Internet Linkage and International Trade: From the Perspective of Risk Alleviation*

Jie Duan†
National University of Singapore

Zengxi Hu‡
Central University of Finance and Economics

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Abstract

Extensive research has studied the effect of the Internet on trade, yet little is known about its role in trade facilitation through risk alleviation. This research investigates how internet linkage facilitates exports, particularly through the novel channel of risk alleviation. Theoretically, this paper introduces a gravity model augmented with export risk to establish the stimulating effect of internet linkage on exports. Empirically, this paper uses inter-domain hyperlinks as a proxy for Internet linkage in 2009, uncovering a statistically significant positive impact of Internet linkage on exports. Notably, there is a 27.8% increase in exports in reaction to a doubling of the Internet linkage intensity. By employing various techniques, we meticulously address potential endogeneity issues and substantiate the risk-alleviation mechanism at both the country and product levels. Particularly, we find that exports to riskier countries and of riskier products benefit more from Internet linkage. This study sheds new light on the novel channel through which the Internet promotes exports, enriching the existing literature in this field.

Keywords: Internet Linkage; International Trade; Export Risk; Risk Alleviation

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†Department of Economics, National University of Singapore. Blk AS1, #01-02, 1 Arts Link, Singapore 117570. *Email*: duanjie@u.nus.edu.

‡School of International Trade and Economics, Central University of Finance and Economics, Beijing, 102206, China. *Email*: zengxi_hu@163.com

1 Introduction

In recent years, Internet usage has upsurged remarkedly. Specifically, the International Telecommunication Union (ITU) reported that approximately 4.1 billion individuals were actively using the Internet by 2019, with a consistent annual growth of 10%.[1] Moreover, the Internet penetration rate escalated from 17% in 2005 to over 53% in 2019. Despite the global disruptions caused by the COVID-19 pandemic, international bandwidth usage experienced a substantial 38% increase in 2020, surpassing the growth rate of the previous year by 6%. Concurrently, global trade demonstrated an upward trend from 2000 to 2019, despite some downturns during crisis periods. By plotting the hyperlinks and export values across countries in 2009, as illustrated in Figure 1, we observe that countries with higher Internet linkages are associated with higher export values.[2] Such a remarkable correlation prompts the question of whether the Internet facilitates exports and, if so, how.

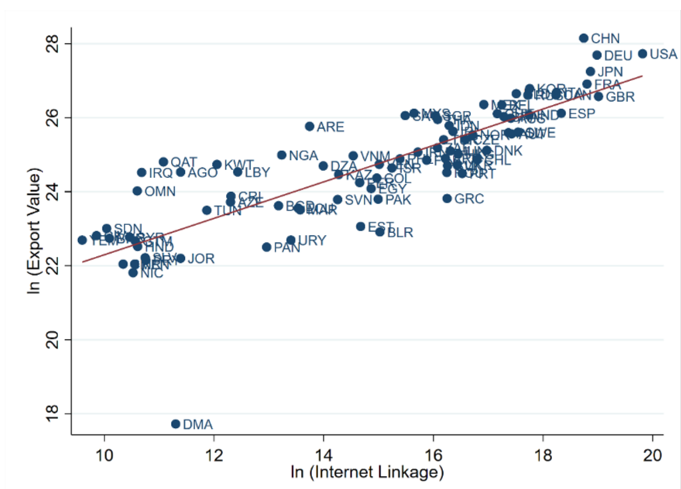

Figure 1: The Correlation between Internet Linkage and Exports

[1]Data is retrieved from https://www.itu.int/en/ITUD/Statistics/Documents/facts/FactsFigures2020.pdf.

[2]Internet linkage or Internet connection is measured by the logarithmic hyperlink counts sent from the exporting country to importing country; the exporting performance is measured by the log exporting value. The data of Internet linkage comes from Hellmanzik and Schmitz (2015) and Chung (2011); the trade data comes from UN COMTRADE. Further analysis regarding the relationship between the Internet linkage and exporting performance will be demonstrated in section 3.

Prior studies suggest that the Internet facilitates exports by lowering information costs, which are acknowledged as a crucial trade barrier in an open economy (Rauch, 1999; Allen, 2014). Specifically, information costs are formally identified as the costs incurred to achieve the intended communication objectives among entities. These include not only the costs of searching for transaction partners in a frictional market but also the cost of information asymmetry, the latter of which potentially hinders the completion of transactions.

Yet, the prevalence of the Internet has created a global ''vein'' for unimpeded information flow, thereby effectively reducing information costs in international trade. This is evident as the Internet, by providing exporters with extensive information at considerably reduced costs, effectively fosters trade activities (Bakos, 1997; Anderson and Van Wincoop, 2004; Fink et al., 2005). However, much of the existing literature has focused on reducing search costs for trading parties, with less attention paid to the role of Internet linkages in reducing information asymmetry, which is closely linked to transaction risks and uncertainties (Steinwender, 2018).

In particular, international trade is impeded by various risks and uncertainties arising from information asymmetry (Handley and Limão, 2017; Gervais, 2018).[3] Within this context, exporters have to make crucial decisions based on their anticipation of demand shocks occurring in destination countries, while information asymmetry often places exporters at a disadvantage in acquiring information, especially compared to importers who possess a more in-depth understanding of their domestic markets (Steinwender, 2018). Typically, exporters rely on relatively outdated information from destination countries to

[3] Risk is typically perceived as a circumstance in which decision-making individuals possess knowledge about the probability of each potential outcome yet remain uncertain about which specific outcome will materialize. On the other hand, uncertainty denotes a situation in which the probabilities associated with various outcomes are unknown and cannot be accurately gauged, thereby leading individuals to lack sufficient economic information necessary for making well-informed decisions (Park and Shapira, 2017). In practice, the situation often lies somewhere between these two extremes when exporters become more informed about their destination countries. As such, both risk and uncertainty can be perceived as probabilities of potential losses incurred by exporters; hence, we employ the term ''risk'' in the subsequent text to encompass both concepts.

predict future market conditions, which leads to increased trading risks and substantial profit losses.

However, information theory asserts that information reduces uncertainty and, consequently, mitigates risks in decision-making. Essentially, decision-makers, upon acquiring more information, are better equipped to navigate and reduce the risks associated with their decisions (Shannon, 1948). To be specific, through internet linkage, exporters can access more recent information, which helps them shape their expectations and, consequently, maximize their expected profits based on their improved forecasting accuracy. Internet searches, in particular, enhance the speed at which information seekers access real-time information (Hoag, 2006; Jeon and Nasr, 2016) and bolster the quantity and precision of information obtained (Mondria et al., 2010; Abeliansky and Hilbert, 2017). For example, in the scenario where exports are seeking carriers in destination countries, insufficient information about the local enterprises might lead them to choose a company with a questionable reputation, resulting in delays in material flows, increased carrier costs, potential sales losses, and ultimately reduced profits. However, with the aid of Internet searches, exporters can easily locate a trusted carrier. A simple Google search can provide carrier rankings in the destination market, aiding exporters to make a well-informed decision and thus mitigating exporting risks. Additionally, Internet linkages with destination countries enable exporters to stay informed of the latest trends in target markets, including changes in product preferences, dynamics of market competition, and technological advancements (Mondria et al., 2010; Abeliansky and Hilbert, 2017). The access to up-to-date market information allows exporters to strategically tailor their inventory management, which effectively alleviates their exporting risks (Novy and Taylor, 2020).[4][5]

[4]Following the 2008 financial crisis, China saw the rise of international trade data service platforms, among which Waimaobang, established in 2010, stands out as a representative example. These platforms provide various services that exporters can purchase. By searching on these platforms, exporters can be better informed of various aspects of the trade market. This includes detailed descriptions of regional buyers and suppliers, transaction dates, types of products, transaction frequencies, quantities, and pricing. Such comprehensive data empowers exporters to better understand and navigate the market.

[5]Note that every time an exporter searches for relevant information about the destination market, it represents an Internet connection from the exporting country to the importing country. In essence, Internet

Therefore, this paper examines the role of Internet linkage in bolstering exports by alleviating the risks arising from information asymmetry. Theoretically, we introduce a parsimonious gravity model featuring a constant elasticity of substitution (CES) utility function. This model is further augmented with the exporting risk and Internet linkage, which captures the effect of Internet linkages on exports through risk alleviation. Specifically, by actively seeking pertinent information about the destination market through the Internet, exporters can better foresee and mitigate potential risks, thereby reducing losses attributed to information asymmetry.

To empirically estimate the effect of Internet searches on exports, we use Internet linkage as a proxy, as it effectively captures the essence of Internet searches. Each information search conducted by the exporting country about the importing country through the Internet is equivalent to an Internet linkage originating from the exporting country and directed towards the importing country, so the hyperlink transmitted from the exporter to the importer in 2009 can act as a proxy for Internet search. The benchmark regression, in particular, reveals the stimulating effect of Internet linkage on exports, and such promotion still holds even after controlling for gravity variables and country-specific fixed effects, echoing the model proposition. In addition, by employing the Poisson Pseudo Maximum Likelihood Method (PPML), we find that the effect of Internet linkage on exports remains significantly positive.

Next, we tackle the potential endogeneity issue attributed to omitted variables and reverse causality. To address the issue of omitted variables, we sought to identify the potential omitted variables at the country-pair level, given that we have already controlled for country-specific fixed effects. These variables should be correlated with Internet linkage and could potentially impact exports. Drawing insights from previous studies by Head and Ries (1998) and Caballero et al. (2018), we introduce three additional variables into our benchmark estimation: the presence of a common regional trade agreement be-

linkage is the embodiment of Internet search.

tween the trading countries, the volume of migrants moving from the exporter to the importer, and the level of bank connectivity between the trading countries. To mitigate concerns about reverse causality, we directly examine the reverse correlation. Notably, we find that the impact of lagged exports on Internet linkage is significantly smaller than the effect of lagged Internet linkage on exports, which alleviates the concern of reverse causality. Furthermore, we employ instrumental variables to address the endogeneity issue. Inspired by the approach of Beverelli et al. (2017), we use the Internet linkages between other countries or regions (country pairs other than the exporting and the destination countries) as an instrumental variable for the Internet linkages from the exporting country to the destination country, with this variable being weighted by per capita GDP. In addition, we attempt an alternative instrumental variable provided by Hellmanzik and Schmitz (2015): hyperlinks emitted by the exporter in 1998 and 2003. Through various methodologies to address endogeneity concerns, we can confirm the robust effect of Internet linkage in driving exports.

Despite our extensive efforts to address the concerns of omitted variables and reverse causality, our cross-sectional analysis may be subject to spurious correlations due to the oversight of globalization trends. To address this, we estimate the dynamic effect of Internet linkage on exports and observe a vanishing effect over time. To control for potential spurious correlations resulting from country-specific time-variant financial, economic, and social conditions, we incorporate exporter-time and importer-time fixed effects using trade data spanning from 2010 to 2014. It is important to point out that our baseline analysis is based on cross-sectional Internet linkage data from 2009, as a balanced panel dataset is not available.[6] Nevertheless, in the robustness check, we pool the Internet linkages data from 1998, 2003, and 2009 in a fully saturated model to account for time-invariant country-pair characteristics and time-varying country-specific dynamics.

[6]Although hyperlink data is also available for 1998, 2003, and 2009, there is much missing data among them, particularly for countries with higher risk, so we rely solely on cross-sectional data to examine the proposed mechanisms.

Next, we investigate the channel of risk alleviation and conjecture that the impact of Internet linkages in promoting exports is more pronounced if importers and products have higher levels of risk. This conjecture is validated by two strands of analysis. On one hand, we corroborate the risk reduction mechanism at the country level, predicting that exports to riskier countries will experience a relatively greater increase. To measure the risk of destination countries, we use a variety of indicators. The first indicator is price variance, which captures fluctuations in the demand market and correlates with the extent of information asymmetry (Allen, 2014; Steinwender, 2018). The second indicator is the turnover time in the destination country. Beyond these, we also measure the risk in importing countries by the (i) ICRG risk score, (ii) OECD risk ranking, or (iii) OECD membership status for robustness. Regardless of the indicator used, the results consistently indicate that the promoting effect becomes greater if exporting to countries with higher risk profiles.

On the other hand, we validate the mechanism of risk alleviation at the product level. Following Rauch (1999), we categorize traded goods into three distinct groups based on the level of product differentiation: those traded on organized exchanges, those with reference prices, and all other commodities. These categories are labeled homogenous, reference, and differentiated goods, respectively. According to Ranjan and Lee (2007) and Caballero et al. (2018), goods with greater differentiation tend to possess higher export risks. Therefore, we examine whether the exports of riskier goods benefit more from the Internet linkage. By including product classification, we can additionally control for both product-specific and country-pair-specific fixed effects. Overall, our findings in this strand of exercises consistently reveal that Internet linkage exerts a more substantial impact on exports of riskier products, thus supporting the risk alleviation mechanism.

Lastly, we proceed with some extension discussions. First, we explore the interaction between Internet linkages and geographical distance in influencing exports. This exercise underscores the significant role of information and communication technology (ICT) in effectively countering the challenges posed by geographical distance, which resonates with the notion of the ''death of distance'' brought about by Internet linkage. Second, we investigate the heterogeneous effects of Internet linkage across countries with different levels of Internet penetration. In particular, our findings reveal that the effect of Internet linkages on export is more pronounced in countries with lower levels of Internet development, irrespective of their status as an importer or an exporter. This observation aligns with our earlier findings regarding the role of Internet linkages in alleviating information asymmetry issues. Third, we offer additional evidence to support our proxy selection. Specifically, we compare the effects of emitted hyperlinks against received hyperlinks on exports and find that the impact of received hyperlinks is statistically insignificant and notably weaker than half of the effect induced by emitted hyperlinks. Last, we examine the effects of Internet linkages on both the extensive and intensive margins of trade. Notably, our analysis indicates a more significant impact on the extensive margin, suggesting that Internet linkages primarily expand the variety of exports, rather than increase the volume of existing exports.

This paper adds to the growing body of literature on the economic benefits of Internet usage. While the general benefits of the Internet are well-established in the literature, its specific influence on international trade deserves further investigation (World Bank Group, 2016). A substantial body of research has examined the influence of the Internet on bilateral trade. For example, Freund and Weinhold (2004) find that a 1% increase in Internet usage was associated with a 0.02% rise in exports, attributable to reduced entry fixed costs in imperfectly competitive markets. Additionally, Clarke and Wallsten (2006) highlight the regional heterogeneities in the benefit of Internet penetration, noting that developing countries with higher Internet usage tended to export more to developed countries with greater Internet penetration. Similar research has been undertaken by Choi (2010), Lee (2012), Lin (2015), and Akerman et al. (2022). In addition to exploration at the aggregate country level, there is a growing interest in the micro-level impact of the Internet on trade. For instance, Bernal-Jurado and Moral-Pajares (2010) find a positive correlation between Internet intensity and trade activities, drawing on industrial sector data from Spain. Furthermore, firm behavior and industry trends in response to Internet connectivity have been conducted by Ferro (2011), Ricci and Trionfetti (2012), and Fernandes et al. (2019). Although micro-level research offers insights into firm reactions, our study concentrates on the aggregate effect at the country level and provides additional evidence that supports the significant role of the Internet as a driving force in international trade.

Moreover, this paper enriches the existing literature on understanding the mechanisms through which the Internet fosters exports. Previous studies have primarily focused on the frictional costs involved in searching for transaction partners, addressing trade costs from both the demand side (Jang et al., 2008; Su, 2008; Heil and Prieger, 2010) and the supply side (Autor, 2001; Atrostic and Nguyen, 2005; Hagen and Zeed, 2005). However, the risks arising from information asymmetry, had received relatively less attention (Steinwender, 2018). While comparative advantage theory and the new trade theory emphasize the importance of cost reduction, they do not specifically discuss the impact of risk. Recent studies, however, have started to explore the effect of risk on transnational economic activities. By testing product-level Australia imports with a model-consistent indicator of risk, Handley (2014) illustrates the new channel of reducing risk for trade creation and shows that trade policy risk will delay the entry of exporters and make them less responsive to applied tariff reductions. Other relevant works that focus on the role of risk in international trade behavior include those by Ramondo and Rodríguez-Clare (2013), Tunc et al. (2018), and Feng et al. (2017). In our analysis, we concentrate on the risks stemming from information asymmetry. Specifically, due to insufficient information regarding the destination countries, exporters face potential losses in goods, finances, and other areas. Our findings suggest that Internet linkage serves as a crucial means of accessing comprehensive and up-to-date information, thereby mitigating asymmetric information problems and reducing associated risks in international trade. By examining the role of Internet linkage in alleviating exporter risks, our paper bridges the gap in understanding the mechanisms through which the Internet facilitates trade.

Additionally, our paper contributes to the existing literature by introducing a novel indicator for measuring Internet linkage. Previous research on its measurement can be categorized into three groups: (1) Internet usage intensity, also known as the Internet user ratio (Lin, 2015; Choi and Yi, 2009), which refers to the number of Internet users per capita; (2) the total number of web hosts assigned to each country (Freund and Weinhold, 2002, 2004); and (3) the number of Internet users, defined as individuals who have accessed the Internet through any device in the last 12 months (Clarke and Wallsten, 2006).[7] While these indicators gauge Internet connectivity to some extent, they fall short in accurately measuring the intensity of Internet linkage between trading countries. Our approach diverges by adopting an innovative measure pioneered by Hellmanzik and Schmitz (2015) and Chung (2011), which uses bilateral inter-domain hyperlink data to quantify Internet linkage. This approach has two major advantages. First, the number of hyperlinks transmitted between countries more accurately represents the intensity of Internet searches between trading countries, which aligns more closely with the essence of the Internet linkage discussed in this paper. In contrast, traditional indicators predominantly reflect a country's overall ICT development and may not necessarily indicate specific Internet usage intensity, as they include both regular and occasional users. Second, traditional indicators are measured at the unilateral level, focusing only on the number of users within a single country and overlooking the bilateral interaction essential for information acquisition in international trade. In contrast, our use of bilateral hyperlinks enables us to estimate the mutual affinity between exporters and importers, offering a deeper insight into their interactions.

The paper is structured as follows: Section 2 outlines the theoretical framework. Sec-

[7] Except for the three main measures, broader indexes such as the incorporation and use of ICT or the Internet bandwidth are used as well.

tion 3 introduces the data and the estimation specification. Section 4 presents the baseline estimation, along with the robustness checks. Section 5 analyzes the underlying mechanisms. Section 6 presents further discussions. Section 7 concludes.

2 Theoretical Framework

In this section, we elaborate on the theoretical framework that elucidates how Internet linkage encourages exports by alleviating export risk. Specifically, we create a parsimonious gravity model with a constant elasticity of substitution (CES) utility function in Feenstra (2015) and augment it with the Internet linkage.

Assume that there are N countries, and each country produces a unique set of M^i goods. Let c_{ij}^k denote country j's consumption of product k exported by country i. In addition, the representative consumer's preference in each country is characterized as the constant elasticity of substitution (CES), and then, the utility function in country j is expressed as

$$U^j = \sum_{i=1}^{N} \sum_{k=1}^{M^i} \left(c_{ij}^k \right)^{\frac{\sigma-1}{\sigma}}, \tag{1}$$

where $\sigma > 1$ is the elasticity of substitution. For simplicity, we assume that all products exported from country i to j are sold at the same price p^{ij} (c.i.f.price), including insurance, transportation cost, etc. This means that the expenditure of country j on all products sold by country i is the same. p^i (f.o.b.price) is the price of all goods produced by country i and sold domestically. Beyond that, we introduce the iceberg cost denoted by $T^{ij} > 1(i \neq j$, and $T^{ii} = 1)$, that is a wedge between the price sold in country j and domestic i, which suggests that $p^{ij} = T^{ij} p^i$. Then the utility function is transformed into

$$U^j = \sum_{i=1}^{N} M^i \left(c^{ij} \right)^{\frac{\sigma-1}{\sigma}}. \tag{2}$$

Given that balanced trade is assumed, the country j's total output Y^j is equal to its expenditure on all products from all other countries. So, the budget constraint is expressed as

$$Y^j = \sum_{i=1}^{N} M^i p^{ij} c^{ij}. \tag{3}$$

The optimization of the utility function subject to budget constraint yields the demand function of c_{ij} and the price index P^j:

$$c^{ij} = \left(\frac{p^{ij}}{P^j}\right)^{-\sigma} \frac{Y^j}{P^j}, \tag{4}$$

$$P^j = \left(\sum_{i=1}^{N} M^i \left(p^{ij}\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}. \tag{5}$$

Combing with equation (4), the total export value from country i to j, $X^{ij} \equiv M^i p^{ij} c^{ij}$, yields

$$X^{ij} = M^i Y^j \left(\frac{p^{ij}}{P^j}\right)^{1-\sigma}. \tag{6}$$

Considering that the number of products in country i, that is M^i, cannot be observed, we resort to the zero-profit condition to derive M^i (Krugman, 1980). Assume that labor is the only input, the output of the manufacturer is a constant $\bar{y}$, according to the characteristics of monopolistic competition, fixed markup pricing strategy, and zero-profit condition of free entry. So, the total output of country i is $Y^i = M^i p^i \bar{y}$. By substituting this into equation (6), the gravity model can be explicitly expressed as

$$X^{ij} = \frac{Y^i Y^j}{p^{i\sigma} \bar{y}} \left(\frac{T^{ij}}{P^j}\right)^{1-\sigma}. \tag{7}$$

Previous literature extensively examines the wedge T^{ij}, which includes trade barriers, search costs, and transportation costs, among others. For the sake of simplicity, this paper narrows to two key dimensions: geographical distance (linked to trade costs) and export risks generated by information asymmetry. As for the interaction between geographical distance and ICT technology represented by the Internet in shaping the trade, contrasting viewpoints emerge. On one hand, advancements in ICT would cause the ''death of distance'' (Cairncross, 2001; Lendle et al., 2016). On the other hand, the magnitude of the blocking effects of distance has increased since the 1970s, giving rise to the ''distance puzzle'' (Disdier and Head, 2008). Beyond that, Akerman et al. (2022) find that the Internet increases the elasticity of distance and makes trade more sensitive to distance. Given that the interaction between distance and the Internet is ambiguous, we do not impose any constraints on their interplay in the model but explore this further in the section of further discussion.

This paper focuses on the risks linked to the likelihood of incurring losses in goods, finances, and other pertinent areas due to information asymmetry, rather than on information frictions encountered in the search for trade partners, an area extensively explored by other researchers (Allen, 2014). In particular, importers, carriers, and other stakeholders in destination markets typically possess more comprehensive knowledge about their financial status, domestic market preferences, the quality of domestic bureaucracy, and other trade-related information. Consequently, the absence of information can potentially lead to substantial losses for exporters. Moreover, the cost of asymmetric information is often intangible and non-quantifiable. While exporters can access transparent and accurate information for certain aspects like transportation costs and tariff rates, other forms of asymmetric information are challenging to measure precisely and keep up to date. This is particularly true for cultural or political issues that may emerge in the importer's country. For exporters located thousands of miles away, it is highly improbable to immediately understand internal conflicts, predict market conditions, assess policy tendencies, or evaluate government stability in the importing countries.[8]

[8] This specification of risk is also intertwined with the level of differentiation present in the traded goods (Berkowitz et al., 2006; Ranjan and Lee, 2007), a facet we do not explicitly theorize in the model but will examine in subsequent sections.

However, Internet linkage serves as a crucial means to overcome the issue of information asymmetry engaged in export activities by seeking information about the destination market via Internet search in a timely, comprehensive, and precise manner. Firstly, Internet search improves the speed at which information seekers acquire real-time information (Hoag, 2006; Jeon and Nasr, 2016). The evolution of the Internet has substantially reduced the time lag for information seekers to procure pertinent information about the target market. By simply refreshing the webpage, exporters can access the latest updates concerning a remote market thousands of miles away, allowing them to swiftly adjust their corresponding export strategies in response to any informational shocks, thereby effectively mitigating their exporting risks. Second, Internet search expands the volume of information accessible to information seekers (Mondria et al., 2010; Abeliansky and Hilbert, 2017). By creating a virtual community wherein a wealth of information is informally exchanged, the Internet search enables exporters to collect more information about the target market within a specific time frame. Consequently, exporters can preemptively assess risks in all transactions. Last, the precision of information acquisition can be enhanced by the internet search (Mondria et al., 2010). The Internet hosts numerous specialized trade service platforms that not only provide up-to-date and precise data about the destination market, but also offer professionally curated reports by analysts involving their comprehensive insights into competitors' sales and technological advancements, which significantly improve the accuracy of information. Consequently, Internet linkages effectively diminish export risk by surmounting information asymmetry.

Given that the export risks due to information asymmetry can be alleviated if exporters in country i are searching for more information in exporting market country j via the Internet, we assume that

$$T^{ij} = D^{ij}(R^j)^{1-E^{ij}}, \tag{8}$$

where D^{ij} is the geographical distance between country i and j. The exporting risks borne by exporters are mainly generated by some factors occurring in the demand market (Li, 2018; De Sousa et al., 2020), and any inferiority in information acquisition about the demand market by exporters leads to a higher export risk for exporting country j, denoted as R^j. E^{ij} represents the intensity of Internet linkages between countries i and j. Notably, a higher level of Internet linkage can effectively mitigate the export risks arising from information asymmetry.

By combining (7) and (8) and taking logs, we obtain:

$$\ln X^{ij} = \ln Y^i + \ln Y^j - (\sigma - 1)D^{ij} - (\sigma - 1)\ln R^j + (\sigma - 1)E^{ij}\ln R^j - \sigma \ln p^i - \ln \bar{y} + (\sigma - 1)\ln P^j. \quad (9)$$

Two main propositions can be drawn from this equation:

Proposition 1. *As Internet linkage has increased, so has bilateral trade.*

Proposition 2. *The effect of Internet linkages becomes stronger if the exporting risk to a particular destination country j (R^j) is larger.*

We will test these two predictions in the following sections.

3 Empirical Strategy and Data

3.1 Empirical Strategy

The benchmark estimation specification is directly derived from the above gravity model:

$$Inexp_{ij} = \beta_0 + \beta_1 linkage_{ij} + \gamma' GV_{ij} + \eta_i + \eta_j + \epsilon_{ij}, \quad (10)$$

where the key explaining variable $linkage_{ij}$ is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation.[9] Since we seek to explore the effects of lagged Internet linkage on the export, the

[9]The hyperlinks transmitted from the exporter to the importer directly mirror the information acquisition at the exporter's end, which holds more significance for export-related activities. In the subsequent

explained variable is the (log) export value from country i to country j in 2010. The vector GV_{ij} contains a set of control variables specified at country-pair level, including the geographical distance $dist_{ij}$, whether having been contiguous with each other $contig_{ij}$, whether speaking common language by at least 9% of the population $comlang_{ij}$, whether having the common legal origins $comleg_{ij}$, whether using the common currency $comcur_{ij}$, whether the country pair ever in colonial relationship $colony_{ij}$, whether having common colonizer post-1945 $comcol_{ij}$. η_i is exporter-specific fixed effect, and η_j is importer-specific fixed effect. Lastly, ϵ_{ij} is the error term.

In the baseline regression, we employ cross-section Internet linkages in 2009 only, due to the absence of a balanced panel for bilateral Internet linkage. Although hyperlink data for 1998 and 2003 are available, their quality is compromised because of excessive missing values, especially for countries with higher risk.[10] As a result, the baseline analysis hinges on the cross-section data in 2009. Nevertheless, multiple-year data is employed for robustness tests. In particular, we use the fully saturated model for these three years with the exporter-year, importer-year, and exporter-importer fixed effects:

$$Inexp_{ijt} = \beta_0 + \beta_1 linkage_{ijt} + \eta_{ij} + \eta_{it} + \eta_{jt} + \epsilon_{ij}. \tag{11}$$

Given that Internet linkages encourage exports through risk alleviation, export will benefit more if the exporting risk to destination country j is higher. To examine this, we extend our analysis by proxying for export risk:

$$Inexp_{ij} = \beta_0 + \beta_1 linkage_{ij} \times risk_j + \gamma' GV_{ij} + \eta_i + \eta_j + \epsilon_{ij}, \tag{12}$$

where $risk_j$ measures the exporting risk to country j. Both Li (2018) and De Sousa et al. (2020) suggest that the risks and uncertainties encountered in exports primarily stem

discussion section, we also examine the effects of hyperlinks from the importer to the exporter or vice versa. The findings reveal that the influence of the hyperlinks originating from the exporter takes precedence over other linkages.

[10]See the data description in Table 1 Summary statistics.

from demand-side factors, with alterations in the importing market exerting an impact on the optimal export decisions of the exporter. Consequently, variations in the destination countries can be perceived as risks confronted by exporters.

To measure the risk in the destination country j, we refer to several indexes. The first index is the variance of product price in importing country j, $risk\_price_j$, which primarily captures its demand variation. In particular, a more fluctuant product price in importing countries j is associated with a higher risk of exporting to country j. This index, drawn from the methodologies proposed by Gervais (2018) and Aghion et al. (2018), measures the effect of price variation in the importing country on exporters at the product level and then aggregated to the destination country level. It is imperative to note that this indicator is closely intertwined with information friction (Allen, 2014; Steinwender, 2018). The second index is the import turnover time in the destination country, $risk\_imptime_j$. Typically, a lengthier turnover time implies less controllable goods transportation, resulting in heightened exporting risks. In particular, delays in material flows can lead to escalated costs, potential sales losses, and ultimately diminished profits (Gervais, 2018).[11] Given that country risk encompasses various types of risks that can result in potential losses due to a range of factors, including political, economic, exchange-rate, or technological evolutions, we also turn to alternative comprehensive indexes issued by professional analysts and institutions: the International Country Risk Guide (ICRG) rating, the Country Risk Classification regularly updated by the OECD, and whether an OECD member or not for robustness. All of them are further elaborated on in the data description.

In addition to the institutional quality and commercial environment in the destination country, the exporting risk is also determined by the differentiation degree in the traded goods. Given the heightened challenges associated with contract enforcement, more differentiated goods would be subject to higher risk (Berkowitz et al., 2006; Ranjan and Lee,

[11] This phenomenon is often attributable to imperfections in the destination country's infrastructure, policies, and its implementation, resulting in a lack of timely information regarding unexpectedly prolonged turnover.

2007). Initially, we estimate the baseline model for each type of export characterized by its degrees of differentiation. Additionally, we estimate the coefficient of the interaction between the Internet linkages and the index reflecting the differentiation level of the goods at a more granular SITC-4 level. This specification enables us to control for country-pair-specific fixed effects that cannot be accounted for in the benchmark model:

$$Inexp_{ijk} = \beta_0 + \beta_1 linkage_{ij} \times Diff_k + \gamma' GV_{ij} + \eta_{ij} + \eta_k + \eta_{ijk}, \tag{13}$$

where the dummy variable $diff_k$ indicates how differentiated product k is. η_{ij} refers to the country-pair-specific fixed effect, and η_k refers to the product-specific fixed effect.

3.2 Data Description

Before proceeding to the estimation result, it is necessary to briefly introduce the dependent variable exp_{ij} and the key explanatory variable $linkage_{ij}$. In the previous section, we have explained why the bilateral hyperlink is more appropriate to be the proxy for the Internet linkages, so we will move on to describe data characteristics.

We start with the dataset of Chung (2011) who compiled the bilateral hyperlink data for 2003 and 2009 covering 88 countries. Subsequently, we combine this hyperlink dataset with a smaller group of countries (30 countries in total) obtained from the OECD Communications Outlook 1999, the latter dataset is used by Hellmanzik and Schmitz (2015). In Appendix Table A1, we list the top 10 countries that sent out the most hyperlinks in 2009. The bilateral trade data with the 4-digit SITC code comes from the UN COMTRADE. As for control variables, we take them from the CEPII database. The statistical summary of relevant variables is shown in Table 1.

The measures of country risk are sourced from multiple databases. To construct the price-related risk index for each destination country, we start with the price variance index computed by Gervais (2018) for each product at the HS-6 level using BACI trade data, and then calculate the risk index for each destination country by taking the weighted average over products, building upon the methodology introduced by Aghion et al. (2018). To construct the risk index related to the turnover in the target market, we rely on the import and export delivery time index provided by the World Bank. Note that the World Bank's import and export delivery time index lacks data for the year 2009; it is only available in 2007 and 2010 onwards, so we use the index in 2007.

Additionally, the International Country Risk Guide (ICRG) rating dataset provides a set of rating scores assessing the country risk for 140 nations. Specifically, The ICRG rating includes political risk factors such as consumer confidence, ethnic tensions, bureaucracy quality, and corruption, as well as financial risk factors such as financial disputes and the financial environment, alongside economic risk. These factors are usually associated with the issue of information asymmetries; for instance, the latest bureaucratic quality is always better known by the trading parties in the destination country than the exporting countries.[12] To ensure that the ICRG rating score co-moves with a country's risk level, we manipulate each ICRG index by subtracting the original score from its maximum scale, ensuring that an increase in index score corresponds to an increase in risk. After that, we utilize Principal Components Analysis (PCA) to compute a weighted risk score for each country (denoted by $riskpca_j$) (Caballero et al., 2018).

Besides that, the country risk ranking index (denoted by $riskrank_j$) is published by the OECD Country Risk Classification to gauge transfer and convertibility risk, as well as instances of force majeure. Lastly, we measure the country's risk based on whether the country is an OECD member, and the OECD member list is available on the OECD official website. It is widely acknowledged that OECD countries excel in risk management and nationwide governance, while non-OECD countries usually suffer from relatively riskier environments.

[12]However, exporters with information disadvantages can stay informed about these changes through Internet searches, which significantly aids them in assessing the status of the target market.

Table 1: Summary Statistics

VarName	Obs.	Mean	SD	Min	Max
$export\ value_{ij}$	3952	18.66	3.45	0	26.52
$linkage98_{ij}$	794	7.02	1.76	1.09	12.26
$linkage03_{ij}$	1820	10.92	2.33	0	17.03
$linkage09_{ij}$	3952	10.11	3.01	1.60	17.70
$riskprice_j$	3952	0.16	0.81	-11.59	8.81
$riskimptime_j$	3473	4.92	4.18	1	35
$riskpca_i$	3849	10.90	3.49	3.48	20.91
$riskrank_i$	3934	2.13	2.47	0	7
$dist_{ij}$	3792	8.45	0.84	4.74	9.84
$contig_{ij}$	3792	0.03	0.17	0	1
$comlang_{ij}$	3792	0.10	0.29	0	1
$comleg_{ij}$	3792	0.29	0.45	0	1
$comcur_{ij}$	3792	0.04	0.20	0	1
$colony_{ij}$	3792	0.03	0.18	0	1
$comcol_{ij}$	3792	0.02	0.15	0	1

4 Effects of Internet Linkages on Exports

4.1 Baseline Result

Table 2 presents the baseline results, where we explore the effect of Internet linkage on exports. Since both the export and the Internet hyperlinks have undergone log transformation, the magnitude of the coefficient should be interpreted as the elasticity. Firstly, the positive correlation in column (1) indicates a positive correlation between Internet linkages and the following year's exports. The driving-up effect remains salient and significant at the 1% level even after controlling for the country-fixed effects, adding more gravity variables, and clustering standard errors at the country level, as seen in columns (2) and (3). In particular, the export value would increase significantly by 27.2% if the hyperlink transmitted from the exporter to the importer doubles. In addition, such a promoting effect still holds under the Poisson Pseudo Maximum Likelihood Method proposed by Silva and Tenreyro (2010), as shown in column (4).

4.2 Robustness

4.2.1 Endogeneity Issues

Despite the compelling results observed in the baseline regression, we maintain a cautious stance regarding potential endogeneity issues. These concerns are rooted in the potential omitted variables and reverse causality.

We begin by addressing the issue of potential omitted variables. While the baseline regression has controlled for country-specific fixed effects, i.e., absorbing variations at the country level, the possibility of omitted variables at the country-pair level remains. To mitigate it, we attempt to identify and include as many relevant variables as possible. In particular, we consider another three variables: whether the countries are under a regional trade agreement (RTA), the stock of migrants relocating from the exporter to the importer, and the bank linkages between the exporting and importing countries. The inclusion of the RTA variable is motivated by the fact that trade is more likely to occur among countries operating within a common regional trade agreement, which generally aims to eliminate trade barriers across countries or regions. Moreover, the burgeoning body of literature underscores the impact of migrant networks on international trade. According to research conducted by Head and Ries (1998) and Girma and Yu (2002), migrants contribute significantly to the exports of their origin country. With regard to bank linkages, Caballero et al. (2018) posit that the establishment of new bank connections in a particular country pair can bolster the trade flow between them in the subsequent year.

The results with these additional control variables are presented in Table 3, Column (1). Notably, the effect of Internet linkage slightly declines, indicating that the promoting effect might be absorbed by the plausible omitted variables. Nevertheless, the positive effect of Internet linkages remains evident.

On the other hand, the encouraging impact attributed to Internet linkage could po-

Table 2: Baseline results

	(1) *export value*	(2) *export value*	(3) *export value*	(4) *export value*
linkage	0.866***	0.615***	0.272***	0.015***
	(0.013)	(0.053)	(0.052)	(0.003)
dist			-0.946***	-0.046***
			(0.060)	(0.003)
contig			0.149	-0.001
			(0.243)	(0.012)
comlang			-0.398***	-0.023***
			(0.150)	(0.008)
comleg			0.525***	0.032***
			(0.078)	(0.004)
comcur			-0.465***	-0.031***
			(0.111)	(0.006)
colony			0.563***	0.029***
			(0.192)	(0.010)
comcol			0.421	0.025
			(0.314)	(0.017)
_cons	9.849***	12.451***	23.818***	3.162***
	(0.132)	(0.535)	(0.872)	(0.048)
N	3952	3913	3754	3754
FE		i, j	i, j	i, j
Adjusted R^2	0.55	0.71	0.74	

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. The explained variable is the export value from country i to country j in 2010 in logarithm. We control importer and exporter fixed effects in columns (2) to (4). Column (4) is estimated using the Poisson Pseudo Maximum Likelihood Method. Standard errors clustered at the country-pair level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

tentially stem from spurious correlation. It is plausible that an anticipated increase in exports could prompt exporters to actively establish additional Internet connections to acquire more information about potential traders or markets. To directly mitigate the possibility of reverse causality, we examine the effects of lagged exports on Internet linkage. If reverse causality is present, exporters anticipating an upsurge in exports would likely establish Internet linkages with potential importers. In other words, lagged exports are expected to contribute to the Internet linkage at present. To test its validity, we examine the influence of exports in 2008 on Internet linkages in 2009. As shown in column (2) of Table 3, such an effect is only approximately one-eighth of the effect of Internet linkages on exports. The substantial disparity in the magnitude of the coefficient indicates that reverse causality is not the primary driving force behind our baseline result and, to some extent, eliminates the possibility of reverse causality.

To further address the endogeneity issue, we employ the approach of instrumental variables (IV), which hinges on identifying suitable instrumental variables. We draw inspiration from Beverelli et al. (2017), who used the weighted average of service trade barriers from other countries (specifically, countries other than the ones being analyzed, denoted as $k \neq i, j$) as an instrument for the trade barriers between a particular country pair (i and j). In a similar manner, we use the weighted average of Internet linkages between any country pairs other than the pair under study as the instrumental variable for the Internet linkage between exporter i and importer j, with each pair being weighted by its per capita GDP. This selection is motivated by the following considerations:

First, Internet linkages among other countries or regions are correlated with the bilateral Internet linkages between a particular exporting country and its destination country. Interconnectivity acts as a fundamental basis for the existence of the Internet. As Metcalfe's Law states, the interconnectedness of a network is determined by the number of its connected users in the system and the expansion of Internet linkages represents a pivotal means to maximize the value of the network. Consequently, an increase in Internet linkages in any other country pairs inevitably boosts Internet connectivity between a particular pair of countries. Furthermore, when constructing the instrumental variable, we use the similarity in per capita GDP as the weighting factor. This is informed by the pattern that countries with similar per capita GDPs are likely to have a comparable number of network links, which in turn fosters a stronger ''learning effect'' among countries at similar developmental levels.

Second, trade between the two countries is unaffected by Internet connections in countries other than these two countries. Typically, exporters focus their information search on their specific target destination country or region, rather than countries unrelated to their intended destinations. Furthermore, the construction of instruments is based on the Internet connections among country pairs other than the two countries involved in trade, which effectively rules out the possibility of indirect transit trade and the likelihood of exporters searching for information about third-party re-exporting countries. In addition, we have repeated the baseline regression with instrumental variables as the explanatory variables. The estimation coefficient fails to be statistically significant, suggesting no correlation between the instrument variable and the dependent variable.

The index construction method is as follows:

$$\text{IV\_otherlink}_{ij} = \sum_{c \neq i, d \neq j} \text{linkage09}_{cd} \times \text{SI}_{ci} \times \text{SI}_{dj}, \tag{14}$$

where $linkage09_{cd}$ is the Internet linkages from country c to country d in 2009, with the exclusion of trading countries i and j. SI_{ci} represents the weight between country c and country i, and SI_{dj} represents the weight between country d and country j:

$$\text{SI}_{ci} = 1 - \left(\frac{\text{pcGDP}_i}{\text{pcGDP}_i + \text{pcGDP}_c} \right)^2 - \left(\frac{\text{pcGDP}_c}{\text{pcGDP}_i + \text{pcGDP}_c} \right)^2, \tag{15}$$

where $pcGDP_c$ is GDP per capita of country c. The estimation results with instrument variables are shown in Table 3, columns (3) and (4).

Furthermore, we are indebted to the work conducted by Hellmanzik and Schmitz (2015), which provides us with another instrumental variable: hyperlinks emitted by the exporter in 1998 and 2003. Network development is a protracted and large-scale engineering process that is characterized by path dependence, where the earlier network development shapes the foundational structure of future networks, thereby affecting subsequent network development and service quality. Therefore, the Internet linkage in 1998 and 2003 satisfies the relevance condition. More importantly, the Internet linkage from the historical period bears no direct correlation with the current trade value between countries. Consequently, in this paper, we employ the historical variable as another instrumental variable for Internet linkages in 2009. The corresponding results are detailed in Table 3, Columns (5) and (6).

As for the relevance test, the weak identification hypothesis for each instrument variable is rejected, as evidenced by the Cragg-Donald Wald F statistics of 410.281 and 386.776 in columns (3) and (5), respectively. Concerning the exogeneity condition, we apply the two instrument variables simultaneously and turn to the Sargan Statistic, where we cannot reject the null hypothesis that all instrumental variables are exogenous. These findings consistently indicate that an increase in the intensity of Internet linkages leads to a concurrent rise in exports, regardless of the chosen instrument variable, which exactly aligns with our findings in the baseline regression.

4.2.2 Time-Variant Consideration

Given the continual growth of the Internet over time, along with the concurrent expansion of bilateral linkages and trade, potential spurious correlations in our cross-sectional results may arise from the oversight of globalization trends. To mitigate such concerns, we conduct the robustness check by considering time-varying factors.

First, we delve into the dynamic impact of Internet linkages on exports. Intuitively, if the Internet linkage fosters exports by facilitating the information flow, we would antici-

Table 3: Robustness: Endogeneity Issues

	(1) *export value*	(2) *linkage*	(3) *first stage*	(4) *export value*	(5) *first stage*	(6) *export value*
linkage	0.149**			0.813***		0.287***
	(0.061)			(0.048)		(0.071)
export value		0.036***				
		(0.008)				
RTA	0.203*					
	(0.118)					
banklink	0.081***					
	(0.028)					
migration	0.034**					
	(0.014)					
IV_otherlink			2.069***			
			(0.102)			
*IV_linkage*98					0.117***	
					(0.032)	
*IV_linkage*03					0.538***	
					(0.020)	
_cons	24.421***	11.954***				
	(1.026)	(0.351)				
N	783	3754	3772	3772	3772	3772
control variables	✓	✓	✓	✓	✓	✓
FE	i, j	i, j	i, j	i, j	i, j	i, j
Wald F			410.281	410.281	386.776	386.776
Sargan p-value					0.1729	0.1729
Adjusted R^2	0.90	0.96				

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. *export value* is the export value from country i to country j in 2010 in logarithm. We control importer and exporter fixed effects in columns (1) to (6). The IV used in columns (3) to (4) is the weighted Internet linkages between other countries or regions; the first stage result is shown in column (3), and the second stage is in column (4). The IV used in columns (5) to (6) are hyperlinks emitted by the exporter in 1998 and 2003 simultaneously; the first stage result is shown in column (5), and the second stage is in column (6). Standard errors clustered at the country-pair level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table 4: Robustness: Dynamic Effects

	(1) 2011	(2) 2012	(3) 2013	(4) 2014	(5) 2010 – 2014	(6) 2010 – 2014
linkage	0.243***	0.202***	0.209***	0.187***	0.222***	0.222***
	(0.057)	(0.048)	(0.047)	(0.049)	(0.039)	(0.040)
_cons	25.831***	26.570***	26.037***	26.665***	25.885***	25.889***
	(0.900)	(0.776)	(0.792)	(0.787)	(0.642)	(0.651)
N	3599	3518	3501	3397	24056	24056
control variables	✓	✓	✓	✓	✓	✓
FE	i, j	i, j	i, j	i, j	i, j, t	it, jt
Adjusted R^2	0.79	0.80	0.81	0.77	0.74	0.78

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. The dependent variable is the export value from country i to country j in logarithm. Control variables include gravity regressors in the baseline results. Standard errors clustered at the country-pair level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

pate that the encouraging effect gradually diminishes as information becomes outdated. Columns (1) to (4) in Table 4 illustrate the dynamic effect of Internet linkages in 2009 on exports over the subsequent four years. Notably, the coefficient of the Internet linkage is significant yet declining over the years, depicted as 0.243, 0.202, 0.209, and 0.187, respectively, which suggests that the stimulus generated by Internet linkages tends to diminish over time.

Additionally, the stimulating effect in the baseline regression might be spurious due to country-specific time-varying financial, economic, and social conditions. To mitigate this concern, we use trade data compiled from 2010 to 2014, enabling the inclusion of exporter-time and importer-time fixed effects. In Table 4, Column (5) accounts for country and year fixed effects separately, while Column (6) controls for country-year fixed effects. Encouragingly, the results remain robust and significant at the 1% level, even after considering country-specific characteristics with time variance.

Moreover, the correlation in our cross-sectional estimation could be generated by his-

Table 5: Robustness: Fully Saturated Model

	(1) *export value*	(2) *export value*	(3) *export value*	(4) *export value*
linkage	0.161***	0.068***	0.167***	0.020*
	(0.020)	(0.009)	(0.030)	(0.012)
_cons	25.647***	19.651***	25.708***	20.104***
	(0.457)	(0.099)	(0.559)	(0.137)
N	6280	3980	6280	3980
control variables	✓	✓	✓	✓
FE	i, j, t	ij, t	it, jt	ij, it, jt
Adjusted R^2	0.78	0.97	0.78	0.98

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 1998, 2003, and 2009, which takes the log transformation. The dependent variable is the export value from country i to country j in logarithm in 1999, 2004, and 2010. Control variables include gravity regressors in the baseline results. Standard errors clustered at the country-pair level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

torically established country ties. To address this concern, we can impose the country-pair fixed effects in a fully saturated estimation. Despite the presence of numerous missing values for hyperlink data in 1998 and 2003, particularly in countries with higher country risk, we pool the Internet linkage data from 1998, 2003, and 2009 to estimate a fully saturated model and present the corresponding results in Table 5. In particular, Column (2) additionally controls for both country pair and time-fixed effects, revealing that the effect of Internet linkages is still statistically significant.

Furthermore, Column (4) controls for exporter-time, importer-time, and country-pair fixed effects. This approach allows us to account for any time-invariant country-pair characteristics and time-varying country-specific dynamics that might contribute to a positive relationship between exports and Internet linkages. The findings indicate that the effect of Internet linkages somewhat diminishes yet remains positive and statistically significant.

5 Do Internet Linkages Alleviate Trade Risk?

Having established the stimulating impact of Internet linkages on exports, we proceed to explore the channel through which this effect operates. Different from prior research that predominantly emphasizes the reduction in trade costs, this paper introduces a novel channel of export risk alleviation. By examining its implications at both the country and product levels, we find evidence that supports the channel of risk alleviation. In particular, we find that the effect of Internet linkages is greater for countries characterized by higher risk. Moreover, the effect of Internet linkages is more pronounced for products associated with higher risk.

5.1 Do Internet Linkages Matter More for Exports to Riskier Countries?

As stated above, the risks faced by exporters are primarily determined by demand-side factors (De Sousa et al., 2020; Li, 2018), so we examine whether the facilitation arising from Internet linkage is greater when trading with risker importers.

To examine it, we first consider price-relevant risks. The result, presented in column (1) in Table 6, indicates that the beneficial effect of Internet linkage on exports is greater when exporting to countries with higher risks, where risk is quantified by $riskprice_j$. Second, we use the import turnover time of the destination country $riskimptime_j$, to gauge export risk. The finding in column (2) corroborates that the promotional effect of Internet linkage becomes more pronounced when trading with higher-risk importers. In addition to that, we also resort to the *International Country Risk Guide (ICRG)* rating dataset that provides a set of rating scores for evaluating the country risk for 140 countries. After a simple transformation of the ICRG original scores, we calculate a weighted risk score for each country $riskpca_j$. Similarly, the significantly positive coefficient of the interaction term in column (3) suggests that a larger impact of Internet linkages when exporting to higher-risk countries. Next, we rely on $riskrank_j$ updated by OECD as an alternative measure of country risk, with higher rankings implying higher country risk. Unsurprisingly, the result reported in column (4) confirms that the promoting effect of Internet linkage on exports has been amplified if the country risk of the importer is larger. Beyond these methods, we have conducted the subgroup regressions on the OECD countries and non-OECD countries, with the latter presumed to be the representative of riskier countries. From column (5), it is observed that the driving-up effect is relatively weaker if exporting to OECD member countries. Above all, estimations using different measures of country risk collectively affirm the proposition that the positive impact on exports becomes more pronounced when exporting to countries with higher risk, which acts as an important implication of the risk alleviation by Internet linkage.

5.2 Do Internet Linkages Matter More for Exports of Riskier Goods?

In this part, we sought to substantiate the hypothesis that the driving force exerted by Internet linkages is more pronounced on exports of differentiated goods characterized by higher export risk. Drawing on the work of Ranjan and Lee (2007), we acknowledge that more differentiated goods are inherently associated with higher export risk. Based on this insight, we aggregated the trading data with 4-digit SITC codes into three subgroups at the country-pair level, categorized according to ascending risk levels: goods traded on an organized exchange, goods not traded on organized exchanges but possessing a reference price, and all other goods. Following the labeling convention employed by Hellmanzik and Schmitz (2015), the product subgroups are designated as homogenous goods, reference goods, and differentiated goods.

We subsequently test our proposition by comparing the magnitude of the promoting effect on each subgroup. The findings presented in Table 7 illustrate a discernible trend, wherein the degree of encouragement in export facilitation is positively correlated with the risk level of the traded goods. Specifically, if the intensity of Internet linkages increases by one percent in 2009, the subsequent year's export value will increase by 0.199% for riskier goods, whereas the effect for goods with a reference price stands at 0.13%. Fur-

Table 6: Mechanism Analysis at the Country Level

	(1) *export value*	(2) *export value*	(3) *export value*	(4) *export value*	(5) *export value*
linkage	-0.009	0.022	0.162***	0.396***	0.358***
	(0.083)	(0.076)	(0.053)	(0.057)	(0.068)
linkage × *riskprice*	0.937*				
	(0.529)				
linkage × *riskimptime*		0.029**			
		(0.013)			
linkage × *riskpca*			0.022***		
			(0.006)		
linkage × *riskrank*				0.046***	
				(0.009)	
linkage × *OECD*					-0.320***
					(0.037)
_cons	23.898***	24.941***	24.008***	24.112***	23.685***
	(0.873)	(0.971)	(0.872)	(0.856)	(0.863)
N	3754	3307	3671	3754	3754
control variables	✓	✓	✓	✓	✓
FE	i, j	i, j	i, j	i, j	i, j
Adjusted R^2	0.74	0.74	0.74	0.74	0.75

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. *export value* is the export value from country i to country j in 2010 in logarithm. We control importer and exporter fixed effects in columns (1) to (6). Standard errors clustered at the country-pair level are in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 7: Mechanism Analysis at the Product Level by Goods Classification

	(1) *differentiated*	(2) *reference*	(3) *homogeneous*
linkage	0.199*	0.130	-0.122
	(0.115)	(0.112)	(0.126)
_cons	12.121***	12.881***	14.103***
	(2.223)	(2.173)	(2.262)
N	3752	3732	3630
control variables	✓	✓	✓
FE	i, j	i, j	i, j
Adjusted R^2	0.38	0.39	0.45

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. We control importer and exporter fixed effects in columns (1) to (3). Standard errors clustered at the country-pair level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

thermore, we also examined the impact of Internet linkages on each subgroup of goods after controlling for product-specific fixed effects at the country-pair SITC 4-digit product level, and the results are detailed in Appendix Table A2. Notably, the analysis affirms that Internet linkages indeed foster greater exports of differentiated goods, followed by the exports of referenced goods, and, lastly, the exports of homogenous goods.

However, we recognize that we have not addressed the potential bias arising from omitted variables at the product level, nor have we excluded the potential endogeneity at the country-pair level. To address it, we controlled for the product-specific fixed effect in Table 8, Column (1). This reveals that Internet linkage contributes more significantly to the export of riskier goods, with the most notable increase observed in the exports of differentiated goods. Subsequently, in Columns (2) and (3), we controlled for both the country-pair-specific and product-specific fixed effects. The regression results, reported with standard errors clustered at the country-pair and importer-exporter levels, show a statistically significant increase in the export of riskier goods. These consolidated findings

Table 8: Mechanism Analysis at the Product Level

	(1) *export value*	(2) *export value*	(3) *export value*
linkage	0.073*		
	(0.044)		
linkage × *differentiated*	0.393***	0.414***	0.414***
	(0.019)	(0.019)	(0.071)
linkage × *reference*	0.284***	0.289***	0.289***
	(0.015)	(0.015)	(0.056)
_cons	16.067***	4.383***	4.383***
	(0.700)	(0.188)	(0.705)
N	1360406	1360398	1360398
control variables	✓	✓	✓
FE	i, j, k	ij, k	ij, k
Adjusted R^2	0.48	0.50	0.50

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. We control importer, exporter, and product fixed effects in column (1), and control country pair and product fixed effects in columns (2) and (3). Standard errors clustered at the country-pair level are in parentheses in (1) and (2). Standard errors clustered at the exporter and importer level are in parentheses in (3). $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

allow us to confidently validate our proposition that the facilitation provided by Internet linkage indeed favors the export of riskier goods.

6 Further Discussion

6.1 The Role of Geographic Distance

In our theoretical framework, we have not imposed any explicit assumptions on the interaction between geographic distance and the Internet linkage, and thus we refrain from discussing the role of Internet linkage in affecting the impeding effect of geographic distance on exports. To better understand this, we examine the impediment of geographic distance on exports by excluding Internet linkages from the baseline regression. As shown in Table 9, Column (1), in the absence of Internet linkages, the value of exports would decrease by 1.462% solely due to the effect of geographical distance. However, by comparing this with the estimated coefficient in Table 2, Column (3), it is evident that the adverse impact of geographical distance on exports can be significantly mitigated with the presence of Internet connections. Specifically, with the aid of Internet linkages, this adverse effect diminishes by approximately 50%, holding other factors constant. This finding supports the notion that advancements in information and communication technology (ICT) have led to what has been described as the ''death of distance'' (Cairncross, 2001; Lendle et al., 2016).

6.2 Do Internet Linkages Matter More for Countries with Higher Internet Penetration?

Given that less developed countries or regions are typically characterized by higher trading risks, the potential for Internet linkage to promote exports by mitigating these risks suggests a stronger marginal stimulating effect in such countries or regions. Therefore, we sought to investigate how the contribution of Internet linkage to exports depends on Internet penetration rates in exporting or importing countries. To this end, we extract data on Internet penetration rates, measured as the number of Internet users per capita, from the World Bank World Development Indicators (WDI) database. In Table 9, Column (2), we introduce the interaction between the Internet development of importers or exporters with Internet linkages. The findings reveal that the impact of Internet linkages on exports is more pronounced in countries with lower levels of Internet development, regardless of whether they are importers or exporters. This observation implies the role of Internet linkage in addressing the information asymmetry issue. Countries with lower Internet penetration rates are typically less developed, and trading with them tends to be exposed to severe issues of information asymmetry. Consequently, the information gleaned through Internet linkages is expected to have a greater marginal contribution to the mitigation of information friction in these countries, and an associated stronger stimulus on exports.

6.3 Emitted or Accepted Internet Linkage Matters?

In our estimation specification, the hyperlink sent from the exporter to the importer is used to capture the information acquired about the importers by exporters, which acts to overcome the inferior information position held by exporters.

To corroborate this idea, we turn to examine whether the accepted Internet linkages matter for exports. Specifically, we introduce hyperlinks accepted by the exporting country from the importing country and compare their effect on exports with that of hyperlinks sent by exporters. The findings are presented in Table 9, Column (3). Notably, the effect of the accepted Internet linkages is approximately half that of the emitted Internet linkages, and its statistical significance becomes much weaker. This finding aligns with the argument by Osnago and Tan (2016) that bilateral exports are more affected when there is an increase in Internet adoption by exporters.

6.4 Intensive or Extensive Margin?

A related implication of the role of Internet linkage in alleviating the issue of information asymmetry is its effect on export margins. Essentially, a better and instant understanding of the demand market through Internet linkage can help exporters identify a wider range of potential demands. This, in turn, allows them to diversify their export portfolio by introducing more new products.

To shed light on the role of Internet linkage on export margins, we explore whether Internet linkages aid in either launching new products or boosting the volume of existing ones. To investigate it, we first calculate the intensive and extensive margin at the country pair level, following the approach by Hummels and Klenow (2005). Based on this, we estimate the effect of Internet linkages on either intensive or extensive margins, with the results presented in Table 9, Columns (4) to (7). Notably, for Columns (5) and (7), we applied the Poisson Pseudo Maximum Likelihood Method. The findings indicate that Internet linkages have a stronger impact on the extensive margin as compared to the intensive margin, which is consistent with the pattern discovered by Handley (2014).

Table 9: Further Discussion

	(1) *export value*	(2) *export value*	(3) *export value*	(4) *IM*	(5) *IM*	(6) *EM*	(7) *EM*
linkage		1.163***	0.203***	-0.000	0.057	0.028***	0.093***
		(0.183)	(0.051)	(0.003)	(0.042)	(0.003)	(0.009)
$linkage \times exportInt$		-0.185***					
		(0.032)					
$linkage \times importInt$		-0.054*					
		(0.029)					
linkageaccept			0.104*				
			(0.053)				
dist	-1.462***						
	(0.053)						
_cons	27.115***	24.056***	23.417***	0.194***	1.630**	1.162***	-0.045
	(0.469)	(0.846)	(1.006)	(0.048)	(0.666)	(0.054)	(0.167)
N	16083	3711	3686	3738	3738	3738	3738
control variables	✓	✓	✓	✓	✓	✓	✓
FE	i, j	i, j	i, j	i, j	i, j	i, j	i, j
Adjusted R^2	0.67	0.75	0.75	0.30		0.90	

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. *export value* is the export value from country i to country j in 2010 in logarithm. *exportInt* (*importInt*) is the Internet penetration rate in the exporter (importer). *linkageaccept* is the amount of Internet hyperlinks accepted by the exporting country i from the importing country j in 2009, which takes the log transformation. *IM* is the intensive margin and *EM* is the extensive margin. We control importer and exporter fixed effects in columns (1) to (7). Standard errors clustered at the country-pair level are in parentheses. $^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

7 Conclusion

This paper theoretically and empirically examines the promoting effect of Internet linkage on exports and rigorously validates the novel channel through which the driving-up effect takes place. To be specific, the baseline estimation suggests that one per cent increment of Internet linkage is associated with a 0.272 per cent increment in exporting for a given country pair. Reassuringly, the causal relationship between the Internet linkage and the export remains significantly positive even after employing multiple methods to alleviate endogeneity concerns. Additionally, we perform other robustness checks with consideration of time variant factors. More importantly, we substantiate the risk alleviation channel through which Internet linkage promotes exports by demonstrating its stronger impact on riskier importing countries and riskier goods.

Our findings are of great importance for the following reasons. First, by adopting a new proxy for Internet linkage, we provide additional evidence to support the positive impact of the Internet on trade. Second, our novel perspective on Internet linkage's role in risk reduction, as opposed to the conventional emphasis on reducing search costs, enriches the understanding of the mechanisms by which the Internet promotes international trade. Last, our result inspires policymakers to consider the role of the Internet in improving aggregate welfare from international trade.

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A Appendix

Table A1: Top 10 Countries by Emitted Hyperlink in 2009

	Exporter	Importer	Internet hyperlinks in 2009 (in millions)	Export in 2010 (in billions)
1	USA	GBR	48.90	52.00
2	USA	JPN	43.90	61.30
3	USA	DEU	40.80	52.90
4	CHN	USA	34.90	331.00
5	JPN	USA	34.10	106.00
6	USA	CHN	32.50	91.30
7	GBR	USA	31.30	45.20
8	USA	ITA	22.10	13.20
9	FRA	USA	21.00	35.10
10	DEU	GBR	20.80	65.50

Table A2: Mechanism Analysis at the Product Level by Goods Classification

	(1) *differentiated*	(2) *reference*	(3) *homogeneous*
linkage	0.441***	0.394***	0.249***
	(0.041)	(0.047)	(0.064)
_cons	15.451***	17.535***	16.810***
	(0.713)	(0.785)	(1.058)
N	930,758	347,716	81,932
control variables	✓	✓	✓
FE	i,j,k	i,j,k	i,j,k
Adjusted R^2	0.55	0.40	0.26

Note: *linkage* is the amount of Internet hyperlinks sent from the exporting country i to the importing country j in 2009, which takes the log transformation. We control importer, exporter, and product fixed effects in columns (1) to (3). Standard errors clustered at the country-pair level are in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.