cost									-0.65***
									(0.04)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.79	0.86	0.79	0.78	0.79	0.83	0.81	0.82	0.80
Observations	3657	1528	3657	3178	3593	3394	3434	3434	3434

Notes: Standard errors in parentheses: *** indicates significance at 1% level, ** at 5% and * at 10%.

Table 3. Firm Characteristics and Market Coverage (Average 2000-2004)

Markets	Employment	Sales per Emp.	Exports	Sales per Market	UK Sales
1	55	134	1978	1978	1878
2	55	115	2681	1341	2191
3	106	130	5995	1998	4482
4	71	121	4771	1193	2627
5	85	121	6375	1275	3986
6-10	121	174	10979	1391	5073
11+	166	246	29095	1509	8611

Table 4. Average Number of Exporters by Destination, 2000-2004

	Exporters		Exporters
UK	584	Saudi Arabia	40
USA	228	Hong Kong	36
Germany	213	Hungary	38
France	210	China	39
Netherlands	183	S. Korea	31
Italy	144	Taiwan	32
Spain	136	India	35
Belgium	139	Brazil	23
Sweden	122	New Zealand	33
Denmark	110	Malaysia	31
Portugal	76	Egypt	26
Switzerland	87	Philippines	21
Japan	75	Argentina	19
Norway	74	Kuwait	23
Canada	71	Mexico	24
Austria	69	Lebanon	17
Finland	78	Nigeria	22
Poland	61	Slovak R.	14
Australia	65	Slovenia	19
South Africa	56	Jordan	17
Greece	59	Thailand	20
Russia	43	Pakistan	17
Israel	53	Chile	15
Turkey	41	Algeria	7
Czech R.	46	Morocco	8
UAE	44	Tunisia	5
Singapore	40		

Table 5. Benchmark Gravity Model

	Ln Total Exports	Ln Number of Firms	Ln Average Firm Exports
Ln Distance	-0.71***	-0.53***	-0.18*
	(0.17)	(0.10)	(0.10)
Ln GDP	0.83***	0.39***	0.44***
	(0.14)	(0.07)	(0.08)
Year Dummies	Yes	Yes	Yes
R2	0.50	0.50	0.35
Observations	252	252	252

Notes: Robust standard errors in parentheses, adjusted for clustering by country.

*** indicates significance at 1% level, ** at 5% and * at 10%.

Table 6. Common Language

	Ln Total Exports	Ln Number of Firms	Ln Average Exports	Ln Total Exports	Ln Number of Firms	Ln Average Exports
Ln Distance	-0.87***	-0.62***	-0.25**	-0.61***	-0.43***	-0.18*
	(0.15)	(0.07)	(0.11)	(0.16)	(0.09)	(0.10)
Ln GDP	0.79***	0.37***	0.42***	0.78***	0.34***	0.44***
	(0.12)	(0.07)	(0.07)	(0.14)	(0.07)	(0.08)
English Dummy	0.93**	0.53***	0.39			
	(0.36)	(0.20)	(0.25)			
Ln % English				0.17**	0.17***	-0.01
				(0.08)	(0.05)	(0.05)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.54	0.55	0.38	0.53	0.60	0.35
Observations	252	252	252	252	252	252

Notes: Robust standard errors in parentheses, adjusted for clustering by country.
*** indicates significance at 1% level, ** at 5% and * at 10%.

Table 7. Accessibility

	Ln Total Exports	Ln Number of Firms	Ln Average Exports	Ln Total Exports	Ln Number of Firms	Ln Average Exports
Ln Distance	-0.65***	-0.48***	-0.17*	-0.65***	-0.47***	-0.18*
	(0.16)	(0.10)	(0.10)	(0.15)	(0.08)	(0.10)
Ln GDP	0.99***	0.53***	0.45***	0.97***	0.53***	0.44***
	(0.16)	(0.09)	(0.09)	(0.14)	(0.08)	(0.08)
Ln Area	-0.16**	-0.14***	-0.02	-0.09	-0.10**	0.01
	(0.07)	(0.05)	(0.05)	(0.09)	(0.05)	(0.06)
Ln Urban Pop.				1.60**	1.05***	0.54
				(0.61)	(0.22)	(0.46)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.53	0.57	0.35	0.58	0.65	0.38
Observations	252	252	252	247	247	247

Notes: Robust standard errors in parentheses, adjusted for clustering by country.
*** indicates significance at 1% level, ** at 5% and * at 10%.

Table 8. Communications Infrastructure

	Ln Total Exports	Ln Number of Firms	Ln Average Exports	Ln Total Exports	Ln Number of Firms	Ln Average Exports
Ln Distance	-0.55***	-0.38***	-0.18	-0.57***	-0.40***	-0.17
	(0.17)	(0.09)	(0.11)	(0.15)	(0.07)	(0.10)
Ln GDP	0.82***	0.39***	0.44***	0.79***	0.36***	0.43***
	(0.13)	(0.06)	(0.08)	(0.12)	(0.05)	(0.08)
Ln Telephones	0.58**	0.56***	0.03			
	(0.24)	(0.14)	(0.16)			
Ln Computers				0.41***	0.36***	0.05
				(0.12)	(0.06)	(0.08)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.56	0.68	0.36	0.6	0.73	0.36
Observations	247	247	247	247	247	247

Notes: Robust standard errors in parentheses, adjusted for clustering by country.

*** indicates significance at 1% level, ** at 5% and * at 10%.

Table 9. Procedures and Costs of Trade

	Ln Total Exports	Ln Number of Firms	Ln Average Exports	Ln Total Exports	Ln Number of Firms	Ln Average Exports	Ln Total Exports	Ln Number of Firms	Ln Average Exports
Ln Distance	-0.60***	-0.42***	-0.19*	-0.63***	-0.45***	-0.18	-0.73***	-0.55***	-0.18*
	(0.18)	(0.10)	(0.10)	(0.18)	(0.09)	(0.10)	(0.17)	(0.09)	(0.10)
Ln GDP	0.83***	0.39***	0.44***	0.80***	0.36***	0.44***	0.87***	0.43***	0.44***
	(0.13)	(0.06)	(0.08)	(0.12)	(0.06)	(0.08)	(0.16)	(0.09)	(0.08)
Ln Import Documents	-0.80**	-0.85***	0.05						
	(0.34)	(0.19)	(0.23)						
Ln Import Time				-0.66***	-0.64***	-0.02			
				(0.22)	(0.11)	(0.15)			
Ln Import Cost							-0.64	-0.54**	-0.10
							(0.39)	(0.24)	(0.23)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.53	0.61	0.35	0.56	0.67	0.35	0.53	0.56	0.36
Observations	252	252	252	252	252	252	252	252	252

Notes: Robust standard errors in parentheses, adjusted for clustering by country.

*** indicates significance at 1% level, ** at 5% and * at 10%.

Table 10. Extended Gravity Model

	Ln Total Exports	Ln Number of Firms	Ln Average Exports
Ln Distance	-0.54***	-0.33***	-0.21***
	(0.08)	(0.04)	'(0.06)
Ln GDP	0.89***	0.41***	0.48***
	(0.08)	(0.03)	(0.06)
Ln % English	0.19***	0.16***	0.03
	(0.04)	(0.02)	(0.03)
Ln Import Time	-0.01	-0.12*	0.11
	(0.17)	(0.07)	(0.12)
Ln Area	-0.07	-0.06***	-0.02
	(0.05)	(0.02)	(0.04)
Ln Urban Pop.	1.60***	0.65***	0.95***
	(0.36)	(0.15)	(0.27)
Ln Phones	0.05	0.22***	-0.17
	(0.15)	(0.06)	(0.11)
Year Dummies	Yes	Yes	Yes
R2	0.62	0.78	0.39
Observations	247	247	247

Notes: Robust standard errors in parentheses, adjusted for clustering by country.
*** indicates significance at 1% level, ** at 5% and * at 10%

Table 11. Sector Summary Statistics

	Food & Drink	Traditional Manufacturing	High-Tech Manufacturing	Traded Services
Average Markets	5.8	3.5	9.7	5.1
Median Markets	3	1	6	2
Average Entry	0.42	0.29	0.78	0.55
Average Exit	-0.44	-0.27	-0.54	-0.45
% Exports to UK	45	58	36	25
% Total Firms	19	47	11	23
Average Export Growth	1	0.7	0.6	2.4

Table 12. Sector-Level Gravity Model

	Ln Total Exports	Ln Number Firms	Ln Average Exports
Food and Drink			
Ln Distance	-0.83***	-0.61***	-0.22**
	(0.12)	(0.05)	(0.09)
Ln GDP	0.80***	0.35***	0.45***
	(0.08)	(0.03)	(0.06)
English Dummy	0.65**	0.29***	0.36*
	(0.28)	(0.11)	(0.20)
R2	0.36	0.52	0.22
Observations	248	248	248
Traditional Manufacturing			
Ln Distance	-1.54***	-0.92***	-0.62***
	(0.11)	(0.07)	(0.07)
Ln GDP	0.88***	0.42***	0.46***
	(0.08)	(0.04)	(0.05)
English Dummy	1.62***	0.82***	0.80***
	(0.25)	(0.15)	(0.16)
R2	0.57	0.55	0.43
Observations	249	249	249
High-Tech Manufacturing			
Ln Distance	-0.94***	-0.45***	-0.49***
	(0.10)	(0.04)	(0.08)
Ln GDP	0.85***	0.25***	0.60***
	(0.07)	(0.03)	(0.05)
English Dummy	0.76***	0.22***	0.54***
	(0.22)	(0.08)	(0.17)
R2	0.51	0.5	0.43
Observations	245	245	245
Traded Services			
Ln Distance	-1.03***	-0.59***	-0.44***
	(0.12)	(0.05)	(0.10)
Ln GDP	0.72***	0.38***	0.34***
	(0.08)	(0.03)	(0.07)
English Dummy	1.24***	0.53***	0.71***
	(0.27)	(0.10)	(0.23)
R2	0.38	0.57	0.17
Observations	251	251	251

Notes: Robust standard errors in parentheses, adjusted for clustering by country.
*** indicates significance at 1% level, ** at 5% and * at 10%.

Figure 1

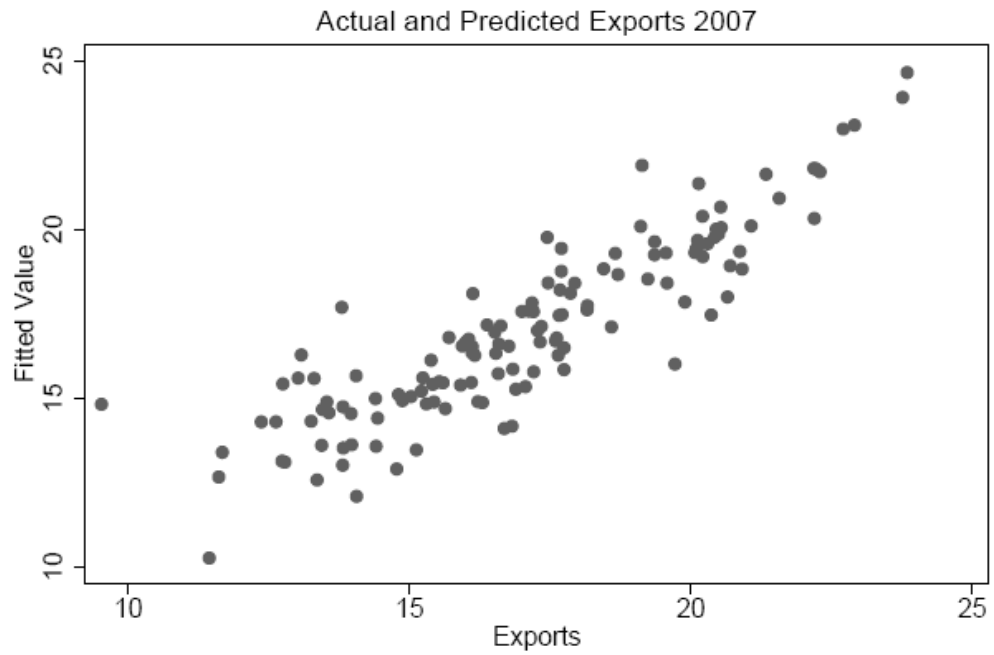

Figure 2

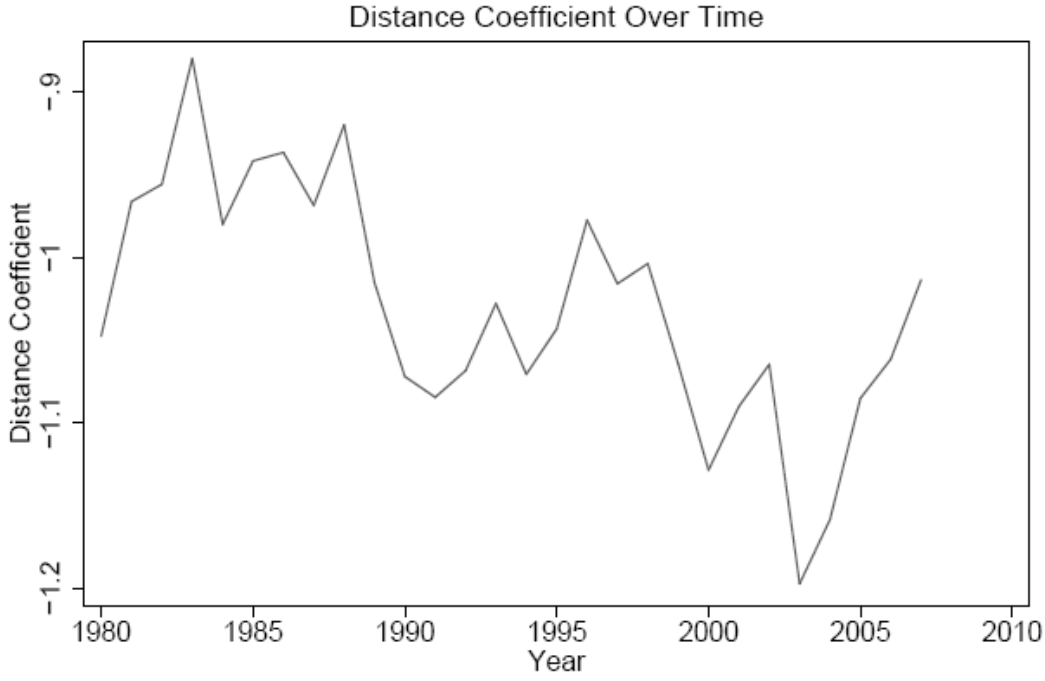

Figure 3

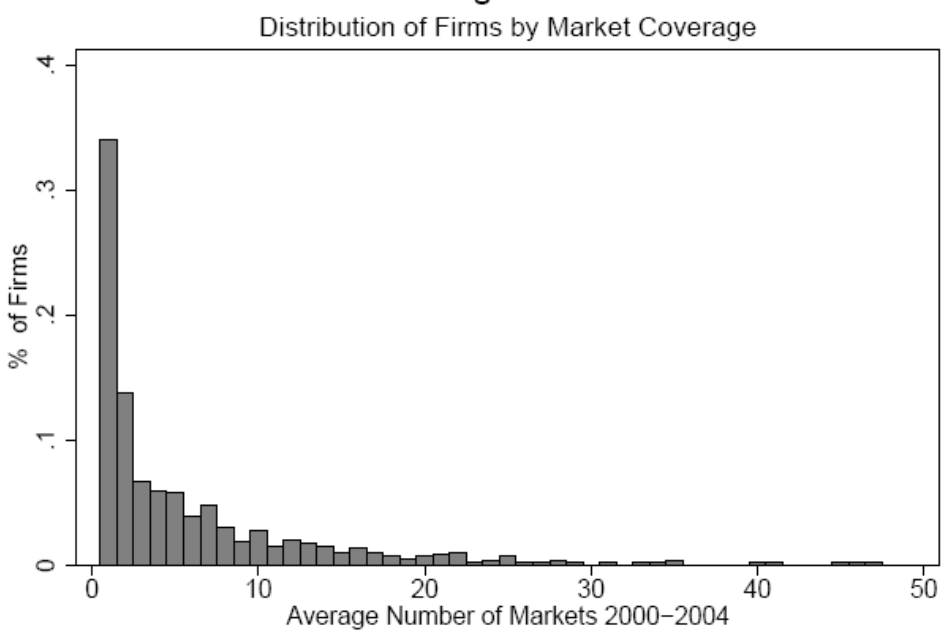

Figure 4