Iran. Econ. Rev. Vol. 21, No.1, 2017. pp. 21-44

The Effect of Innovation on International Trade: Selected Medium-High-Technology Industries, Evidence on Iran+3

Abdollah Ghanbari*[1]
Marzieh Ahmadi[2]

Received: 2016/09/07 Accepted: 2016/11/15

Abstract

The relationship between technology and international competitiveness dates back to the neo-technological trade theories of the 1960s. This approach considers difference in technology as the primary motive for difference among nations in terms of trade performance. The technology gap approach emphasizes inter-country differences in innovativeness as the basis for international trade flows. The gravity equation is the most successful and celebrated empirical model in international Trade. The empirical gravity literature does not include any form of multilateral resistance in the analysis. The importance of using fixed effects to control for country-specific characteristics has been emphasized in an influential paper by Anderson & Van Wincoop (2003). This paper investigates the effect of innovation on international trade. It examines the impact of R&D as a proxy of innovation on three medium high-tech industries exports in Iran, Japan, Korea and Australia using panel data method over a period of 10 years. We incorporate an industry-specific intercept into the model for estimating the role of innovation in explaining industry-level trade across selected countries. Our findings show that innovation has a positive and economically large effect on export performance of all industries. This suggests innovation is a central driver of trade.

Keywords: R&D, Innovation, International Trade, Gravity Equation.
JEL Classifications: F10, O31, F4, L6.

1. Introduction

The various contributions on International trade theory have explained

---

1. Department of Economics, Isfahan University, Isfahan, Iran (Corresponding Author: A.ghanbari@emofid.com).
2. Department of Economics, Isfahan University, Isfahan, Iran (ahmadi335@yahoo.com). We thank Professor Massimiliano Tani (School of Business, UNSW, Canberra, Australia) for assistance and comments that greatly improved paper.

that innovation plays an essential role in country's international competitiveness (Posner, 1961; Vernon, 1966; Fagerberg, 1997). According to Posner (1961), absolute technological advantage of one industry in a country relative to an industry in another country generates both an absolutes advantage and a temporary monopoly in trade until the point when the second country imitates. Since knowledge is a public good, it will flow to other developing economics. This flow is subject to imitation lags, which is dependent on the capacity of foreign producers to adapt their production structure in order to produce new goods with cheaper labor.

The pioneering work of Jan Tinbergen (1962) initiated a vast theoretical and empirical literature on the gravity equation for trade. Theories based on different foundations for trade, including endowment and technological differences, increasing returns to scale, and "Armington" demands, all predict a gravity relationship for trade flows analogous to Newton's "Law of Universal Gravitation". Among these theories are Anderson (1979), Helpman & Krugman (1985), Bergstrand (1985), Davis (1995), Deardoff (1998), and Anderson & Van Wincoop (2003).

The main aim of this paper is to provide empirical evidence on the relationship between innovation and three medium high-tech industries exports in Iran, Japan, Korea and Australia. Much attention has been devoted to static linear gravity models to investigate the relationship between these two variables. The contribution of the paper is to develop a dynamic gravity model by extending on Olivero & Yotov (2010) to allow industries to have different intercepts and thus differing trade volumes. So we incorporate an industry-specific intercept into the model for estimating the role of innovation in explaining industry-level trade across selected countries, as suggested by Funk et al. (2006).

The remainder of the paper is organized as follows. In Section 2, we present the theoretical framework. Section 3 explains methodology and the gravity model we use to estimate the effect of innovation on international trade at the industry-level. Section 4 reports the estimated gravity model using panel data method and a number of robustness checks. The last Section concludes.

2. Theoretical Framework

2.1 Innovation and International Trade

The last few decades have witnessed important changes in international trade patterns, with an increasing number of countries that have become closely linked to one another through international trade and foreign direct investment. Innovation plays an important role in this world-wide inter-dependence. Within this framework, international trade theory highlights the importance of innovation in explaining the international competitiveness of a country (Fagerberg, 1997). Traditional trade theories lie between in two approaches, Ricardian & Heckscher-Ohlin Model. Ricardian Trade Theory takes cross-country technology differences as the basis of trade. By abstracting from the roles of cross-country factor endowment differences and cross-industry factor intensity differences, which are the primary concerns of Factor Proportions Theory (such as Heckscher-Ohlin and Specific Factor models), Ricardian Trade Theory offers a simple and yet powerful framework within which to address many positive and normative issues of international trade. It is particularly well-equipped to examine the effects of country sizes, of technology changes and transfers, and income distributions. Furthermore, its simple production structure makes it relatively easy to allow for many tradeable goods and many countries, hence capable of generating valuable insights, which are lost in the standard two-country, two-goods model of international trade. The Heckscher-Ohlin model indicates that trade will increase the demand for the goods produced by the country's abundant resource. Since the abundant resource in most developing countries is labor, the prediction is an increase in demand for labor intensive goods. On the other hand, making trade provides a developing country the opportunity to learn from the more advanced technologies of the developed world. This technological exchange is expected to help developing countries catch-up with the developed countries more rapidly.

In short, the Ricardian model, which relies on differences in technology across countries to explain trade patterns, and the Heckscher-Ohlin (HO) model that relies on differences in factor endowments among countries as the basis for trade. It was assumed then that standard Ricardian and HO models were incapable of providing a foundation for the gravity model. In the HO model, for example, country size has little to do with the structure of trade flows.

It has been known since the seminal work of Jan Tinbergen (1962) that the size of bilateral trade flows between any two countries can be approximated by a law called the “gravity equation” by analogy with the Newtonian theory of gravitation, just as planets are mutually attracted in proportion to their sizes and proximity, countries trade in proportion to their respective GDPs and proximity. Initially the gravity equation was thought of merely as a representation of an empirically stable relationship between the size of economies, their distance and the amount of their trade. The extraordinary stability of the gravity equation and its power to explain bilateral trade flows prompted the search for a theoretical explanation for it. Whereas empirical analysis predated theory, we know now that most trade models require gravity in order to work. The first important attempt to provide a theoretical basis for gravity models was the work of Anderson (1979). He did so in the context of a model where goods were differentiated by country of origin (the so-called Armington assumption) and where consumers have preferences defined over all the differentiated products.

2.2 R&D and Innovation

Advances in the state of knowledge have been responsible for much of the economic development historically. Economically useful new knowledge that leads to innovation - product, process and disruptive - plays an important role in economic growth, international trade and regional development. In order to understand the exact role that knowledge and therefore innovation plays in the economy the measurement of knowledge inputs and knowledge outputs is critical. Our understanding of the role of knowledge in economic activity has traditionally been guided by the state of the measurement of knowledge. However, such data have always been incomplete and, at best, represented only a proxy measure reflecting some aspect of the process of technological change. Kuznets (1962) observed that the greatest obstacle to understanding the economic role of technological change was a clear inability of scholars to measure it.

Measures of technological change have typically involved one of the three major aspects of the innovative process: (1) a measure of the inputs into the innovation process, such as R&D expenditures; (2) an intermediate output, such as the number of inventions which have been patented; or (3) a direct measure of innovative output. During the 1950s and 1960s our understanding of the economy was advanced by developing measures of research and development (R&D), an input measurement, as a proxy for innovative output. R&D suffers from measuring only the budgeted resources allocated towards trying to produce innovative activity. During the 1970s, advances made in the use of patent data (an intermediate measure of economic activity) as a proxy for economic output[1]. Although patents are good indicators of new technology creation, they do not measure the economic value of these technologies (Hall, Jaffe, & Trajtenberg, 2001). According to Griliches (1979) and Pakes & Griliches (1980) "patents are a flawed measure (of innovative output) particularly since not all new innovations are patented and since patents differ greatly in their economic impact." In contrast to proxies of innovation activities such as R&D expenditures or patents, literature-based innovation output measures provide a direct indicator of innovation. These indicators originate in the work of Pavitt et al. (1987) Edwards & Gordon (1984). Sampling the new product sections of trade and technical journals generates literature-based innovation output indicators. The advantage of these indicators over patents and R&D expenditures is that they document the ultimate end of every innovation process: the commercialization of technical ideas.

However, they also suffer from some shortcoming. One potential problem is that these indicators might under-represent large firm innovations because those firms might feel less need to announce their new products than small companies. Literature-based innovation output measures are very expensive to produce and therefore are available for only select years and in select countries (Acs et al., 2002).

Table A shows some of the most relevant indicators (composite indices) that measure countries' endowment of technological innovation. The use composite indices is criticized by Grupp & Mogee (2004), since composite scores and country rank positions can vary considerably depending on the selection process and alternative

1. For a review of the patent literature see Griliches (1990).

method of calculation. Table B shows single variables, mostly related to R&D, that have also been used in recent years to measure the effect of innovation in different countries and regions.

Table A: Measurement of Technological Innovation with Composite Indices

Source	Description	Variable
Archibugi & Coco (2004)	This index takes into account three dimensions: creation of technology (number of patents, number of scientific papers), diffusion of technology (internet penetration, telephone penetration, electricity consumption) and development of human skills (gross tertiary science and engineering enrolment, mean years of schooling, adult literacy rate).	ArCo
ITR (2004)	The "Internet Traffic Report" monitors the flow of data around the world. The index takes values between zero and 100. Higher values indicate faster and more reliable connection.	ITR
Phillippa Biggs, UNCTAD (2003)	The index of Information and Communication Technology (ICT) diffusion consists of two dimensions: Connectivity (Internet hosts, PCs, telephone mainlines and cellular subscribers) and access (Internet users, literacy, GDP per capita and cost of a local call). Moreover, a third dimension (policy) is presented separately.	ICT
UNDP (2001)	The "Technology Achievement Index" is built up of four dimensions: Creation of technology (number of patents granted to residents, receipts of royalty and license fees from abroad), diffusion of recent innovations (Internet hosts, exports of high technology and medium technology products), diffusion of old innovations (number of telephones, electricity consumption) and human skills (mean years of schoolings, gross tertiary science enrolment ratio).	TAI

Table B: Proxies for Innovation

Source	Description	Variable
Eaton & Kortum (2002)	Level of technology	Variable related to the stock of past research effort and the stock of human capital in countries
Fagerberg (1997)	Input measure of investments in new technologies	R&D expenditure
Furman & Hayes (2004)	National innovative output	International patents
Moreno, Paci, & Usai (2005)	Proxy of innovative output	Average number of patents per capita
Torstensson (1996)	Identifies where countries tend to have relatively efficient technology	R&D expenditure
Verspagen & Wakelin (1997)	Input measure of investments in new technologies Output measure of investments in new technologies	R&D expenditure Number of patents

Empirical work linking R&D to innovation shows that R&D has a significant effect on innovation. For example, Jacques & Mohnen (2004) compare the contribution of R&D to innovation in terms of the various innovation output measures provided by the third Community Innovation Survey (CIS 3) for French manufacturing firms and in terms of accounting for inter-industry innovation differences. They have systematically confronted all the indicators of innovation output that are provided by the French CIS 3: the five dichotomous innovation indicators for the incidence of process innovation, product innovations new to the firm, product innovations new to the market, patent applications and patent holdings and the three censored continuous indicators measuring the shares in total sales of sales accounted for by products new to the firm or new to the market, and that of patent-protected sales. The results indicate that R&D is positively correlated with all measures of innovation output.

Thus, technological progress is generated through firm-level investment in R&D (Grossman & Helpman, 1991; Romer, 1990). Approach in this paper is consistent with Fagerberg (1997) that he considers R&D as a proxy for innovation.

2.3 Literature Review

Grossman (1989) developed a model of dynamic comparative advantage based on endogenous innovation. Firms in each of two countries devote resources to R&D in order to improve the quality of high-technology products. Research successes generate profit opportunities in the world market. The model predicts that a country such as Japan, with abundance of skilled labor and scarcity of natural resources, will specialize relatively in industrial innovation and in the production of high technology goods. Data are provided to support this prediction. I use the model to explore the effects of R&D subsidies, production subsidies and trade policies on the long-run rates of innovation in trade partner countries and on the long-run pattern of trade.

Eaton & Kortum (2002) recently developed a parsimonious representation of the Ricardian model with a continuum of goods, which allows for an arbitrary number of countries with the iceberg costs that are uniform across sectors but vary across country-pairs. Their key idea is to view the technology heterogeneity across countries as a realization from the Frechet distributions, instead of trying to index the goods in a particular order. This yields simple expressions relating the bilateral trade volumes to technology and geographical barriers, and they use these expressions to estimate the parameters needed to quantify the effects of various policy experiments.

Montobbio & Rampa (2005) indicated technological activity is related to export gains in high technology sectors if a country expands in industries with increasing technological opportunities, in medium technology sectors if it moves away from low opportunity sectors, in low technology sectors if it is initially specialized in growing sectors. In high-tech and low-tech sectors, export performance is also affected by the growth of technical capabilities, foreign direct investments, productivity, and the initial level of technical skills and in medium tech by the growth rates of foreign direct investments.

Marquez & Zarzoso (2010) analyzed the effect of technological innovation on sectoral export using a gravity model of trade. The technological achievement index (TAI) and its four components, creation of technology, diffusion of old innovations, diffusion of recent innovations and human skills, are used as proxies for technological innovation. The two first components are considered proxies for knowledge acquisition and assimilation (potential absorptive capacity); whereas the last two are taken as proxies for knowledge transformation and exploitation (realized absorptive capacity). They hypothesize that the effect of technological innovation on trade could vary according to the technological achievement by generating a non-linear relationship between technological innovation and trade. The results indicate a positive and non-linear effect of technological innovation on export performance, which indicates that there are thresholds for positive signs to occur. They suggest fostering exports; countries have to consider not only acquisition and assimilation capabilities, but also transformation and exploitation capabilities once a minimum level of potential absorptive capacity has been achieved.

Marquez & Zarzoso (2010) quoted Estrada et al. (2006) found an inverted “U” relationship between some variables related to innovation (structural characteristics—size, age and foreign capital intensity, technological acquisition —machinery and equipment, technological services— and innovative results—new products, product improvements and diversification—) and the probability to export. They also found a “U” effect of R&D intensity on export probability, implying that companies with a very low or very high R&D intensity have a higher export probability than those with a medium R&D intensity.

3. Methodology

To provide our model we merge the dynamic, endowment economy, gravity model from Olivero & Yotov (2010) (hereafter OY (2010)) with the industry-level models. OY (2010) merge the static gravity model from Anderson & Van Wincoop (2003) with the two-country dynamic models in the macroeconomics literature in order to model dynamic gravity. They incorporate dynamic elements in the gravity framework by introducing asset accumulation and making country size endogenous.

Equation (1) is the structural dynamic gravity equation, an expression for bilateral trade flows (x_{ij}) as a function of the same contemporaneous variables as in the static model, as well as the lagged values of bilateral trade, trade costs and multilateral resistances, world output and output in the origination region:

$$x_{ij,t} = \frac{y_{i,t}}{y_t^W}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}\left[\emptyset y_{j,t}p_{j,t}^{\left(\frac{1}{\alpha}-1\right)} + (1-\delta)\left(\frac{p_{j,t}}{p_{j,t-1}}\right)^{\frac{1}{\alpha}} x_{ij,t-1}^{\frac{1}{\alpha}}\left(\frac{y_{t-1}^W}{y_{i,t-1}}\right)^{\frac{1}{\alpha}}\left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{(\sigma-1)}{\alpha}}\right]^{\alpha} \quad (1)$$

Where $x_{ij,t}$ is trade flow from country i to country j at time t, two countries’ GDPs, denoted by y_i and y_j. In this equation, $p_j$is the consumer price index of j, t_{ij} labels bilateral trade costs for shipments from i to j, σ is the elasticity of substitution between all goods, y_t^W is world nominal income at time t, $\emptyset$ is the investment share of real output and δ represents the depreciation rate. Also $\Pi_{i-t}^{1-\sigma}$and $P_{j-t}^{1-\sigma}$ are the multilateral resistance (MR) terms (outward and inward, respectively), which consistently aggregate bilateral trade costs and decompose their incidence on the producers and the consumers in each region. Outward multilateral resistances (OMRs) are defined as if the sellers in each region shipped to a single world market, while inward multilateral resistances (IMRs) are defined as if the buyers in each region imported from a single world market (see Anderson & Van Wincoop (2003)). As in the static model, this gravity equation predicts that bilateral trade flows are directly related to the GDP of each trading partner, and that trade barriers $t_{ij;t}$ have a negative impact on the volume of bilateral trade. OY (2010) label this effect the static or contemporaneous effect of trade barriers. The fact that they depart from the endowment economy and allow for an endogenous production structure is captured by the second term in square brackets in (1), which they label the dynamic or endogenous country side effect. This intertemporal effect consists of two intuitive components. The first is the lagged volume of trade ($x_{ij;t-1}$), which captures what they label as trade persistence effect. This effect accounts for the autocorrelation in bilateral trade flows and is related to the persistence imposed on the model by the process of capital accumulation, and the fact that a fraction (1-δ) of the capital stock from period (t-1) is still available for production in period t. The second component ($t_{ij;t}$-1) captures the dynamic effect of trade barriers on bilateral trade. They label this effect the protection persistence effect.

OY (2010) translate the structural dynamic gravity equation (1) into an econometric specification. To avoid potential indeterminacy of the nominal model, as they have not specified the monetary side of the economy, their first step is to re-express it in real terms. To do this, they set $p_{j,t}$= 1; ∀t, and equation (1) becomes:

$$x_{ij,t} = \frac{y_{i,t}}{y_t^W}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma}\left[\emptyset y_{j,t} + (1-\delta)x_{ij,t-1}^{\frac{1}{\alpha}}\left(\frac{y_{t-1}^W}{y_{i,t-1}}\right)^{\frac{1}{\alpha}}\left(\frac{t_{ij,t-1}}{\Pi_{i,t-1}P_{j,t-1}}\right)^{\frac{(\sigma-1)}{\alpha}}\right]^{\alpha} \qquad (2)$$

They choose to normalize p_j for two reasons: First, to prevent inflation in any given region from playing a role in the determination of trade flows (notice that p_j washes out from equation (1) after this normalization is performed). Otherwise, the empirical results would be sensitive to the choice of which country's inflation rate to use in equation (1). Second, taking an alternative approach, such as normalizing the price index P_i in any country i, would imply an essentially fixed inward resistance in one of the two countries. This would prevent us from simulating the response of the inward multilateral resistances in both the importer and the exporter country to trade costs shocks.

Next, define size-adjusted trade $\tilde{x}_{ij,t} = \frac{x_{ij,t}}{y_{i,t} y_{j,t}}$ and rewrite (2) to get:

$$\tilde{x}_{ij,t} = \frac{1}{y_t^W} \left(\frac{t_{ij,t}}{\Pi_{i,t} P_{j,t}} \right)^{1-\sigma} \left[\emptyset y_{j,t}^{1-\frac{1}{\alpha}} + (1-\delta) \left(\tilde{x}_{ij,t} y_{t-1}^W y_{j,t-1} \right)^{\frac{1}{\alpha}} \left(\frac{t_{ij,t-1}}{\Pi_{i,t-1} P_{j,t-1}} \right)^{\frac{(\sigma-1)}{\alpha}} y_{j,t}^{-\frac{1}{\alpha}} \right]^{\alpha} \quad (3)$$

Size-adjusted trade is the natural dependent variable choice: First, by using size-adjusted trade, we avoid complications associated with converting nominal trade to real trade values[1]. Second, bringing the exporter's GDP to the left-hand-side of the estimation equation allows us to, at least partially, deal with GDP endogeneity. Finally, as we show below, adjusting for country sizes proves to be a successful tool to attack the important issue of heteroscedasticity that, as shown by Santos & Tenreyro (2006), often plagues gravity estimations.

The dynamic version of the gravity equation is highly non-linear. Therefore, next step is to log linearize it around the deterministic steady state of the model:

$$log\left(\tilde{x}_{ij,t}\right) = \beta_0 + (1-\delta) log\left(\tilde{x}_{ij,t-1}\right) + (\xi\alpha - 1) log\left(y_t^W\right) + (1-\delta) log\left(y_{t-1}^W\right) + (1-\delta) log\left(y_{j,t-1}\right) + (1-\sigma) log\left(t_{ij,t}\right) - (1-\sigma)(1-\delta) log\left(t_{ij,t-1}\right) - log\left(\tilde{\Pi}_{i,t}\right) + (1-\delta) log\left(\tilde{\Pi}_{i,t-1}\right) - log\left(\tilde{P}_{j,t}\right) + (1-\delta) log\left(\tilde{P}_{j,t-1}\right) \quad (4)$$

Here, the constant term β_0 and the coefficient ξ are functions of the parameters in the model and the logarithms of the deterministic steady state values of all explanatory variables, including the multilateral resistances.

Two more steps complete the econometric specification. First, they follow Feenstra (2004) in using source and destination (directional) country fixed effects to account for the unobservable multilateral resistance terms in the last four terms of equation (4), which becomes:

$$log\left(\tilde{x}_{ij,t}\right) = \beta_0 + (1-\delta) log\left(\tilde{x}_{ij,t-1}\right) + (1-\sigma) log\left(t_{ij,t}\right) - (1-\sigma)(1-\delta)\, log\left(t_{ij,t-1}\right) + \beta_{i,t} + \beta_{j,t} \quad (5)$$

1. It is a common practice in the gravity literature to use real GDP and real trade flows. The main problem with this is that it is usually US price index data that are used to deflate all trade values, regardless of source or destination, and this leads to biased gravity estimates.

The structural interpretation of the directional fixed effects is
$\beta_{i,t} = -log(\widetilde{\Pi}_{i,t}) + (1-\delta)log(\widetilde{\Pi}_{i,t-1})$
and
$\beta_{j,t} = -log(\tilde{P}_{j,t}) + (1-\delta)log(\tilde{P}_{j,t-1}) + (\xi\alpha - 1)log(y_{j,t}) + (1-\delta)log(y_{j,t-1})$. However, it should be noted that in addition to the multilateral resistances and the importer's GDP variable, the fixed effects also absorb the current and lagged world output, which vary over time only.

Second, they provide structure behind the trade barriers, $t_{ij,t}{}'s$. Following Anderson & Van Wincoop (2003), they assume that, at each point in time, the unobservable$t_{ij,t}{}'s$ can be approximated by observable variables so that log($t_{ij,t}{}'s$) =$\sum_h \gamma_h z_{ij,t}(h)$, where the z's include the log of bilateral distance, contiguous borders, common language, colonial relationships, etc. Furthermore, the dynamic structure allows to distinguish between trade barriers that are time-invariant (e.g., bilateral distance), and trade costs that vary over time (e.g., transport costs). To make this distinction explicit, they use $t_{ij,t}$ to denote trade costs that vary over time and τ_{ij} for the time invariant trade barriers, after adding an error term, which is assumed to be independently and identically distributed. Equation (5) becomes:

$$log(\tilde{x}_{ij,t}) = \beta_0 + (1-\delta)log(\tilde{x}_{ij,t-1}) + (1-\sigma)log(t_{ij,t}) - (1-\sigma)(1-\delta)log(t_{ij,t-1}) + (1-\sigma)log(\tau_{ij}) + \beta_{i,t} + \beta_{j,t} + \epsilon_{ij,t} \qquad (6)$$

Notice that the static gravity specification for the endowment economy from Anderson & Van Wincoop (2003), log($\tilde{x}_{ij,t}$) = (1 - σ)log($t_{ij,t}$) + β_i + β_j, is nested in this setting. As compared to its static counterpart, the dynamic gravity equation has several distinct features. First, it implies that lagged, size-adjusted trade values should be included as regressor in the dynamic gravity specification. This is in accordance with the fact that trade relations are usually persistent. Not accounting for such persistence may cause omitted variable bias in the point estimates of the gravity coefficients. In an empirical study of the historical persistence of trade flows, Eichengreen & Irwin (1998) find such biases to be substantial and conclude that they “will never run another gravity equation that excludes lagged trade flows”.

Second, while the theoretically correct output elasticity in a static gravity model is equal to one, the coefficient of importer's GDP on the right-hand-side in equation (5) implies that this is not necessarily the case in a dynamic setting. Furthermore, the importer fixed effects, $\beta_{j,t}$, which absorb the importer's GDP variable, are time-varying due to the dynamic structure of the model. Similarly, the exporter fixed effects, $\beta_{i,t}$, are also time-varying, which has important implications for the structural interpretation and for the empirical significance of these terms.

Finally, the structural static model cannot differentiate between time-varying trade costs and barriers that are constant over time. More importantly, equation (5) suggests that current, size adjusted bilateral trade is influenced by contemporaneous as well as by lagged time-varying trade barriers. This feature of the dynamic model is usually ignored in gravity estimations; however, it is important because not accounting for the influence of these lagged variables may result in biased coefficient estimates. As discussed earlier, the dynamic and the contemporaneous effects of trade protection on current trade work in opposite directions, which is captured by the opposing signs of the coefficients on $t_{ij,t}$ and $t_{ij,t-1}$ in (6).

The above specification of the gravity model aggregated trade flows over countries, but we disaggregate data into 3 medium-high technology industries. Further, this model assumes that all exporter-importer pair has a same intercept (β_0).

To provide our final model, however, following Funk et al. (2006), we allow industries to have different intercepts and thus differing trade volumes. So we incorporate an industry-specific intercept into the model (6). After adding an industry-specific intercept, μ_k , our final industry-level gravity model specification thus becomes:

$$log\left(\tilde{x}_{ij,t}^{k}\right) = \mu_k + (1-\delta)log\left(\tilde{x}_{ij,t-1}^{k}\right) + (1-\sigma_k)log\left(t_{ij,t}^{k}\right) - (1-\sigma_k)(1-\delta)log\left(t_{ij,t-1}^{k}\right) + (1-\sigma_k)log\left(\tau_{ij}\right) + \beta_{i,t} + \beta_{j,t} + \epsilon_{ij,t} \qquad (7)$$

where $\tilde{x}_{ij,t}^{k}$ is defined as adjusted exports from i to j in industry k and σ_k is the elasticity of substitution among goods in industry k. There is dynamic bias problem as a potential limitation which is more severe for panels with short time dimension, where simple inclusion of fixed effects or first differencing may not remove the correlation between the lagged dependent variable and the disturbance, such as ours.in spite of this limitation, our model provides clear empirical implications for gravity-type estimations with panel data.

4. Data Sources and Variables

The details on the variables and their expected relationship with trade are explained below:

Innovation: The fundamental importance of innovation and new technology in trade flows is widely recognized both theoretical and empirical. These reviewed comprehensively in section 2. As previously indicated, the R&D is used to measure the innovation.

Language and Colonial Ties as Measures of Cultural Similarities: a number of international trade studies focus on the effect of a shared language. For example, among them, Helliwell (1999) explores the economics of language in 22 OECD countries and 11 developing countries. The author finds that the general common language effect seems to be driven by the role of English. The other languages analyzed, German, French and Spanish, are not fund to be significant in the empirical regressions.

Geography and the Role of Distance: the negative correlation between geographical distance and bilateral trade volume is one of the most robust empirical findings in economics. In recent studies, a number of authors have contributed to the debate on the interpretation of distance effects. Factors such as information costs, tastes and preference, unfamiliarity and differences in factor endowments that provide opportunities for trade have been considered (Marquez, 2007).

Transportation Costs: trends towards geographical regionalization and globalization have led to the decreasing role tariff barriers as an influencing factor on trade. As a result, the relative importance of transport costs has increased and these costs have become a relevant determinant of trade patterns (Marques, 2007). As pointed out above, we use transport costs as a proxy for trade costs.

We obtained bilateral trade data by industry from COMTRADE. The level of disaggregation chosen is based on Classification of manufacturing industries into categories based on R&D intensities using the ISIC Rev. 3 breakdown of activity. (OECD's STI

Scoreboard, 2011). Four categories were introduced: high-, medium-high, medium-low and low technology. In this paper, Due to data limitations, we use only 3 medium-high technology industries, namely, chemicals and related products, n.e.s., Electrical machinery, apparatus and appliances, n.e.c. and general industrial Machinery and equipment, n.e.c. . The sample comprised of four countries over the period 2003-2012. The databases used to construct the exogenous variables for the regression analysis are Word Bank (2014) for GDP (constant 2005 US$), the Doing Business database (2014) for transport costs and R&D from OECD stat for Japan, Korea and Australia. As regards Iran, we get R&D data from Statistical national center that vary across industries. Distance between capitals, a common official language, contiguity and the colonial dummy are taken from CEPII.

5. Empirical Analysis

5.1 Model Specification and Estimation

To investigate the effects of innovation on the volume of bilateral trade in industry-level, a gravity model equation is specified and estimated for the disaggregated data. The estimated equation is:

$$ln\left(\tilde{x}_{ij,t}^{k}\right) = \beta_0^k + \beta_1 ln\left(\tilde{x}_{ij,t-1}^{k}\right) + \beta_2 ln\left(RD_{i,t}^{k}\right) + \beta_3 ln\left(RD_{j,t}^{k}\right) + \beta_4 ln(Tc_i) + \beta_5 ln\left(Tc_j\right) + \beta_6 ln\left(dist_{ij}\right) + \beta_7 comlang_{ij} + \beta_8 colony_{ij} + \beta_9 contig_{ij} + \beta_{i,t} + \beta_{j,t} + \epsilon_{ij,t} \quad (8)$$

Here ln denotes natural logarithms; $\tilde{x}_{ij,t}^{k}$ is defined as adjusted exports from i to j in industry k , $RD_{i,t}^{k}$ and $RD_{j,t}^{k}$ are research and development in the exporter's industry k and importer's industry k respectively, Tc_i and Tc_j are the transport costs of the exporting and importing countries, respectively. $dist_{ij}$ is the geographical distance in kilometers between capital of country i to j. $comlang_{ij}$ is a dummy for countries sharing a common official language. $colony_{ij}$ is a dummy that takes the value of 1 when trading partners have had a colonial link at any time and $contig_{ij}$ contiguous borders between countries.

First, we estimate (8) without including the lagged dependent variable in the set of regressors. Estimation results are reported in the first column of Table 3. As expected, we find that distance is a negative impediment to trade, while colonial tie is positive and insignificant. Because of not common border and common language official between countries, these dummies are o mitted. The estimates from column (1) suggest a positive and not significant in both exporter's R&D and importer's R&D effects. The coefficients on transport costs are negative for both exporter and importer, as expected, but not significant.

The column (2) shows the estimated coefficients obtained using OLS when we consider the lagged dependent variable as a regressor in (8). Results reveal, first, the introduction of the lagged dependent variable improves significantly the overall adequacy and explanatory power of the model, which can be seen by the improvement in the R^2. Second, the introduction of the lagged dependent variable does not improve the importer's R&D estimate. As can be seen from the table below, the importer's R&D estimate of 0.06 is still not significant, while exporter's R&D estimate of 0.23 is significant. These points are potential problems (Endogeneity) with importer's R&D variable. As can be seen from the column (2), we obtain a high lagged trade estimate of about 0.6. The upward bias in the lagged OLS dependent variable is expected: This empirical regularity is known as the Nickel (1981) dynamic bias, and it is due to the positive correlation between the lagged dependent variable and the unobservable country-pair fixed effects (FEs) that are part of the error term in (8).

Next, we follow methods of OY (2010) in addressing these problems using the fixed effects estimator as a solution to this endogeneity. Column (3) shows results obtained from estimating (8) with country-pair fixed effects. Results reveal firstly, once the endogenous nature of the importer's R&D is accounted for, its signification has not change. Secondly, it is clear from the table that the exporter's R&D variable becomes insignificant. In the next specification, we use instrumental variables to account for residual endogeneity, if any, of the lagged trade variable and R&D endogeneity. Our instruments include second (2-year) lags of the dependent variable as well as patent. As can be seen from column (5) IV estimates are statistically different than the OLS numbers from column (3). This suggests that, as expected with a short time period[1], the country-pair fixed effects have not completely accounted for the Nickel dynamic bias. As column (5) indicates, exporter's R&D variable is found to be positive and significant, as expected. However, importer's R&D variable has a negative and significant.

Table 3: The Effect of Innovation on International Trade

Variables	(1) OLS	(2) OLS (lagged dependent variable)	(3) fixed-effects	(4) Difference GMM	(5) IV	(6) FGLS
$\tilde{x}^k_{ij,t-1}$	-	0.59 (0.04)*	0.19 (0.05)*	0.31 (0.16)*	0.38 (0.14)*	-
$RD^k_{i,t}$	0.07 (0.1)	0.23 (0.06)*	0.05 (0.07)	0.83 (0.57)	1.51 (0.35)*	0.46 (0.05)*
$RD^k_{j,t}$	0.11 (0.08)	0.06 (0.05)	0.1 (0.05)	-0.17 (0.09)	-0.85 (0.29)*	0.17 (0.07)*
Tc_i	-1.25 (0.78)	-1.02 (0.54)	-0.42 (0.47)	0.14 (0.43)	1.96 (1.36)	-6.34 (0.66)*
Tc_j	-0.48 (0.47)	-0.26 (0.31)	-0.59 (0.29)	-0.13 (0.42)	-0.02 (0.31)	1.19 (0.25)*
$dist_{ij}$	-0.35 (0.75)	-0.02 (0.23)	-	-0.33 (0.57)	-0.42 (0.23)	0.35 (0.14)*
$colony_{ij}$	3.2 (2.13)	0.96 (0.68)	-	-	0.61 (1.99)	2.99 (0.35)*
$const$	8.52 (9.06)	2.09 (4.69)	2.42 (3.5)	-11.26 (11.06)	-23.62 (10.7)*	16.48 (4.74)*
R^2	0.28	0.89	0.91	-	0.46	-

Notes: * indicate significance at 5%. The standard error is reported below each coefficient in parentheses.

The problem of heteroscedasticity should be taken into account. A simple method to correct it is to use FGLS. Also recently, the problem of the zero flows has been revisited. The literature distinguishes several methods of dealing with that problem. Truncation (elimination) or censoring methods have been widely used. However, these methods have not a strong theoretical support and do not guarantee consistent estimates, so they have not been employed frequently in the literature. One of alternative solution is Feasible

1. The remedy is to instrument for the lagged dependent variable. Anderson and Hsiao (1982) are the first to achieve consistency in short time period setting by using appropriate lagged levels and differences of the dependent variable as instruments for the lagged dependent variable.

General Least Squares (FGLS) (Gomez & Milgram, 2010). Column (6) presents the estimated coefficients using FGLS method, which controls more properly for heteroscedasticity and zero flows. The exporter's and importer's R&D coefficients are 0.46 and 0.17, respectively, which are both positive and significant, as expected. These results are consistent with Marquez (2007).

Table 4: The Effect of Innovation on International Trade for each industry

Variables	*(1)* *FGLS*	*(2)* *FGLS*	*(3)* *FGLS*
$RD_{i,t}^{k}$	0.44 (0.09)*	0.81 (0.1)*	0.39 (0.09)*
$RD_{j,t}^{k}$	0.29 (0.09)*	-0.01 (0.15)	-0.07 (0.15)
Tc_i	-2.53 (0.85)*	-3.42 (1.25)*	-8.45 (1.46)*
Tc_j	-0.36 (0.41)	1.97 (0.6)*	0.6 (0.62)
$dist_{ij}$	0.52 (0.16)*	0.47 (0.31)	0.57 (0.31)
$colony_{ij}$	2.9 (0.51)*	2.99 (0.93)*	4.42 (0.89)*
$const$	-1.48 (6.25)	-13.67 (9.2)	39.27 (9.63)*

Notes: * indicate significance at 5%. The standard error is reported below each coefficient in parentheses.

In addition to, we estimate equation (8) for each industry separately by FGLS method only, which findings reported in table (4). Column (1) shows that the chemicals and related products, n.e.s. industries experienced a rise in exports when they decide to rely more on R&D in both source and destination country. By contrast, in column (2) and column (3), the coefficient on importer's R&D has a negative sign and not significant in Electrical machinery, apparatus and appliances, n.e.c. industries and General industrial Machinery and equipment, n.e.c. industries respectively, although, exporter's R&D coefficients are positive and significant at both industries.

5.2 Robustness Checks

Even though, due to short time period in our sample, the use of bilateral fixed effects (as indicated in the column 3 of table 3), is not sufficient to eliminate the endogeneity issues, we also experiment difference GMM estimators as a first robustness check. The obtained results show in the column(4) of table 3.The results indicate that the coefficients obtained for variables are not statistically different than the OLS numbers from column(3). This confirms the limitation of model, which implies fixed effects and difference GMM may not remove the dynamic bias problem. The findings illustrate main variables, exporter's and importer's R&D, are insignificant but have the expected positive sign. Although, lagged dependent variable is only significant and have positive effect on trade flows with an estimated coefficient of 0.31.

As a second robustness check, the model specification was estimated by patent proxy as alternative measure of innovation using FGLS method. The results report in the table (5). Comparisons between the estimates from table (5) and their counterparts obtained with R&D variable show that they yielded approximately similar quantitative and qualitative results which confirms the robustness of our results. According to the results obtained, we see that the coefficients for exporter's patent in all three industries are positive and significant between about 0.1 and 0.2 as expected. Also, we find that distance is a significant impediment to trade. This finding is supported by the negative and significant estimate of the coefficient on $dist$, varying from 0.44 in chemical industry to about 1 in machinery industry. However, importer's patent couldn't lead to promote trade performance except for chemical industry with a coefficient of 0.07.

Table 5: The Effect of Patent on International Trade

Variables	***(1) FGLS (All industries)***	***(2) FGLS (Chemical...)***	***(3) FGLS (Electrical…)***	***(4) FGLS (Machinery…)***
$PR_{i,t}^{k}$	0.2 (0.02)*	0.19 (0.00)*	0.1 (0.01)*	0.09 (0.04)*
$PR_{j,t}^{k}$	0.003 (0.01)	0.07 (0.00)*	0.005 (0.01)	0.006 (0.04)
Tc_i	-0.12 (0.18)	0.28 (0.06)*	0.34 (0.22)	0.54 (0.76)
Tc_j	0.26 (0.17)	-0.06 (0.06)	-0.23 (0.22)	-0.41 (0.75)
$dist_{ij}$	-0.98 (0.06)*	-0.44 (0.01)*	-0.83 (0.05)*	-1.01 (0.14)*
$const$	4.92 (0.8)*	7.88 (1.8)*	5.43 (0.67)*	7.14 (1.77)*

Notes: * indicate significance at 5%. The standard error is reported below each coefficient in parentheses.

6. Conclusion

This paper aims to provide empirical evidence on the relationship between innovation and international trade. In order to do so, R&D is used in the empirical analysis as a proxy for innovation. Following Funk et al. (2006), we also allow industries to have different intercepts and thus differing trade volumes and merge this term with structural dynamic gravity model to provide a new model. This model has three main implications. First, persistence in both trade flows and trade barriers should be controlled for, second, multilateral resistance terms should be accounted for by time-varying directional (source and destination) fixed effects and three consider an industry-specific intercept.

The estimated coefficients obtained using different methods in order to check which one performs better. The results suggest that heteroscedasticity is responsible for the main differences between methods. So we use FGLS method to address this problem.

Our findings indicate a positive and significant effect of innovation on export performance of medium high-tech industries when we consider sample as a whole. Additionally, the results obtained show the existence of a positive relationship between colonial ties and trade. However, when we allow industries to have different intercepts and estimate model for each industry separately, we find different results. In the chemicals and related products, n.e.s., R&D expenditures in both importer and exporter country enhance trade performance, but in the other two industries, namely, Electrical machinery, apparatus and appliances, n.e.c. and general industrial Machinery and equipment, n.e.c. only exporter's R&D allocated to these industries, has a positive and economically large effect on their exports. It can be concluded that the exports of medium high technology commodities and industries are promoted by R&D expenditures.

To sum up, in a globalizing world, export success can serve as a good measure for the competitiveness of a nation's high technology industries. Exports in high technology have been largely dominated by a small group of nations. For most other countries, comparative advantages lie in primary commodities and traditional manufactures. One major development in international trade over the last two decades is the changing pattern of world trade. There is a consistent trend for exports of technology-intensive products (high technology goods) to grow faster than others. Thus, it is important for countries to create and sustain export competitiveness in industries that are so vital for productivity and economic growth. The empirical evidence of this paper indicates innovation is the central driver of high technology exports in a nation. This evidence suggests that these industries will experience higher levels of trade, if they rely more on R&D or use of new knowledge.

References

Acs, Z., Anselin, L., & Varga, A. (2002). Patents and Innovation Counts as Measures of Regional Production of New Knowledge. *Research Policy*, *31*, 1069-1085.

Anderson, J. (1979). A Theoretical Foundation for the Gravity Equation. *American Economic Review*, *69*, 106-116.

Anderson, J., & Van Wincoop, E. (2004). Trade Costs. *Journal of Economic Literature*, *42*, 691-751.

---------- (2003). Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review, 93*, 170-192.

Anderson, T. W., & Hsiao, C. (1982). Formulation and Estimation of Dynamic Models Using Panel Data. *Journal of Econometrics*, *18*, 47-82.

Archibugi, D., & Coco, A. (2004). A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo). *World Development*, *32*, 629-654.

Biggs, P. (2003). Information and Telecommunication Technology (ICT) Development Indices (Document: WICT-40E). 3rd *World Telecommunication/ICT Indicators Meeting*, *UNCTAD*, Retrieved from https://www.itu.int/ITU-D/ict/WICT02/doc/pdf/Doc40_E.pdf.

Bergstrand, J. (1985). The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence. *Review of Economics and* Statistics, *69*, 474-481.

CEPII (2014). Retrieved from
http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

Davis, D. (1995). Intra-Industry Trade: A Hecksher-Ohlin-Ricardo Approach. *Journal of International Economics*, *39*, 201-226.

Deardoff, A. (1998).Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World? In Frankel, J. (Ed.), *The*

Regionalization of the World Economy. Chicago: University of Chicago Press.
Doing Business (2014). Retrieved from http://www.doingbusiness.org.
Ebersberger, B., Marsili, O., Reichstein, T., & Salter, A. (2010). Into Thin Air: Using a Quantile Regression Approach to Explore the Relationship Between R&D and Innovation. *International Review of Applied Economics*, *24*, 95-102.
Eaton, J. & Kortum, S. (2002). Technology, Geography, and Trade. *Econometrica*, *70*, 1741-1779.
Edwards, K., & Gordon, T. (1984). Characterization of Innovations Introduced on the U.S. Market in 1982, Prepared for the US Small Business Administration. *The Futures Group*, Retrieved from https://books.google.com/books?isbn=3642585248.
Eichengreen, B., & Irwin, D. A. (1998). The Role of History in Bilateral Trade Flows. In Frankel, J. A. (Ed.), *The Regionalization of the World Economy*. Chicago: University of Chicago Press.
Estrada, S., Heijs, J., & Buesa, M. (2006). Innovación y Comercio Internacional: Una Relación No Lineal. *ICE*, *69*, Retrieved from https://books.google.com/books?isbn=1135055904.
Fagerberg, J. (1997). Competitiveness, Scale and R&D. In Fagerberg, J., Hansson, P., Lundberg, L., & Melchior, A. (Eds.), *Technology and International Trade*. Cheltenham: Edward Elgar.
Feenstra, R. (2004). *Advanced International Trade*. Princeton: Princeton University Press.
Funk, M., Elder, E., Yao, V., & Vibhakar, A. (2006). Intra-NAFTA Trade in Mid-South Industries: A Gravity Model. *The Review of Regional Studies*, *36*, 205-220.
Gomez, E., & Milgram, J. (2010). Are Estimation Techniques Neutral to Estimate Gravity Equations? An Application to the Impact of EMU on Third Countries' Exports. *Mimeo*, Retrieved from http://www.etsg.org/ETSG2009/papers/gomez.pdf.
Griliches, Z. (1990). Patent Statistics as Economic Indicators: A Survey. *Journal of Economic Literature*, *28*, 1661-1707.
---------- (1979). Issues in Assessing the Contribution of R&D to Productivity Growth. *Bell Journal of Economics*, *10*, 92-116.

Grossman, G. M. (1989). Explaining Japan's Innovation and Trade: A Model of Quality Competition and Dynamic Comparative Advantage. *NBER Working Paper*, *3194*, Retrieved from https://ideas.repec.org/p/nbr/nberwo/3194.html.

Grossman, G. M., & Helpman, E. (1991). *Innovations and Growth in the Global Economy*. Cambridge, MA: MIT Press.

Hall, B., Jaffe, A., & Trajtenberg, M. (2001). The NBER Patent Citations Data file: Lessons, Insights and Methodological Tools. *National Bureau of Economic Research*, *WP8498*, Retrieved from http://www.nber.org/papers/w8498.

Helliwell, J. F. (1999). *Language and Trade, In Exploring the Economics of Language*. Toronto: University of Toronto.

Helpman, E., & Krugman, P. (1985). *Market Structure and Foreign Trade*. Cambridge: MIT Press.

ITR (Internet Traffic Report) (2004). Retrieved from http://www.internettrafficreport.com/.

UNDP (United Nations Development Program) (2001). *Human Development Report*. New York: Oxford University Press.

Jacques, M., & Mohnen, P. (2004). The Importance of R&D for Innovation: a Reassessment Using French Survey Data. *NBER Working Paper*, *10897*, Retrieved from http://www.nber.org/papers/w10897.

Kuznets, S. (1962). Inventive Activity: Problems of Definition and Measurement. In Richard, R. N. (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton University Press.

Marquez, R. L. (2007). *New Determinants of Bilateral Trade: An Empirical Analysis for Developed and Developing Countries* (Doctoral Dissertation, Universitat Jaume I, Castellón), Retrieved from www.tesisenred.net/bitstream/handle/10803/10361/marquez.pdf.

Márquez, R., L., & Zarzoso, I. M. (2010). *The Effect of Technological Innovation on International Trade*. Retrieved from https://www.econstor.eu/bitstream/10419/30327/1/623280515.pdf.

Montobbio, F., & Rampa, F. (2005). The Impact of Technology and Structural Change on Export Performance in Nine Developing Countries. *World Development*, *33*, 527-547.

Moreno, R., & Usai, S. (2005). Spatial Spillovers and Innovation Activity in European Regions, *Environment and planning*, *37*, 1793-1812.

OECD (2011). *OECD Science, Technology and Industry Scoreboard*

2003. OECD Publishing, Retrieved from http://www.oecd-ilibrary.org/science-and-technology/.

Olivero, M. P., & Yotov, Y. V. (2012). Dynamic Gravity: Endogenous Country Size and Asset Accumulation. *Canadian Journal of Economic, 45*, 64-92.

Pakes, A., & Griliches, Z. (1980). Patents and R&D at the Firm Level: A First Report. *Economics Letters, 5,* 377-381.

Pavitt, K., Robson, M., & Townsend, J. (1987). The Size Distribution of Innovating Firms in the UK: 1945-1984. *Journal of Industrial Economics, 55,* 291-316.

Posner, M. V. (1961). International Trade and Technical Change. *Oxford Economic Papers, 13,* 323-341.

Ramos, M., & Zarzoso, M. (2010). The Effect of Technological Innovation on International Trade. *Open Assessment E-Journal*, *4,* 1-30.

Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy, 98,* S71-S102.

Santos, S. J., & Tenreyro, S. (2006). The Log of Gravity. *The Review of Economics and Statistics, 88,* 641-58.

Statistical National Center of Iran (2013). Retrieved from http://www.amar.org.ir/ .

Tinbergen, J. (1962). *The World Economy, Suggestions for an International Economic Policy*. New York, NY: Twentieth Century Fund.

Torstensson, J. (1996). Technical Differences and Inter-industry Trade in the Nordic Countries. *Scandinavian Journal of Economics*, *98,* 93-110.

UN Comtrade: International Trade Statistics (2014). Retrieved from http://www.comtrade.un.org/data/.

Vernon, R. (1966). International Investment and International Trade in the Product Cycle. *Quarterly Journal of Economics*, *80*, 190-207.

Verspagen, B., & Wakelin, K. (1997). Technology, Employment and Trade: Perspectives on European Integration. In Fagerberg, J., Hansson, P., Lundberg, L., & Melchior, A. (Eds.), *Technology and International Trade* (56-74). Cheltenham: Edward Elgar.

World Bank (2014). *World Development Indicators*. Retrieved from http://data.worldbank.org/data-catalog/world-development-indicators.