ELSEVIER

Journal of International Economics 62 (2004) 171–189

Journal of INTERNATIONAL ECONOMICS

www.elsevier.com/locate/econbase

The effect of the Internet on international trade

Caroline L. Freund[a,*], Diana Weinhold[b]

[a] Development Economics Research Group, MC3-329, The World Bank, 1818 H Street, NE, Washington, DC 40433, USA
[b] Development Studies Institute, London School of Economics, Houghton Street, London WC2A 2AE, UK

Received 28 June 2001; received in revised form 7 June 2002; accepted 19 February 2003

Abstract

We find that the Internet stimulates trade. Evidence from time-series and cross-section regressions shows a significant effect of the Internet on trade in recent years. Our results suggest that a 10 percentage point increase in the growth of web hosts in a country leads to about a 0.2 percentage point increase in export growth. For the average country in our sample, the Internet contributed to about a 1 percentage point increase in annual export growth from 1997 to 1999. We also find evidence of proximity-biased trade growth, i.e. that trade growth is lower for more distant countries, but we do not find evidence that the Internet has directly affected this bias. The evidence is consistent with a model in which the Internet reduces market-specific fixed costs of trade. In particular, we show that an Internet-related reduction in fixed costs is likely to enhance export growth. The model also shows that the Internet does not directly affect the relationship between distance and trade; however, to the extent that competition is enhanced as a result of its development, the Internet will *increase* the overall effect of distance on trade.

Keywords: Internet; Technology; Trade; Distance; E-commerce

JEL classification: F12; F14; F15

1. Introduction

Anecdotal evidence that the Internet has affected international trade is everywhere. Women in a remote part of Guyana are using the Internet to sell hand-woven hammocks to people around the world (NYT 3/28/2000). An importer in the Dominican Republic found a

* Corresponding author. Tel.: +1-202-473-7102; fax: +1-202-522-1159.
E-mail address: cfreund@worldbank.org (C.L. Freund).

0022-1996/$ - see front matter
doi:10.1016/S0022-1996(03)00059-X

Bolivian supplier of Soya oil and a Chinese supplier of sewing machines over the Internet.[1] A producer of draperies and other goods from Hicksville, Long Island is using the Internet to negotiate deals in Turkey, Saudi Arabia, and South Africa, after years of serving only the domestic market (Long Island Business News, 8/21/2000). Of greater importance for sheer trade volumes, global business-to-business web sites have already been set up in a number of industries. Some examples include SciQuest, a global marketplace for laboratory and scientific materials; Commerx, a global exchange for plastics, metals, and packaging materials; and e-Steel, which links buyers and sellers of steel products around the world. In one well-known example, Daimler-Chrysler, GM, and Ford founded COVISINT, an Internet-based market for car parts that aggregates thousands of suppliers worldwide. Such initiatives are not limited to industrialized countries. The fast-moving and fragmented fresh flower business in Ecuador relies on e-marketplaces such as florastream.com to match buyers with sellers and facilitate logistics. A web-based market is being developed in greater China for international suppliers of agricultural products (Chicago Sun Times 9/12/2000). Forrester Research, a leading consulting company, estimates that global e-commerce cross-border trade was \$44 billion in 2000, and will grow to \$1.4 trillion in 2004, accounting for 18 percent of total exports (Sanders, 2000).

The main purpose of this paper is to quantify the effect that the Internet has had on international trade in recent years. We motivate the analysis using a model with imperfect competition and fixed costs of entry into a foreign market. Evidence suggests that market-specific fixed entry costs have historically been very important for a large share of trade in goods. The Internet has the potential to reduce these costs because suppliers can more easily find information about new markets and can advertise to numerous buyers at once. This has important implications for trade volumes and for bilateral trade patterns. In particular, we show that if the new technology reduces entry costs then Internet growth will promote export growth. We also show that proximate countries will experience faster trade growth. The intuition is that as competition increases with the Internet, there is a strategic incentive for each firm to increase exports, in order to dampen exports from other firms. We show that this *strategic effect* is dependent on distance, and is larger for near firms than for far firms, thus enhancing the effect of distance on trade.

We take advantage of time-series and cross-sectional variation in bilateral trade data to explore whether Internet usage can help explain trade growth and observed trade patterns. In brief, using data on bilateral trade from 1995 to 1999 and controlling for the standard determinants of trade growth, we find that growth in the number of web sites in a country helps to explain export growth in the following year. Specifically, our results from the growth regressions imply that an increase of 10 percentage points in web hosts in 1998 would have led to about a 0.2 percentage point increase in exports in 1999. We also find that overall trade growth over this period has been proximity-biased, consistent with the prediction that enhanced competition will lead to relatively greater trade among near countries. However, we find little evidence that the Internet has directly altered the impact of distance on trade. Evidence from cross-section analysis supports these results.

[1] Authors' discussion with Munne and Co., Santo Domingo (2002).

It should be noted that while the Internet is likely to impact trade in both goods and services, the effects on the two are likely to be very different. As mentioned above, trade in goods will be affected because Internet technology improves information about foreign markets, thereby reducing entry costs. Trade in services will be impacted because new services, which are transmittable via the Internet, can now be traded almost costlessly, irrespective of location.[2] The Internet should therefore have a relatively greater effect on the volume of trade in services and on the way in which distance influences services. In this paper, we focus on goods trade and the market-creating effect of the Internet on goods trade. In a companion paper, we explore the effect of the Internet on services trade (Freund and Weinhold, 2002).

The paper proceeds as follows: Section 2 reviews related literature and develops a theoretical framework to describe the effect of the Internet on trade. Section 3 discusses data and measurement issues, Section 4 presents the results, and Section 5 concludes.

2. A theoretical framework for empirical tests

The purpose of this section is to provide a theoretical framework for empirical examination of how the Internet will influence trade patterns. The model is meant to be illustrative and highlight the ways in which the Internet is likely to impact goods trade. In particular, we want to explore how bilateral trade patterns will be affected, and whether the Internet will change the impact of distance on trade. The relevant innovation of the Internet is that it lowers entry costs into a new market through organized exchanges with numerous buyers and sellers, and through powerful search engines, which enable sellers and buyers to find each other at a low cost. Indeed, a recent survey of 50 global eMarketplaces highlights the entry-cost advantages that the Internet offers. One executive from a Chemicals site notes that "If a French chemicals company wanted to sell in China, it would spend a lot of money to expand into Asia. Now the firm can post on our site. The Chinese buyer looking for PVC is one click away from the French seller" (Sanders, 2000).

We model the effect of the Internet on trade by assuming that it reduces the fixed entry cost of entering a particular market. A large body of work has emphasized the importance of fixed costs in explaining trade flows. In a seminal paper, Baldwin (1988) shows that to the extent that such costs are sunk they may be responsible for explaining observed hysteresis in trade flows. Eichengreen and Irwin (1998) find that historical trade patterns play a large role in determining current trade patterns, and interpret this as evidence that large entry costs must be involved in setting up trade networks. Using firm-level data, Roberts and Tybout (1997) find evidence that sunk entry costs help explain why Colombian firms export in a particular year. Freund (2000) finds that trade links between original members of the European Union are highly persistent, and hypothesizes that entry costs are likely to blame.

[2] Indeed, Quah (1999) argues that because of this new way of trading information, the Internet will change the way business is done.

A related strand of the literature focuses on the entry costs associated with imperfect information and emphasizes the importance of local networks in overcoming these costs. Rauch (1996) develops a search theory of trade in which networks expand the number of possible export markets by increasing the number of draws a firm obtains when it searches for the best match.[3] He uses this theory to explain the importance of family ties and Asian business groups in establishing trade links. In a companion paper, Rauch (1999) shows that trade links, such as colonial ties or a common language, are important in explaining trade patterns, especially for goods that do not trade on an organized exchange or have reference prices. The Internet is likely to reduce this type of entry cost since networks can expand and information can be more easily exchanged.

We develop a model with segmented markets and imperfect competition to demonstrate the effects of a reduction in fixed costs of entry. Both market segmentation and imperfect competition are likely to be important characteristics of markets with fixed costs. Firms will not export to markets where profits are low and fixed costs are large, implying that the level of competition will be different across countries. Moreover, perfect competition and fixed costs are not mutually consistent because two exporters could never compete profitably in the same export market since average cost would exceed marginal cost. Finally, there is ample empirical evidence showing that firms 'price to market' in international trade, implying that imperfect competition and market segmentation are important in practice (Goldberg and Knetter, 1997).

We consider p countries, each with a fixed number of firms, m_i, producing a homogeneous good. Competition in this market is Cournot, and welfare gains are a result of the increase in competition that trade introduces (as in Brander and Krugman, 1983). Demand for the imperfectly competitive good in country j is

$$P_j = K_j - Q_j,$$

where P_j is price and K_j is a constant.[4] Markets are assumed to be segmented, that is, it is prohibitively costly to cross-haul output. Each firm produces with a constant marginal cost, c. In addition, there is a transport cost, t, that increases with distance, d, because it is more costly to ship goods over long distances, $t_{ij} = wd_{ij}$, where w is a constant.

We further assume that each foreign firm incurs a market-specific fixed cost in order to participate in a given market. This includes costs such as finding out information about the market, advertising the product, and establishing a distribution network. Specifically, we assume that the fixed cost of a firm from country i entering market j is drawn from a uniform distribution between 0 and $F_{ij}^{\max}$. The intuition for the variation in costs within a country is that some firms are likely to have special information about a particular market, perhaps because the manager has traveled there, has relatives there, or has other unique

[3] In related work, Rauch and Trindade (2000) show that trade is increasing in market familiarity, where more market familiarity means that finding a joint-venture partner is relatively easier. In this type of model, innovations such as the Internet which improve market familiarity would also increase trade.

[4] The model is partial equilibrium. We could assume a quasi-linear demand function with a perfectly competitive numeraire good to embed the model in a general equilibrium setting, but that would still abstract from real resource allocation effects. Putting fixed costs into full general equilibrium models is extremely difficult, see, for example, Romer (1994).

connections. We also allow variation in the size of the distribution by country pair. For example, Canadian firms are likely to have fixed costs drawn from a very narrow distribution (a very low $F^{\max}$) with respect to entering the U.S. market because of proximity, common language, and historical linkages. In contrast, the distribution of fixed costs for Pakistani firms exporting to the U.S. market is likely to be significantly wider.

To solve the problem, we first solve for the firms optimal exports, given that the firm exports to a certain market, then we check under what condition exporting will occur in equilibrium. The firms problem is to maximize net profits

$$\max_{q_{ij}} q_{ij}(K_j - q_j^* - q_{ij} - c - wd_{ij}) - F_{ij}, \tag{1}$$

where q_{ij} is the export quantity of a firm from i in market j, and q_j^* is the output for sale by other firms in j. The solution to this problem yields the equilibrium quantity that the firm from i exports to j as a function of output from all other firms. The optimal equilibrium quantity, given that it exports, is

$$q_{ij} = \frac{(K_j - c - n_j wd_{ij} + w\sum_{k \neq i} d_{kj})}{n_j + 1} = \frac{(K_j - c - w\bar{d}_j)}{n_j + 1} + \frac{n_j w(\bar{d}_j - d_{ij})}{n_j + 1}, \tag{2}$$

where n_j is the total number of firms competing in market j and d_j is the average distance of the exporters to country j and $\sum_{i \neq k} d_{kj} \approx (n_j - 1)\bar{d}_j$. Eq. (2) implies that firms with relatively low transport costs (small d_{ij}) export a greater quantity. The first term on the far right is the Cournot quantity that firm i would export if all firms were symmetric; it shows that output is increasing in market size and decreasing in costs and in the number of firms in the market. The second term shows the extent to which exports differ depending on relative transport costs. Because exports are strategic substitutes, firm i's exports increase when other firms' exports decrease. This means that in addition to being dependent on own transport costs, exports are dependent on other firms' transport costs. Specifically, firm i's exports exceed (are below) average exports when i's distance from j is less than (greater than) average distance.

Next, we solve for profits and export share. Plugging the quantity from Eq. (2) into Eq. (1) and solving, gross profits are

$$\pi_{ij} = q_{ij}^2. \tag{3}$$

With a fixed cost of exporting, exporting is worthwhile only if profits exceed the fixed cost. Let F_{ij}^* be defined as the cutoff level of fixed cost in each country such that a firm is willing to enter a foreign market. Entry will occur up to the point where net profits are zero, $\pi_{ij} - F_{ij}^* = 0$. This implies that the share of firms from country i that export to country j is equal to the realized gross profits of each firm that entered market j relative to the maximum fixed cost, $\pi_{ij}/F_{ij}^{\max}$.

Total exports from i to j, X_{ij}, are dependent on the share of firms that export, the quantity that each firm exports, and the total number of firms as follows:

$$X_{ij} = \frac{\pi_{ij}}{F_{ij}^{\max}} q_{ij} m_i = \frac{q_{ij}^3}{F_{ij}^{\max}} m_i. \tag{4}$$

This yields four hypotheses about trade in the imperfectly competitive good with fixed costs. (i) Proximate countries will export relatively more because transport costs are lower. (ii) Countries with a low maximum fixed cost, such as proximate countries and countries with historical linkages, will export more because the share of firms that export is relatively larger. (iii) Firms export more to large markets, i.e. markets where K_j is large. (iv) Large countries export more, i.e. countries where the number of firms (m_i) is large. Note that these predictions broadly describe the widely used gravity model of trade.[5]

Next, we consider how trade changes with the Internet. We assume that the Internet reduces the fixed-cost that firms face in markets with sufficient Internet penetration. The intuition is that the Internet helps firms acquire information about foreign countries with web-based markets and helps networks share information about particular markets. The Internet effectively lowers the cost of doing business in a foreign country.[6] In particular, we assume that there is an indicator of Internet connectedness between countries i and $j, x_{ij}(0 < x_{ij} < 1)$, which represents the extent to which the fixed cost of each firm is lowered as information is improved. Specifically, the indicator is decreasing in Internet connectedness, such that the fixed cost of a firm from i in country j is $x_{ij}F_{ij.}$ Hence, fixed costs are lowest when x_{ij} is small and Internet connectedness is high. This implies that the share of firms from i that enter market j is now $\pi_{ij}/x_{ij}F^{\max}$. Hence, with the Internet, total exports from i to j are

$$X_{ij} = \frac{q_{ij}^3}{x_{ij}F^{\max}} m_i. \tag{5}$$

All else equal, exports are greater when the fixed cost is lower (and Internet connectedness is greater) because more firms enter the foreign market. However, greater entry also implies that the quantity that each firm exports will decline and profits will fall, somewhat dampening the effect of entry on exports.

For our empirical work it is useful to write Eq. (5) in growth rates. Using hat calculus (and taking the number of firms m_i as fixed), export growth from i to j is

$$\frac{\mathrm{d}X_{ij}}{X_{ij}} = \frac{\mathrm{d}x_{ij}}{x_{ij}} + 3\frac{\mathrm{d}q_{ij}}{q_{ij}}. \tag{6}$$

The first term on the right-hand side of Eq. (6) is export growth from i to j as a result of a the reduction in fixed costs through Internet growth. The second term is export growth that results from the change in optimal export quantity of each firm. Quantity effects are amplified because they feed into profits, and as profits increase, the share of firms that export also increases.

[5] Feenstra et al. (2001) use a model with oligopolistic competition to examine how income elasticities differ under various trade models. They also show that this so-called reciprocal dumping model is consistent with the gravity equation.

[6] Our motivation is to focus on foreign market entry and not domestic entry, so as a simplifying assumption, we do not investigate how the Internet affects domestic startups. See also footnote 12.

Since we do not have data on firm-level exports and we would like to use the analysis to guide our empirical work, we expand the last term. Referring back to Eq. (2), a firms export quantity will change as a result of a change in the import market size (K_j), a change in the level of competition in the importing market, as measured by the number of firms (n_j), or a change in the average distance of exporters, d. Specifically, the total derivative of quantity is

$$\mathrm{d}q_{ij} = \frac{1}{n_j+1}\mathrm{d}K_j + \left(\frac{-(K-c-w\bar{d}_j)}{(n_j+1)^2} + \frac{w(\bar{d}_j - d_{ij})}{(n_j+1)^2}\right)\mathrm{d}n_j + \frac{(n_j-1)w}{n_j+1}\mathrm{d}\bar{d}_j. \tag{7}$$

The first term in Eq. (7) is the increase in export-quantity from import-market expansion. The second term is the change in exports due to increased competition in market j. The last term is the change in exports due to a change in the average distance of exporters. As the average distance increases, there is a strategic incentive for each firm to increase exports, since other exporters export less, all else equal.

Note that the decline in exports as a result of increased competition (greater n) is steeper for more distant firms. The logic stems from the fact that exports are strategic substitutes. Therefore, when the number of firms increases, total exports increase, causing each firms equilibrium exports to decline. The extent of the firm-level output decline is a function of proximity: distant firms reduce exports by a greater extent than near firms. Therefore, to the extent that increased Internet penetration in the importing country is associated with increased entry, we expect to see an *increase* in the overall effect of distance on trade growth. This implies that, contrary to conventional wisdom, the Internet could *enhance* the overall effect of distance on trade through its effect on competition. It is important to note, however, that the model does not predict a direct impact of the Internet on the relationship between trade and distance. That is, in Eq. (6), the effect of the Internet on trade is the same irrespective of the proximity to market. Only if the Internet explicitly has a distance-saving component to itfor example, for a given level, it reduces fixed costs from distant countries to a greater extent than from near countrieswould we expect to see it reduce the effect of distance of trade.

Eqs. (6) and (7) imply that bilateral export growth is a function of the reduction in fixed costs through growth in Internet connectedness, import-country growth, growth in competition, growth in the average distance of exporters, and the relative proximity of the two countries. Specifically,

$$\frac{\mathrm{d}X_{ij}}{X_{ij}} = F\left(\overset{-}{\frac{\mathrm{d}x_{ij}}{x_{ij}}}, \overset{+}{\frac{\mathrm{d}K_j}{K_j}}, \overset{-}{\frac{\mathrm{d}n_j}{n_j}}, \overset{+}{\frac{\mathrm{d}\bar{d}}{\bar{d}}}, \overset{?}{d_{ij}}\right). \tag{8}$$

Internet growth (or a reduction in fixed costs) should enhance export growth, growth in the import market should increase export growth, growth in the total number of exporters should reduce export growth, and growth in the average distance of exporters should enhance export growth. The distance of the exporter from the market will also affect export growth, but the direction is ambiguous. If import-market growth is primarily responsible for export growth then growth is likely to be greater for more distant countries, since the marginal effect of market size on export quantity is constant and more distant countries export less. Alternatively, if increased competition is more important, then distance is likely to be associated with slower export growth because firms from near countries reduce exports by less as competition intensifies, and firms from near countries export greater quantities. Finally, it is also possible that technology has been biased towards (or away from) more distant exporters, in which case distance would also affect export growth.

World trade will increase as a result of the Internet, provided there is not a large increase in average distance of exporters to markets. That is, the gain in the number of exporters more than offsets the decline in firm-level output, unless entry is highly distance biased. This implies that the price of the imperfectly competitive good is likely to fall. Note, however, that this is only suggestive of a welfare gain. It is possible, as shown by Brander and Krugman, that increased trade can reduce welfare because of waste in the form of transport cost (and in this case there is additional waste in terms of fixed costs).

This framework yields three predictions about how the Internet will affect trade flows. (i) Growth in Internet connectedness between two countries will facilitate bilateral trade growth. (ii) To the extent that the Internet strengthens competition, the Internet will lead to greater import growth from more proximate countries, thus, increasing the effect of distance on trade. (iii) Internet development is likely to increase aggregate trade.

The remainder of the paper tests the positive predictions of the model. Specifically, we first examine whether the development of the Internet has led to increased bilateral trade flows in recent years. Theory suggests that trade should expand because firms with access to the Internet have better access to information about foreign markets and hence lower costs of entry. Second, we explore whether the Internet has altered the effect of distance on trade. While public rhetoric has emphasized the death of distance, theory does not offer such a definite prediction with respect to its fate. Third, we examine whether the Internet increased aggregate trade.

3. Data

To measure Internet development across countries, we use data from the Internet Software Consortium (http://www.isc.org) on the number of web hosts attributed to each country that is obtained from counting top-level host domain names. A top-level domain name is either an ISO country code or one of the generic domains (com/org/net/etc). There are some problems with this data that deserve mention. In particular, there is not necessarily a strong correlation between a host's domain name and where it is located. For example, the ISC data attributes a host with a .NL domain name to the Netherlands, when it is possible that the site could be located in another country. In addition, hosts under domains edu/org/net/com/int could be located anywhere.

Still, it is likely that our measure of the Internet, which we call *HOST*, is correlated with the relative Internet development in each country. If a host site with, say, a Venezuelan top-level domain name is located in the United States, it is likely that the content of the web site is aimed at Venezuelans. Thus the number of 'Venezuelan' sites, irrespective of the physical location of the related businesses, should to a large extent reflect Venezuelan

Table 1
List of countries

Algeria	Kenya
Argentina	Kuwait
Australia	Malaysia
Austria	Mexico
Belgium	Morocco
Bolivia	Netherlands
Brazil	New Zealand
Canada	Norway
Chile	Pakistan
China	Paraguay
Colombia	Peru
Denmark	Philippines
Ecuador	Poland
Egypt	Portugal
Finland	Saudi Arabia
France	Singapore
Germany	South Africa
Greece	South Korea
Hong Kong	Spain
Hungary	Sweden
Iceland	Switzerland
India	Thailand
Indonesia	Tunisia
Iran	Turkey
Ireland	United Kingdom
Israel	United States
Italy	Uruguay
Japan	Venezuela

Internet usage. In all of the specifications reported in the paper, we do not attribute hosts under the domains *.org*, *.edu*, *.net*, *.com* or *.int* to any particular country.[7]

Because of the possible problems with the data noted above, in an earlier version of this paper we have also used estimates of the number of Internet users in each country (as provided in the World Bank, World Development Indicators), as an alternative measure of cybermass. These data are available for 34 of the 56 countries in our sample and the analyses yielded qualitatively similar results (see Freund and Weinhold, 2000).

Table 1 lists all of the countries included in the study. Summary statistics on the number of host sites by top-level domain name, for the 56 countries in the sample, are presented in the top panel of Table 2. Between 1995 and 1997 the number of such host sites

[7] As the vast majority of sites with *.org*, *.edu*, *.net*, *.com* or *.int* domain names could be expected to reside in the United States, the U.S. Internet measure is likely to be biased downward. To check whether this particular bias could have an effect on the results, the analysis was repeated including a dummy variable for any country pair that included the United States, interacted with our host measures. Its inclusion in the regression did not significantly change any of the other results. We also redo the regressions assuming that 85 percent of these sites are in the United States (not reported). The results were very similar to the base case.

Table 2
Summary statistics for host sites by country top-level domain names

Year	Mean	Std. Dev.	Minimum	Maximum
1995	29 770.64	54 367.70	0	241 191
1996	63 456.91	112 886.26	0	452 997
1997	114 035.04	193 965.52	0	734 406
1998	191 086.11	329 857.61	17	1 226 568
1999	266 346.20	460 465.73	25	1 718 935

approximately doubles each year. In 1998 and 1999 this exponential rate slows slightly, but is still quite high.

Data on bilateral merchandise trade flows, GDP, and population are from the IMF. Data on geographic distances between countries was generously provided by Shang-Jin Wei (1996) who compiled them from Direct-Line Distances (1986). Data on common linguistic heritage and colonial links were compiled from Rand McNally and Co. Historical Atlas of the World (1994) and are available from the authors. Data on free trade areas come from the World Trade Organization web site (www.WTO.org).[8] All data were collected for 56 countries for the years 1995–1999.

4. Empirical estimation

As illustrated in Section 3, the advent of the Internet is likely to influence trade patterns. First, access to the web should increase exports because countries have more information about foreign markets and costs of accessing these markets are reduced. Second, the web could significantly alter the significance of physical distance as an impediment to trade. Third, the Internet should lead to higher overall trade. In order to investigate these questions, we exploit both time-series and cross-sectional variation in the data and present a series of panel and cross-section regressions that follow our theoretical model.

4.1. Panel data estimation

We begin by looking at the growth rates of both the Internet and exports. Using growth rates has advantages as compared with levels because Internet penetration is likely to be correlated with many other socio-economic characteristics that could conceivably influence trade. In this way, we difference out of the equation levels-fixed effects that would include many of the correlated unobservables, (for example, Internet intensity is likely to be correlated with levels of development and education, as well as with high-tech production, all of which could influence trade).

According to Eq. (8), the main determinants of annual export growth are import-country GDP growth, growth in the level of competition, Internet growth, and proximity to

[8] The FTAs included are the EU, NAFTA, Mercosur, ECO, Sparteca, Bangkok, ASEAN, EFTA, CEFTA, and the Tripartite agreement.

market. We include GDP growth in the importing country since a greater market size will lead to higher exports from all countries.[9,10] To control for changes in competitiveness, we include year-fixed effects. We include distance between the exporter and importer in order to determine if trade growth is biased with respect to geography as the model predicts. In addition, we control for initial log-levels of exports, as adjustment is likely to be more rapid in countries with very low exports. Provided 1995 was a 'typical' year, this will also capture many time-invariant idiosyncratic features of the trade relationship between two countries. Finally, we introduce the growth rates of our HOST variable in both the exporting country and the importing country. Since we would expect the introduction of new web sites to effect trade only with a time lag, the growth rates of the host variables are lagged one period. As the growth of web sites would be expected to be correlated with the initial level (with those starting from a lower level growing faster) we also control for the 1995 log-level of HOST for each country.[11] Thus our baseline panel growth regression takes the following form:

$$\begin{aligned} Growth(Exports_{12})_t = {} & \beta_0 + \beta_1 Growth(GDP_2)_t + \beta_2^* Log(Exports_{12})_{1995} \\ & + \beta_3^* Log(Distance_{12}) + \beta_4 Growth(Host_1)_{t-1} \\ & + \beta_5^* Growth(Host_2)_{t-1} + \beta_6^* Log(Host_1)_{1995} \\ & + \beta_7^* Log(Host_2)_{1995} + \gamma_t + \varepsilon_{12}. \end{aligned} \tag{9}$$

Our data span the period 1995 to 1999, so after taking growth rates and introducing time lags into the specification our final model is estimated on export growth for the three-year period from 1997 to 1999. We control for heteroskedasticity and allow for general time dependence between time periods using Den Haan and Levin HAC (Heteroskedasticty and Autocorrelation Consistent) estimation (see Den Haan and Levin, 1996).

The panel data growth regression results on exports are reported in Tables 3 and 4. Regression (1) in Table 3 is the baseline specification described above, for exports from country 1 to country 2, without the HOST variable included, while regression (2) introduces HOST variables. Consistent with the theory, both initial levels of HOST are significant, as is exporter growth of HOST, and the inclusion of Internet information improves the fit of the model. If we conservatively discount the significance of the initial level HOST variables on the grounds that they are more likely to be correlated with

[9] We also used lagged GDP growth to control for possible endogeneity and the results on the host variables were slightly stronger. We report results using contemporaneous GDP growth because the coefficient on lagged GDP growth was not robust, in addition, since the dependent variable is *bilateral* exports, the endogeneity problem is relatively minimal and contemporaneous GDP growth does a better job of controlling for other factors that might influence trade.

[10] The model suggests that export-country growth should also be in the regression if it leads to a change in the number of firms in the exporting country. We experimented with including current and lagged export-country GDP growth. The magnitude of the coefficient on exporter growth was very small, changed sign in various regressions, and was never significant; while the results from the other variables remained unchanged, so we do not include it in the reported results.

[11] An alternative would be to include log-level lagged twice of both *exports* and *Host*. Results do not change significantly when this approach is taken (not reported).

Table 3
Panel growth regressions

Dependent variable: Growth of exports from country 1 to country 2	(1)	(2)	(3)	(4)	(5)
Growth(HOST$_1$)$_{t-1}$		0.025	0.024	0.023	0.023
		(2.09)	(3.07)	(2.89)	(3.02)
Growth(HOST$_2$)$_{t-1}$		−0.003	−0.001	−0.002	−0.000
		(−0.28)	(−0.24)	(−0.41)	(−0.02)
Log(HOST$_1$)$_{95}$		0.008	0.005	0.011	0.013
		(2.31)	(2.55)	(3.87)	(4.65)
Log(HOST$_2$)$_{95}$		0.010	0.009	0.009	0.012
		(4.15)	(5.88)	(4.38)	(5.45)
Log(EXPORT$_{12}$)$_{95}$	−0.017	−0.026	−0.013	−0.028	−0.040
	(−5.32)	(−6.10)	(−5.25)	(−6.95)	(−9.38)
Growth(GDP$_2$)	0.105	0.113	0.136	0.139	0.135
	(3.19)	(3.46)	(6.97)	(7.08)	(7.00)
Log(DISTANCE$_{12}$)	−0.026	−0.031	−0.028	−0.048	−0.060
	(−1.72)	(−2.02)	(−6.17)	(−8.76)	(−10.39)
Growth(ExchRate$_1$)$_{t-1}$				0.104	0.147
				(2.03)	(2.94)
Growth(ExchRate$_2$)$_{t-1}$				0.041	−0.111
				(0.78)	(−2.05)
Log(GDP$_1$)$_{95}$				−0.004	0.001
				(−0.60)	(0.08)
Log(GDP$_2$)$_{95}$				0.011	0.017
				(1.90)	(2.62)
Log(POP$_1$)$_{95}$				0.025	0.030
				(6.41)	(7.26)
Log(POP$_2$)$_{95}$				0.008	0.009
				(2.02)	(2.05)
Growth(EXPORT$_{12}$)$_{t-1}$					−0.222
					(−11.59)
Year-Fixed Effects	Yes	Yes	Yes	Yes	Yes
Adjusted R-square	0.010	0.025	0.030	0.033	0.094
No. observations	9057	9057	8601	8292	8292

Heteroskedasticity and autocorrelation consistent (HAC) t-statistics in parentheses (see Den Haan and Levin, 1996). Columns (1) and (2) report the results using all available data, columns (3)–(5) report the results when outliers, with error term more than four standard deviations from zero, are deleted.

unobservable determinants of bilateral trade growth, our baseline results suggest that Internet growth affects trade primarily through the exporting country.

The intuition for this result follows from the fact that Internet hosts are not a perfect proxy for Internet connectedness across countries. In the estimation, we use data on the number of web sites in the importing and the exporting country to proxy for the Internet-connectedness variable in the theoretical model. But, exporter and importer hosts influence bilateral exports in different ways. Internet expansion in the importing country will facilitate exports from all countries with Internet access. As the importing country increases Internet connectedness with the rest of the world, the number of firms in the market will increase and competition will intensify. Because of substitution effects, the equilibrium quantity that each exporting firm sells will decline. Thus, Internet penetration in the importing country should have a

Table 4
Panel growth regressions: the effect of distance

Dependent variable: growth of exports from Country 1 to Country 2, 1997–1999	(5)
Growth$(\mathrm{HOST}_1)_{t-1}$	0.022
	(1.94)
Growth$(\mathrm{HOST}_2)_{t-1}$	−0.008
	(−1.18)
Log$(\mathrm{HOST}_1)_{95}$	0.011
	(3.86)
Log$(\mathrm{HOST}_2)_{95}$	0.009
	(4.31)
Log$(\mathrm{DISTANCE}_{12})$	−0.049
	(−6.56)
$\mathrm{LONGDIST}_{12}$	−0.008
	(−0.41)
Growth$(\mathrm{HOST}_1)_{t-1}$ *$\mathrm{LONGDIST}_{12}$	0.003
	(0.21)
Growth$(\mathrm{HOST}_2)_{t-1}$ *$\mathrm{LONGDIST}_{12}$	0.011
	(1.02)
Adjusted. R-sq	0.033
No. Observations	8292

Heteroskedasticity and autocorrelation consistent (HAC) t-statistics in parentheses (see Den Haan and Levin, 1996). Year fixed effects, log of 1995 exports, logs of 1995 GDP and Population for exporter and importer, growth of exporter and importer real exchange rates, and importer GDP growth included in regression equation (not reported).

smaller effect on bilateral exports than Internet penetration in the exporting country because importing-country web access leads to greater exports from other countries.[12]

To ensure that our results are not being driven by a few outlier observations, we delete all observations where the error term is more than four standard deviations from zero. The results are reported in regression (3). The coefficients on the host variables remain roughly unchanged. As expected, the standard errors are now somewhat smaller, especially on the distance variable. The outliers largely reflect very high trade growth in country-pairs that had near zero trade initially. These tend to be small countries that are far apart, such as Bolivia and Hungary.

[12] In the model, all entry is foreign. In principle, the Internet could also facilitate domestic entry, in which case importing-country Internet penetration would have an even smaller effect on exports.

In order to minimize the possibility that our HOST variables are proxying for omitted variables in the regression, we include several variables that could be correlated with the Internet and with trade growth as a robustness check. In regression (4), we present an augmented baseline model which controls for initial log levels of GDP and population in both the importing and exporting countries, and also lagged growth of local-currency/dollar real exchange rates. The intuition for including GDP and population is that the Internet could be proxying for stage of development, as more highly developed countries are likely to have both greater Internet penetration and higher growth rates of the Internet. The real exchange rate variables will control for changes in competitiveness due to macro adjustments. Finally, in regression (5) we add lagged growth of exports. The introduction of the lagged dependent variable should help control for omitted variables, but also introduces bias into the estimation. We include it primarily as a robustness check. In all specifications, we find that initial conditions and growth of exporter HOST are significant, with coefficients on exporter growth consistently estimated at just over 0.02. The fact that the magnitude and significance of our HOST variables are not changed significantly by the inclusion of a lagged dependent variable suggests that this was not a major source of bias.[13]

The relatively consistent coefficient of 0.02 for the growth of HOST in the exporting country estimated in regressions (2)–(5) implies that a 10 percentage point increase in the growth of the Internet in the exporter country would lead to about a 0.2 percentage point increase in export growth. Given the rapid growth in the Internet over the period, these results imply that the Internet made a notable contribution to trade growth. For the average country in our sample, Internet growth (in log differences) was around 50 percent each year from 1996 to 1998, implying that the Internet contributed about 1 percentage point to annual export growth from 1997 to 1999. For the countries in the sample, aggregate export growth was about 2.5 percent per year on average from 1997 to 1999, suggesting the Internet was a key contributor to export growth over this period.

We turn next to the relationship between distance and trade. The coefficient on distance is negative, implying that trade growth has been biased toward relatively closer countries.[14] This is consistent with the model, which shows that as competition intensifies (n increases) the distance–trade locus becomes steeper. However, the coefficient changes only slightly when the host variables are included, suggesting that the Internet has not had a large effect on the way in which distance affects bilateral trade growth. To examine this question further, we introduce a dummy variable, $\mathrm{LONGDIST}_{12}$, which equals one if the distance between countries 1 and 2 exceeds the average distance between all countries. We then interact this with the growth of HOST variables and include the full set of controls from our regression (3).[15] If the Internet has reduced (increased) the impact of distance on trade then the coefficient on the interaction term should be positive (negative). The results are

[13] We performed a further robustness check by first-differencing the baseline specification from regression (2); in other words we introduce fixed effects into the growth equation. The coefficient estimate for growth of exporter HOST remained statistically significant and increased slightly in magnitude.

[14] This result is robust to the inclusion of dummies for adjacency and free trade areas (neither of which was significant) in the regression.

[15] We do not include the lagged dependent variable as this could introduce bias. Controlling for the lagged dependent variables increases the magnitude and statistical significance of HOST.

presented in Table 4, regression (5). We find that the interaction between growth of HOST and LONGDIST_{12} is positive but not statistically significant for the importing country, and close to zero and not significant for the exporting country. Thus, our results offer little evidence that increased Internet penetration has altered the effect of distance on trade.

4.2. Cross section, 'gravity model' estimation

Our panel regression specifications have been chosen to minimize the possibility of omitted variable bias and to capture some of the dynamic impact of the Internet. Cross-section estimation is more prone to these problems, as it is impossible to control for country-fixed effects while using country-specific variables. Nevertheless, cross-section estimation eliminates the possibility of co-trending variables over time and thus provides a useful robustness check of our results. Table 5 presents the results from a series of modified gravity equations in 1995 and 1999 to test whether an impact of the Internet on trade patterns exists in the cross section as well as in the time series. A basic gravity equation depicts trade between countries as proportional to the product

Table 5
Cross-section gravity regressions

	Dependent variable: Log(trade between countries i and j)				
	1995 (6)	1995 (7)	1999 (8)	1999 (9)	1999 (10)
$\text{Log}(\text{HOST}_i{*}\text{HOST}_j)_t$		−0.002		0.103	
		(−0.39)		(4.41)	
$\text{Log}(\text{HOST}_i{*}\text{HOST}_j)_{t-2}$					0.018
					(2.10)
$\text{Log}(\text{GDP}_i{*}\text{GDP}_j)_t$	1.034	1.040	1.157	0.969	0.211
	(59.15)	(43.97)	(36.24)	(19.30)	(5.12)
$\text{Log}(\text{POP}_i{*}\text{POP}_j)_t$	−0.097	−0.101	−0.136	−0.033	−0.019
	(−5.62)	(−4.96)	(−5.32)	(−0.94)	(−1.08)
$\text{Log}(\text{DISTANCE}_{ij})$	−0.797	−0.796	0.826	−0.885	−0.216
	(−23.13)	(−23.11)	(−15.51)	(−16.48)	(−6.18)
COMMON	0.755	0.757	0.927	0.859	0.305
LANGUAGE	(7.61)	(7.61)	(7.18)	(6.70)	(4.67)
COLONIAL	0.544	0.536	0.476	0.495	0.019
LINK	(2.75)	(2.71)	(2.21)	(2.27)	(0.26)
ADJ	0.497	0.496	0.518	0.489	−0.098
	(3.16)	(3.16)	(2.84)	(2.69)	(−1.39)
FTA	0.172	0.172	0.277	0.149	0.021
	(1.76)	(1.76)	(2.08)	(1.15)	(0.37)
$\text{Log}(\text{TRADE}_{ij})_{1995}$					0.810
					(24.20)
Adjusted R-square	0.785	0.786	0.707	0.711	0.874
No. observations	1479	1479	1501	1501	1478

Heteroskedasticity consistent (HuberWhite) t-statistics in parentheses. All regressions run with constant (not reported).

of their economic masses (GDPs) and inversely related to the distance between them. Recall that Eq. (4) in the theoretical framework yielded predictions about bilateral trade that mirror the gravity equation. Specifically, we estimate the following equation:

$$trade_{ij} = \beta_0 + \beta_1(gdp_i gdp_j) + \beta_2(pop_i pop_j) + \beta_3 dist_{ij} + \beta_4 ADJ_{ij} + \beta_5 LANG + \beta_6 LINK + \beta_7 FTA + \beta_8(host_i host_j) + \varepsilon_{ij}, \tag{10}$$

where all lower case variables are in natural logs, and ADJ is a dummy variable for adjacent countries, LANG is a dummy for countries that speak the same language, and FTA is a dummy for countries that are part of a free trade agreement.

Regression (6) reports the results for the 1995 baseline gravity equation, without the HOST variable, while regression (7) includes the HOST variable, which is not statistically significant. In regressions (8) and (9) we repeat the exercise for 1999 and find that HOST variable is highly statistically significant with a coefficient estimate of 0.10.

As suggested above, there are several potential specification problems with regressions (6)–(9). Even though we control for the standard variables in the literature, there is a possibility that these cross-section gravity regressions suffer from omitted-variable bias. In particular, our HOST variable could proxy for a number of omitted variables that are important for trade, such as infrastructure and human capital. In addition, in comparing regression (8) with regression (9), there is a marked change in the coefficients on GDP and population, implying that multicollinearity is a serious concern. Furthermore, as our HOST variable is contemporaneous with the trade variable there is a potential for endogeneity bias if growing trade spurs increased Internet penetration, rather than the reverse.

In regression (10) we attempt to minimize these possibilities by lagging our HOST variable by two periods and controlling for initial trade patterns from 1995 in the regression equation. By lagging the HOST variable we reduce the possibility of reverse-causality. The lagged dependent variable will capture all of the country- and pair-specific unobservable characteristics that are time invariant (and a good deal of the time-varying characteristics as long as these are changing relatively slowly). Including this variable ensures that our HOST variable is not just picking up the effects of some inherent country traits, such as relative wealth.

Column (10) reports the results when 1995 trade is included in the 1999 regression equation and HOST is twice lagged. As expected, the statistical significance of time invariant control variables disappears, but the HOST variable remains positive and statistically significant. Not surprisingly, the coefficient on HOST falls when past trade is included. The coefficient of 0.018 suggests that a 10 percent increase in Internet hosts led to about 0.2 percent more trade in 1999. If this relationship continued to hold over the long run, it would imply that a 10 percent increase in hosts in one country would lead to nearly 1 percent (0.018/(1−0.81)=0.09) higher trade.

The cross-section gravity equations provide a further benefit by allowing us to compare the effect of distance on trading patterns across different years. As shown in the baseline gravity equations of Table 5, the effect of distance on trade increases from

0.797 in 1995 to 0.826 in 1999. This is consistent with the proximity-biased export growth we found in the panel regressions. These results imply that distance is if anything becoming more important—not less important—over time. When HOST is included in the regression equations, the coefficient on distance increases slightly, suggesting that the Internet could be dampening this effect, but the difference is not statistically significant (interactions of host and distance and host and adjacency are also not statistically significant, not reported).

4.3. Aggregate 'openness' estimation

While we have found evidence of an effect of the Internet on trade patterns in both growth rates and levels, this does not necessarily imply that the Internet has *increased* trade overall. It is possible that the Internet has simply reoriented trade, leading countries with high Internet intensity to shift some trade to other high-intensity countries. To investigate this possibility we study the impact of the Internet on the aggregate trade of the countries in our sample; in other words, we estimate the effect of the Internet on trade openness, as opposed to bilateral trade flows. The results are reported in Table 6. The dependent variable is the natural logarithm of total trade relative to GDP, ROWGDP is the natural logarithm of rest-of-the-world GDP, and REMOTE is a distance-weighted measure of other countries GDP. The results are consistent with our previous analyses as we fail to uncover any statistically significant impact of the Internet in the earlier years of the sample. However, these results do show that the Internet has led to increased openness in recent years. The coefficient of 0.05 on host in 1999 suggests that a relative doubling of hosts leads to a 5 percent increase in openness. In other words, the Internet has contributed to overall trade growth.

Table 6
Aggregate trade results

	Dependent variable: Log(aggregate trade/GDP)				
	1995 (11)	1996 (12)	1997 (13)	1998 (14)	1999 (15)
ROWGDP	5.25**	5.39**	5.57**	7.28**	6.93**
	(4.43)	(3.94)	(2.70)	(3.34)	(3.68)
POP	−0.14**	−0.14**	−0.13**	−0.11**	−0.11*
	(−2.50)	(−2.65)	(−2.36)	(−2.00)	(−1.89)
REMOTE	−0.16	−0.18	−0.19	0.22	−0.23
	(−0.78)	(−0.91)	(−0.94)	(−1.11)	(−1.08)
HOST	0.02	0.02	0.03	0.04*	0.05*
	(1.32)	(1.31)	(1.04)	(1.83)	(1.88)
No. Obs.	54	54	54	55	55
R-square	0.21	0.22	0.20	0.19	0.18

All regressions run with a constant (not reported).
Heteroskedasticity-consistent *t*-statistics in parentheses. In all years, the United States is excluded. South Africa is not included in 1995–1997 due to missing data.
** indicates statistical significance at 5%, and * at 10%.

5. Conclusions

This paper has presented a theoretical model of the impact of the Internet on international trade and empirically examined its predictions using both panel and cross-sectional data. The theory suggests that trade should expand because fixed costs associated with trade are reduced. The model also shows that as the number of firms with better information increases, the effect of distance on trade is actually likely to increase. The intuition is that there is a strategic incentive for exporters in nearby markets to increase trade in response to an increase in competition.

Using annual data on the number of Internet hosts per country, we present a series of panel and cross-section regressions of trade and export volumes on our HOST variables. The empirical evidence is broadly consistent with the theoretical model and is robust to alternative specifications and estimation methods. We find that Internet development helps to explain trade growth and bilateral trade patterns from 1997 to 1999. We also find evidence of a proximity bias in export growth. However, we were unable to identify a definitive role of the Internet in altering the role of distance in trade patterns.

Acknowledgements

The authors would like to thank Bruce Blonigen, Simeon Djankov, James Harrigan, Andrew Levin, James Rauch, John Rogers, Andrew Rose, Phillip Swagel, David Weinstein, Kei-Mu Yi, two anonymous referees, and seminar participants at Columbia University, the Federal Reserve Board, the University of Virginia, The World Bank, and the Empirical Investigations in International Trade Conference for helpful comments, and Kathryn Zweig for research assistance. All errors and omissions are our own.

References

Baldwin, R., 1988. Hysteresis in import prices: the beachhead effect. American Economic Review 78, 773–785.

Brander, J., Krugman, P., 1983. A 'reciprocal dumping' model of international trade. Journal of International Economics 15, 313–321.

Den Haan, W., Levin, A., 1996. A practitioners guide to robust covariance matrix estimation. NBER Working Paper No. T0197.

Eichengreen, B., Irwin, D., 1998. The role of history in bilateral trade flows. In: Frankel, J. (Ed.), The Regionalization of the World Economy. University of Chicago Press, Chicago, pp. 33–62.

Feenstra, R., Markusen, J., Rose, A., 2001. Using the gravity equation to differentiate among alternative theories of trade. Canadian Journal of Economics 34, 430–447.

Freund, C., 2000. Different paths to free trade: the gains from regionalism. Quarterly Journal of Economics 115, 1317–1341.

Freund, C., Weinhold, D., 2000. The effect of the Internet on international trade. Federal Reserve Board of Governors International Finance Working paper #693.

Freund, C., Weinhold, D., 2002. The Internet and international trade in services. American Economic Review, 236–240.

Goldberg, P., Knetter, M., 1997. Goods prices and exchange rates: what have we learned? Journal of Economic Literature 35, 1243–1272.

Historical Atlas of the World (1994) Rand McNally and Company, Chicago.
Quah, D., 1999. The weightless economy in economic development. CEPR Discussion Paper #417, February 1999.
Rauch, J., 1996. Trade and search: social capital, Sogo Shosha, and spillovers. NBER Working Paper #5618.
Rauch, J., 1999. Networks versus markets in international trade. Journal of International Economics 48, 7–35.
Rauch, J., Trindade, V., 2000. Information and globalization: wage co-movements, labor demand elasticity and conventional trade liberalization. NBER Working Paper #7671.
Roberts, M., Tybout, J., 1997. The decision to export in Columbia: an empirical model of entry with sunk costs. American Economic Review 87, 545–564.
Romer, P., 1994. New goods old theory and the welfare costs of trade restrictions. Journal of Development Economics 43, 5–38.
Sanders, M., 2000. Sizing global online exports. The Forrester Report, November (www.forrester.com).
Wei, S., 1996. Intra-national versus international trade: how stubborn are nation states in globalization? NBER Working Paper 5331.