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The effect of internet use on trade openness: a panel data analysis.

Abstract

The internet has changed the way of living, doing business, and social behaviour over the last centuries, with the world becoming much more globalized than ever. This paper investigates what the effect of internet use is on trade openness. This is done by using OLS regressions which covers panel data of 164 countries between 1995 and 2017. The main results show that internet use has a positive effect on trade openness. Therefore, the internet should be considered as an important determinant for globalisation.

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I. Introduction

The developments in digital information and communication technology have changed the world in various ways. It changed the way of doing business, education, improved health, and led to cultural and social advantages. This creates opportunities for new innovations and economic activity (International Telecommunication Union, 2020; World Bank, 2021). The internet facilitates commerce because it reduces search frictions. This is because physical search costs are low in online commerce (Dinerstein, et al. 2018). However online commerce also creates new opportunities for profitable online activities. These opportunities could increase cooperation between groups, improve consumer relations, create more personalization, and build new products or services (Enache, 2018).

During the last 2 decades, access to the internet and mobile phones became much more important for trade as the recent expansion of international trade took place together with the diffusion of ICT developments (Rodriquez-Crespo & Billon, 2018). In the UK, online sales increased from 3.4% of total sales in 2007 to 19.2% of total sales in 2019 and during the Covid-19 pandemic it increased even more. (Office for National Statistics, 2021). According to Terzi (2016), the increase in e-commerce leads to an increase in international trade. The research of Freund and Weinhold (2004) showed that the arrival of the internet stimulates trade. Hirst and Thompson (2019) conclude that the new technologies (such as internet, satellites, and IT) invented during the last decades increased the globalisation as it makes it much easier to travel, trade and interact with people around the world.

It would be interesting for policymakers to know the effect of the increasingly important communication infrastructure on variables such as trade, openness, and globalisation. This is because they could make a cost efficient policy to invest in this kind of infrastructure to improve their countries trade and economic performance. Nowadays it is very relevant, because

of the ongoing improvements in internet networks, such as the roll-out of the 5G network, which started in the Netherlands in 2020 (Government of the Netherlands, 2021). During the Covid-19 pandemic, the internet showed its importance as many people around the world were forced to work from home (Hanage, 2020). For these reasons, I want to investigate the effects of using the internet on the trade openness in a country.

The focus will be on trade openness, which is the sum of the imports and the exports in goods and services divided by the GDP of a country. This is an indicator that shows the relative importance of international trade in the economy of a particular country. It could be seen as a degree of globalisation of a country. According to the International Monetary Fund (IMF) trade values are among other things a good illustrator for globalisation (IMF, 2008). Although trade openness has some flaws, like the US has a relatively low level of trade openness but tends to be a great globalised country with high international trade values. Trade openness can still be used as a measure for openness (Learner, 2008). However, the ideal measure would be an index that includes all barriers that distorts international trade. Unfortunately, such indexes that include both tariff and non-tariff barriers are not available for many countries. (Yanikkaya, 2003).

Earlier literature on internet use focused on the effect on economic growth or on bilateral trade, but not on trade openness. Either the focus is on ICT development in general and not specific on the use of the internet. This led to a gap in the existing literature. In this paper the focus will be on the use of the internet and trade openness to fill in this gap. The **research question** is as follows: What is the effect of internet use on trade openness?

As the internet reduces search frictions (Dinerstein, et al. 2018), creates new opportunities (International Telecommunication Union, 2020; World Bank, 2021), and decreases transaction

costs (Kauffman & Kumar, 2008; Venables, 2001), I expect a positive effect of internet use on trade openness.

The panel data, including 164 countries over a period from 1995 to 2017 is derived from the World Development Indicators (WDI). Trade openness is the dependent variable, and internet use is the independent variable. Endogeneity problems may occur while running the OLS regressions. To control for omitted variable biases (OVBs), several control variables will be used when they are correlated with the dependent and independent variable. To control for unobserved characteristics that do not change over time or change at a constant speed, I will add country and time fixed effects to the regression. Furthermore, to tackle reversed causality to some extent, lagged variables will be used in the regressions.

The main findings show that internet use has a positive significant effect on trade openness. A 10 percentage points increase in internet use will result in a 0.76 percentage points increase in trade openness. The positive relation is consistent with the existing literature, although Riker (2014) found a much higher effect of 4.21 percentage points increase in trade openness. The findings showed that the effect is higher for developed countries than for developing countries. However, the results for developing countries were not significant. Nevertheless, the results were similar to the existing literature (Clarke & Wallsten, 2006), although the results were much higher in the paper of Riker (2014). This paper contributes to the existing literature as it shows a relatively small effect while focussing on trade openness and including many countries covering the most recent years. The latter might be the reason that the results of this paper show a smaller effect of internet use on trade openness than related literature. This is because many developed countries have a percentage of internet use that comes close to 100% in the latest years and thus does not change much anymore.

This paper is structured as follows. Section II, the literature review, provides a clear overview of previous theoretical and empirical literature containing the trade theories and studies on internet and trade. Section III shows the descriptive statistics of the data and gives information about the variables. Section IV describes the hypotheses and the methodology used. Section V contains the estimation results of the estimations of the OLS regressions. Section VI, concludes.

II. Literature Review

This section is divided into 2 parts: theoretical literature and empirical literature. The theoretical parts contain theories about several trade theories and show how the internet influences trade. The empirical parts show earlier studies with related topics.

Theoretical literature

In this section some trade theories will be discussed briefly.

According to David Ricardo's theory of comparative advantage, trade rises, because the relative productivity of labour differs between countries. So, trade is based on opportunity costs of producing products. The country that has a comparative advantage over a product will export it and will import products that have relatively higher production costs (Ricardo, 1891).

However, the Heckscher-Ohlin model explains trade, with a mathematical model that trade is based on varieties in natural resources. The model includes the production factors labour and labour cost. So, if a county has low labour costs, it should export more labour intensive products (Leamer & Edward, 1995).

Furthermore, the New Trade Theory explains that firms who are an early entrant may become important in a market, because of economies of scale and market effects. This explains trade between countries with similar factors of production and productivity levels and the existence of many multinational firms (Markusen & Venables, 1998).

Krugman's (1980) model explains that a higher elasticity of substitution between goods magnifies the impact that trade barriers have on trade flows. It shows that consumers prefer a variety of substitute goods. Chaney (2008) builds upon this theory with firm heterogeneity and

finds that when goods are more substitutable, aggregate trade flows are less sensitive to trade barriers.

Melitz's (2003) model considers a steady state equilibrium in a monopolistically competitive industry with heterogeneous firms. It predicts that opening the market (less trade barriers) will lead to less productive firms exiting the market, the most productive firms increase their market share and profit, while the least productive firms decrease their market share and profit. Furthermore, for the operating firms, the exposure to trade increases the productivity and profits, where moderate firms only serve the domestic market, and the most productive firms also export to other countries. This all will lead to more product variety. Moreover, transport costs that arise with distance, information, communication, and entry costs are considered as trade barriers that may affect trade opportunities. So, the internet may reduce these transaction costs that are associated with international trade. As internet use contributes to facilitating information and knowledge about markets, products, and trading partners (Kauffman & Kumar, 2008; Venables, 2001).

However, Jensen & Miller (2018) found another cause of less productive firms exiting the market and more productive firms increasing their profit and quality. Their paper builds forward on Jensen's earlier paper (2007), which is a natural experiment on the spread of mobile phones among fishermen in Kerala, India. It shows that the arrival of mobile phones, changed the behaviour of fishermen in the downstream market for fish, which provided an exogenous shock towards market integration and potential market size in the upstream market for boats. Their newest research finds that increased market integration in the fish market led to a large spillover effect on the degree of integration in the boat market. This resulted in a similar reallocation of firms as described by Melitz (2003). Besides the reallocation of firms, it led to bigger firms, more labour specialization, and gains for the consumers (decrease in prices, higher quality). The authors think that the findings of this natural experiment are external valid

to other industries in developing countries. So, decreasing imperfect information will lead to increased market integration which spillover will benefit to wealth. These market integrations and spillover effects could also be the consequence of developments in the internet in developing countries.

The U.S. International Trade Commission (2014) finds that the internet could significantly reduce international trade costs. The findings show that internet use reduces trade costs with 26 percent on average for U.S. imports and exports of digitally intensive goods and services. This is in line with the theoretical model of Freund and Weinhold (2004) which suggest that trade increases, because the internet reduces fixed costs that are associated with trade.

A common theory about the internet on economic activity is that the internet facilitates commerce because it reduces search frictions as physical search costs are low in online commerce (Dinerstein, et al. 2018). Furthermore, De los Santos (2018) finds that consumers visit relatively few firms and have strong preference for prominent retailers, which also decreases the search costs. Besides search costs, online commerce also creates new opportunities for profitable online activities that could increase cooperation between groups, improve consumer relations, more personalization and build new products or services (Enache, 2018).

Summarizing, earlier trade theories focus on production factors, opportunity costs and market effects. Within these theories, the internet could contribute to trade because of some opportunity costs or because it has an internet intensive sector, but it could also reduce search frictions, transaction or international trade costs that could increase international trade and trade openness and increase market integration, which results in wealth benefits.

Empirical literature

In this section earlier empirical literature about the internet and trade will be discussed briefly.

Freund and Weinhold (2002) were one of the first who contributed to the literature concerning the internet and trade. Their econometric model with US cross border exports in services during 1995-1999 estimated the effect of internet penetration on the trade growth in services of a country. It showed that a 10 percentage points increase of the internet variable results in a 1.7 percentage points growth in exported services in the short run. Their later work, which contains a panel analysis of 56 countries during 1997 – 1999 showed that a 10 percentage points growth of the internet results in a 0.2 percentage points increase in export growth (Freund & Weinhold, 2004).

On the other hand, Riker (2014) used a model in which he investigated the effects of broadband internet users in a country on the openness to trade ratio. The model showed that the growth in broadband use between 2000 and 2011 led to an increase in a country's trade openness by 4.21 percentage points on average. The effect is larger for high income countries than for developing countries, respectively 10.21 and 1.67 percentage points.

The differences between developed and developing countries is in line with Clarke and Wallsten (2006) who found that developing countries export more to other developed countries, but not to developing countries, when there is a growth in internet penetration. They show that when developing countries improve their access to the internet it would result in more exports from the developing country to the developed countries, but not the other way around.

On the contrary, Liu and Nath (2013) investigated 49 emerging countries between 2000 and 2013 and showed that ICT developments had a significant and positive effect on both imports and exports in developing countries.

Furthermore, Rodriquez-Crespo and Billon (2018) investigated the ICT impacts on trade. Their paper focused on the use of the internet, mobile phones, and broadband networks. They used bilateral trade flows and used a dynamic gravity model with panel data covering 55 countries from 2004 to 2013. To deal with endogeneity and reverse causality issues, they used lagged variables as an instrument. They find a positive and significant effect of internet use on bilateral trade, which is a coefficient of 0.166 for the exporter country and 0.101 for the importer country.

Lin (2015) used an augmented gravity equation with the internet from 1990 to 2006 with nearly 200 countries and showed that the short run estimations of the effect of internet users on international trade are higher than the long run estimations.

To summarize, the earlier literature investigated different but similar variables and they all showed that internet developments have a positive effect on trade. The effect tends to be larger for developed countries compared to developing countries. This is in line with the New Trade Theory, discussed earlier, as early entrants benefit more. This led to the following hypothesis:

Hypothesis 1: *internet use has a negative effect on trade openness.*

Because of the differences between developed and developing countries the second hypothesis is as follows:

Hypothesis 2: *internet use has a stronger effect on trade openness for developing countries than for developed countries.*

The third hypothesis will investigate the differences between the short and long run impact of internet use on trade openness.

Hypothesis 3: *the long run effect of internet use on trade openness is greater than the short run effect.*

III. Data

In this section, the database, the sample and all the variables used in the regressions will be described. This includes the table for descriptive statistics and the correlation matrix.

Database and sample

The data used in this research is provided from the World Development Indicators (WDI). This is the primary World Bank collection of development indicators, which shows recent and accurate global development data, such as regional, national, and global estimates compiled from official recognized international sources (The World Bank, 2021).

The sample covers annual panel data with 164 countries from 1995 to 2017. The sample is based on which period and countries contain the most complete data on internet use and trade openness. Sometimes, not all variables for each year are available for some countries. However, the dataset seems to be very complete for 136 countries.

Variables

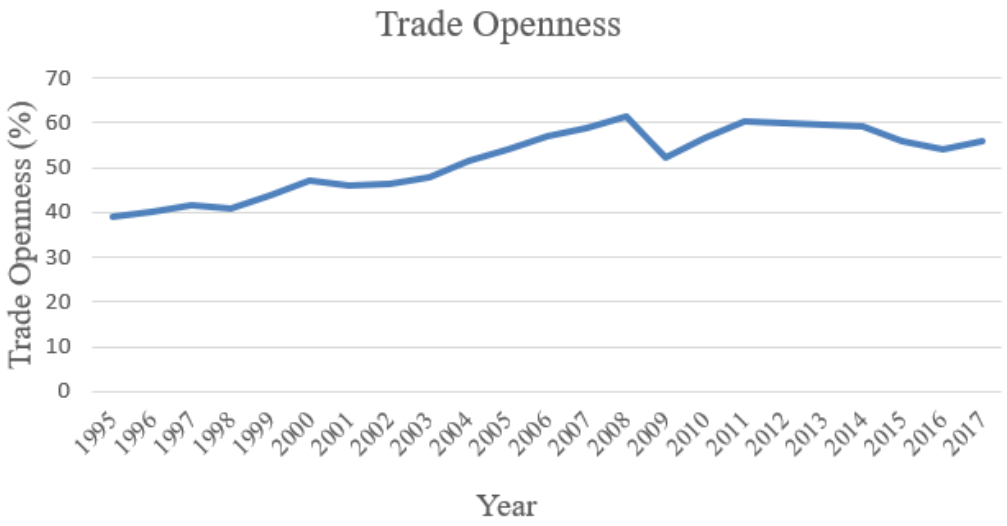
In this part the variables used in the regressions will be elaborated.

Dependent variables

Trade openness is the dependent variable in this research. It is the sum of a country's export and import of goods and services divided by its GDP. The variable is multiplied with 100 to show it as a percentage. Another name for trade openness is the trade-to GDP ratio and it measures the importance of international trade transactions in relation to domestic transactions. Trade openness is a measure that shows the relative importance of international trade in a particular country. It could also be seen as a degree of globalisation. According to the

International Monetary Fund (IMF) trade values are among other variables a good illustrator for globalisation (IMF, 2008). Figure 1 shows a small increase in the average trade openness in the world during the last 3 decades. However, it shows a decrease during the global economic downturn after 2008.

Figure 1: The average level of trade openness (%) in the world between 1995 and 2017.

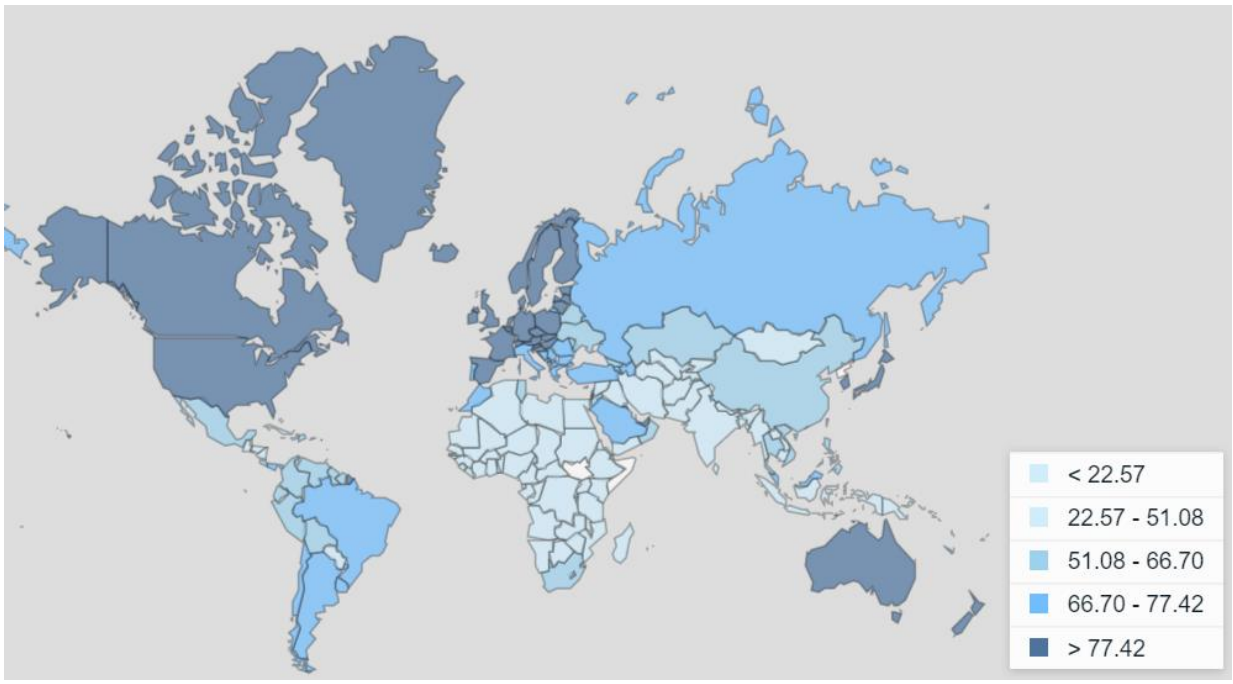


Source: World development indicators (2021).

Independent variable

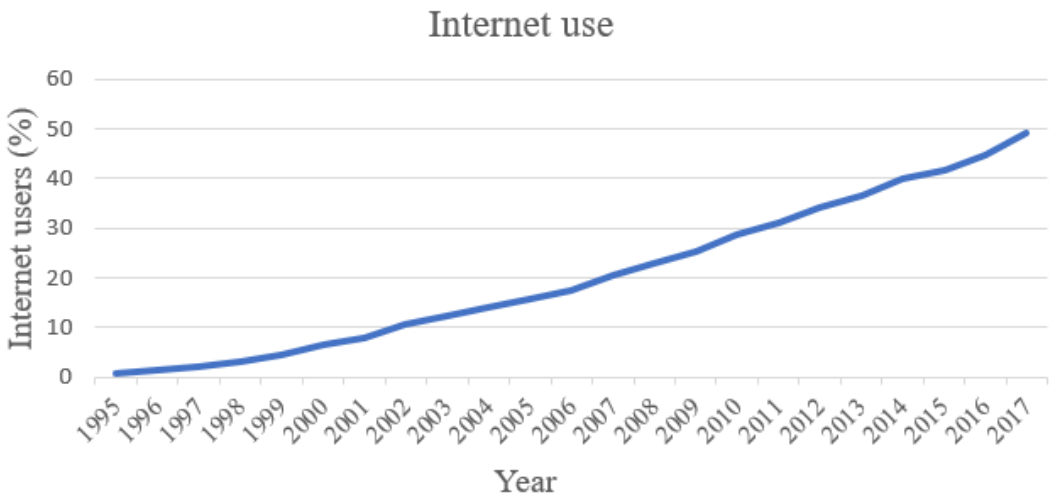
Internet use is the independent variable. It is measured as individuals who have used the internet (from any location and device in the last 3 months) as a percentage of the population. The table below shows that internet use is very different in various parts of the world. In the more developed countries (U.S. Europa, Japan), internet use was above 77.42 percent in 2010. However, in many countries of the world, such as in Africa, the percentage of individuals who use the internet was below 22.57 percent. Furthermore, figure 2 shows the strongly increasing number of internet users in the last 3 decades.

Figure 2: The use of the internet in the world in 2010.



Source: World development indicators (2021).

Figure 3: The average percentage of internet users in the world from 1995 to 2017.



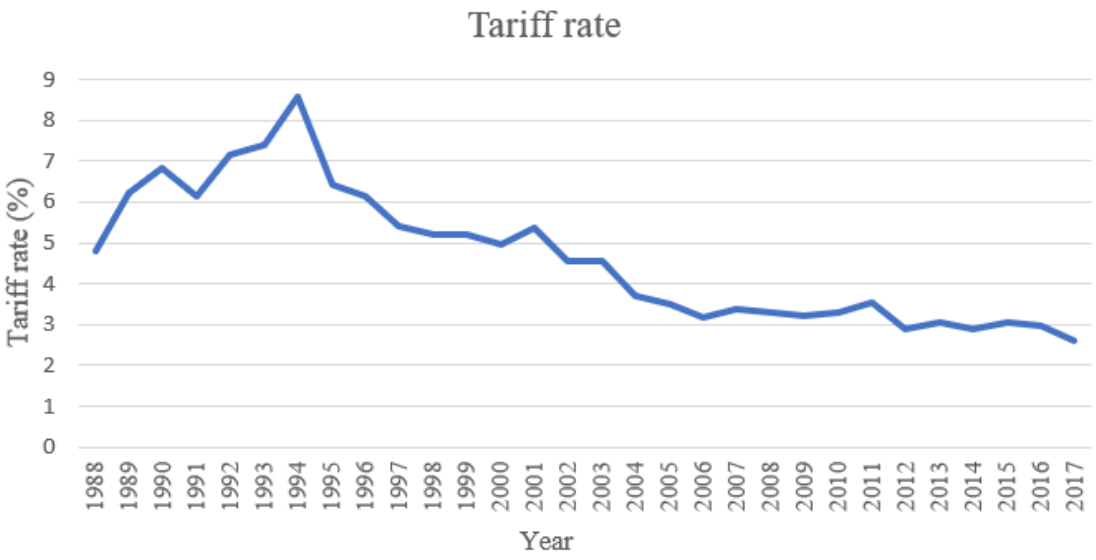
Source: World development indicators (2021).

Control variables

The following control variables will be used: school enrolment, unemployment rate, inflation, tariff rate, fuel export, GDP growth, real GDP per capita, foreign direct investment (FDI) inflows and population. Most variables are described in Appendix A. Only the tariff rate and fuel exports will be discussed here.

The variable *tariff rate* is the weighted mean applied tariff rate over the imported shares of all products. Average tariff rates are used frequently to measure the level of openness. However, non-tariff barriers become relatively more important to measure overall trade barriers (Learner, 2008). Figure 4 shows the tariff rate over the last 3 decades and it shows a drop in the tariff rate from 1994 onwards, which indicates a greater level of openness. To compare the different measures of openness, the tariff rate will be used as the dependent variable in a robustness check later. Tariff rate and trade openness show a correlation coefficient of -0.311. When the tariff rate is used as a control variable it will lead to a higher coefficient for internet use (t-1).

Figure 4: the average weighted mean tariff rate in the world from 1988 to 2017.



Source: World development indicators (2021)

The *fuel export* is used as a proxy for natural resources. This is because real data on natural resources is not easily available. The fuels include mineral fuel, lubricants and related materials and are shown as a percentage of merchandise exports. Natural resources might play a role in internet use and trade openness, so controlling for this variable in the regressions might be valuable. Because the variable concerns exports, it is part of the dependent variable trade openness. Including the variable in the regression will lead to a lower coefficient of internet use (t-1).

Descriptive statistics

To describe the variables that are used in the regression more clearly, table 1 below, shows the following characteristics of the variables: observations, mean, standard deviation, minimum and maximum. The first lags of the dependent and independent variables are added for additional clarification. The mean of the inflation variable is relatively higher than might be expected. This is due to some extreme outliers in the sample. This is also shown in the maximum amount of inflation, which is more than 4800% in 1 year. This variable should be viewed with caution as it might influence the outcomes more than it should. Furthermore, the table shows that the maximum level of internet use is 98.225 percent. This is very close to 100 percent, which might give different estimations in the regression. Appendix B, table A1, shows the regression with only Iceland and Luxembourg between 2015 and 2017. These countries have the highest percentage of internet use. Although the sample is very small, the results show a negative effect on internet use (t-1) on trade openness. This might be due to the level of internet use that goes close to 100 percent.

Furthermore, the scatter plot in figure A1 in the appendix B shows the relationship between the average trade openness and average internet use (t-1) on country level for developing countries

and developed countries. Developed countries show a concave parabolic line while developing countries show an increasing linear increasing line. This means that trade openness increases when countries have a higher level of internet use. Although for developed countries, the level of trade openness decreases when internet use (t-1) comes closer to 100%.

Table 1: summary statistics of the variables used in the main regression.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Trade openness	3,742	85.789	51.720	14.772	442.620
Trade openness (t-1)	3,738	85.295	51.263	17.610	442.620
Internet use	3,669	25.140	28.182	0.000	98.225
Internet use (t-1)	3,586	23.300	27.321	0.000	98.240
School enrolment	2,676	79.580	29.964	5.283	163.935
Unemployment rate	3,588	7.904	5.963	0.140	37.250
Inflation	3,748	12.277	101.749	-27.049	4800.532
Tariff rate	2,767	6.736	9.694	0	421.500
Fuel export (% of total)	3,100	15.372	25.867	0	99.657
GDP growth	3,748	3.843	5.105	-62.076	123.140
Ln real GDP per capita	3,783	8.241	1.576	4.631	11.690
FDI (% of GDP)	3,655	5.336	15.878	-58.323	449.083
Ln population	3.789	15.696	1.993	10.728	21.050

Note: (t-1) means 1 year before period t.
Note: The natural logarithm is taken from the GDP per capita and population.
Note: FDI inflows are in percentage of the GDP and fuel exports is a percentage of total exports.

Correlation matrix

To show all the correlations between the used variables, the correlation matrix is added in Table 2. The table shows a strong correlation between internet use and internet use (t-1), namely 0.993. This indicates that the lagged variable could be used as an instrument.

Table 2: correlation matrix

1	**2**	**3**	**4**	**5**
Trade openness	Trade openness (t-1)	Internet use	Internet use (t-1)	School enrolment
6	**7**	**8**	**9**	**10**
Unemployment rate	Inflation	Tariff rate	Fuel export (% of total)	GDP growth
11	**12**	**13**		
Ln real GDP per capita	FDI (% of GDP)	Ln population		

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.999	1.000											
3	0.332	0.335	1.000										
4	0.328	0.3312	0.993	1.000									
5	0.249	0.249	0.639	0.615	1.000								
6	-0.047	-0.052	-0.022	-0.026	0.184	1.000							
7	-0.052	-0.056	-0.132	-0.130	-0.064	0.012	1.000						
8	-0.311	-0.310	-0.519	-0.505	-0.556	-0.046	0.032	1.000					
9	-0.075	-0.071	0.029	0.022	0.001	-0.077	0.036	0.099	1.000				
10	0.021	0.0062	-0.218	-0.223	-0.196	-0.158	-0.085	0.106	0.005	1.000			
11	0.330	0.330	0.761	0.741	0.824	0.046	-0.123	-0.557	0.077	-0.195	1.000		
12	0.315	0.301	0.109	0.104	0.097	-0.004	-0.025	-0.116	-0.069	-0.007	0.129	1.000	
13	-0.464	-0.468	-0.143	-0.136	-0.170	-0.129	0.047	0.124	0.024	0.047	-0.200	-0.187	1.000

IV. Methodology

In this section, the specifications, estimation methods and the limitations will be evaluated.

Specifications

Ordinary least square (OLS) estimates will be used with the following equation:

$$Trade\ openness_{i,t} = \alpha + \beta_1\ internet\ use_{i,t-1} + \beta_2\ trade\ openness_{i,t-1} + \beta_3\ controls_{\ i,t} + F_i + F_t + \epsilon_{i,t}$$

Where i refers to the variable of country i and t refers to the variable in year t. $t-1$ stands for 1 year prior to t. $Trade\ openness$ is the dependent variable and $internet\ use$ is the independent variable. α is the constant and β is the parameter. The set of control variables contains all the control variables that are described earlier in the data section. $F_i\ and\ F_t$ are respectively the country and the time fixed effects and $\epsilon_{i,t}$ is the error term.

Estimation methods

To measure the effect of internet use on trade openness an OLS estimation will be used. It would be ideal to measure the causal effect, however some important assumptions with respect to internal validity need to hold. It is not likely that all those assumptions will be met in this study, so the results should be watched with caution and should be interpreted as correlations. However, this study tries to avoid biases related to endogeneity or omitted variables. For a causal effect, the independent variable should not be correlated with the error term. Or in other words: the expected value of the error term, given X is equal to 0. Because it is not possible to do a randomized experiment with these macro-economic variables it is not possible to be 100%

sure that this assumption holds. Therefore, it is important that the independent variable is exogenous.

To deal with endogeneity problems it is important that there is no measurement error, reversed causality and omitted variable bias in the estimation. These problems are described below.

The classical measurement error will make it hard to find a causal relationship as it leads to a bias towards zero, which is an underestimation. Other variables could be measured according to different standards in different countries, this could lead to problematic measurement errors as it influences the results. For example, developing countries might be less strict in checking attendance for school enrolment or have a big informal sector what is not taken into account in the GDP. This might lead to some biases and inconsistent estimates.

Omitted variable bias occurs when other determinants of the dependent variable are related to the independent variable. Variables that are correlated with the dependent and independent variable and are not included in the regression could lead to an over- or underestimation of the results, change the sign of the effect or mask that the effect exists. To prevent OVB, various control variables will be added to the regression. In this paper I will use the control variables mentioned earlier in the data section. For example, inflation will control for macroeconomic stability, GDP growth will control for financial development and secondary school enrolment can be used to control for human capital. The tariff rate can also be used as a measure of openness, so using this variable as a control will increases the coefficient for internet use. Unfortunately, when adding control variables, some can be interpreted as bad controls. This is the case when the control variables themselves are outcomes of the independent variable. This might lead to a misinterpretation of the outcomes. The possible control variables that are used in the regression are inflation, FDI and GDP growth. According to Yi and Choi (2005), internet use led to a lower inflation, Choi (2003) showed that an increase in internet use led to an

increase in FDI and Cette, et al. (2005) show that it positively influences GDP growth. So, interpreting the outcomes of regressions with possible bad control variables should be viewed with caution to avoid misinterpretation of the coefficient estimates.

Furthermore, it is not always possible to control for all omitted variables. To control for (un)observed variables and variables that change at a constant speed over time, fixed effects estimations will be used. By adding country and time-fixed effects these variables will be controlled for. For example, cultural and historical differences within countries do not change or barely change in time and country fixed effects can control for it. Another example is macroeconomic shocks, time fixed effects can control for these changes in time. When adding the country and time-fixed effects into this paper's regression, it is possible to control for these (un)observed characteristics. So, using fixed effects will lead to less biased regression estimations.

Reverse causality occurs when the independent variable has a causal effect on the dependent variable and the dependent variable has a causal effect on the independent variable. In this way it is not clear how much the effect is, and this could lead to an over- or underestimation of the results. By using lagged variables as an instrument in the regression it is possible to tackle this issue to some extent. By using the variables from 1 or 2 years ago for the independent variable it is not possible that the dependent variable has a causal effect on the lagged independent variable. In other words, using $t-1$ and $t-2$ for internet use and the control variables and use t for trade openness. However, this method is not ideal as it may be the present t that influences trade openness. Furthermore, expectations about trade openness could influence the variable internet use in $t-1$.

To test whether the dependent and independent variables have a unit root, the Fisher-type unit root test, adjusted for panel date, will be done. This is important because unit roots can lead to spurious regression results.

Limitations

Unfortunately, it is not always possible to add all the omitted variables and measurement errors could still exist, so the results should be viewed with caution. This is because there could be a cofounding variable which is not included in the model that biases the coefficient estimates and measurement errors might lead to inconsistent estimates. To tackle reverse causality, it would have been better to use an instrumental variable (IV), which is a variable that only affects the dependent variable through the independent variable. However, it is very difficult to find a good IV and is beyond the scope of this thesis. Still, Hjort and Poulsen (2019), used the arrival of submarine internet cables in Africa as an instrument for the internet while using a difference-in-difference estimation. This approach could be used in future research.

Due to these limitations, it is hard to find a causal effect of internet use on trade openness. So, the results should be viewed with caution and might be interpreted as a correlation.

Besides the endogeneity problems, using an OLS estimation also has a limitation as it is sensitive to outliers, this could influence the outcomes. The inflation variable for example, shows huge outliers for some developing countries in particular years. Moreover, missing variables in the panel data could be a problem when they are not missing at random. For some developing countries, not all variables are available from the beginning of the sample period, because they started collecting these data at a later period. The consequence is that some periods of these countries are dropped from the sample, which might lead to biased outcomes.

V. Results

This section contains the main empirical results, unit root tests and the robustness checks.

Unit root tests

As described in the estimation methods, the Fisher-type unit root test will be used for both the dependent and the independent variable to test for unit roots. This test is suitable for panel data. The test includes a drift and a two lagged difference. As shown in tables A2 and A3 in Appendix B, the p-values are statistically significant with p-values of 0.000. This indicates that it is possible to reject the null hypothesis: “all panels contain unit root” for both variables.

Robust standard errors

Robust standard errors will be used in the OLS regressions. This led to smaller standard errors and t statistics. Furthermore, this will provide unbiased standard errors under heteroscedasticity.

Main empirical results

Hypothesis 1

Table 3 shows the OLS regression results of our main specification where trade openness is used as the dependent variable with robust standard errors and fixed effects. The first (1) column estimates the effect of only the variable internet use on trade openness without any control variables. This shows that a 10 percentage points increase in internet use results in a 2.20 percentage points increase in trade openness. However, as explained in the methodology section, the lagged variable of internet use will be used (t-1) in the second column (2). This estimates a similar effect, with a coefficient of 0.229. Which indicates that internet use is a relatively slow moving variable. It is not possible to conclude that this might indicate that due to reversed causality the effect of internet use (without the lag) is underestimated by a little.

In column (3), the control variables are included, and this shows that the coefficient for internet use (t-1) becomes bigger. However, when the lagged variable of trade openness is added in column (4), the coefficient decreases to 0.076. As the present value of trade openness might depend on the past value, it should be included in the model. Which means that column (4) is the main regression and has the highest adjusted r-squared. So, when internet use (t-1) increases by 10 percentage points, trade openness increases by 0.76 percentage points. This coefficient is significant at a 1% significance level. This does not necessarily mean that it is a causal relation, as the results should be interpreted as correlations, due to the earlier explained endogeneity concerns.

Table 3: Main results of the effect of internet use (t-1) on trade openness

	1	2	3	4
Trade openness	Coefficient	Coefficient	Coefficient	Coefficient
Internet use	0.220***			
	(4.20)			
Internet use (t-1)		0.229***	0.334***	0.076***
		(4.18)	(5.55)	(4.66)
Trade openness (t-1)				0.841***
				(45.54)
School enrolment			0.101	0.017
			(0.88)	(0.67)
Unemployment rate			0.116	0.307**
			(0.48)	(3.14)
Inflation			0.020	0.014
			(1.24)	(1.32)
Tariff rate			-0.382	-0.093
			(-1.33)	(-1.41)
Fuel exports (% of total)			0.253	0.118***
			(1.63)	(3.60)
GDP growth			0.646***	0.387***
			(6.20)	(4.36)
Ln GDP per capita			-1.764	-1.910*
			(-0.58)	(-2.02)
FDI (% of GDP)			0.018	0.045**
			(0.56)	(2.68)
Ln population			-32.14**	-10.61**
			(-2.78)	(-3.30)
Constant	80.48***	80.85***	598.4**	193.7***
	(61.54)	(63.72)	(3.24)	(3.76)
Number of observations	3621	3541	1915	1914
Number of countries	164	164	136	136
Adjusted R^2	0.074	0.079	0.204	0.783
Country and time fixed effects	YES	YES	YES	YES
Robust standard errors	YES	YES	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Trade openness is the dependent variable, internet use (t-1) is the independent variable, all other variables are used as controls.

In Table A4 in appendix B, the lagged values of the control variables are used instead of the present values. In this case, there could not be reverse causality between the control variables and the dependent variable. Column (1) shows the effect of internet use (t-1) on trade openness with a smaller selection of control variables. This is because there is less data available for school enrolment, tariff rate and fuel exports. Column (2) includes all the described control

variables. The 2 regressions show a significant coefficient of respectively 0.040 and 0.046. This indicates that a 10 percentage points increase in trade openness increases the trade openness with respectively 0.40 and 0.46 percentage points. This is less than in column (4) of table 3. However, both show a significant positive effect of internet use (t-1) on trade openness.

Furthermore, appendix B table A5 shows the effect of internet use (t-1) on trade openness with different sets of control variables. The table shows the same regression as in table 3 column (4), but independently without population (1), tariff rate (2), fuel exports (3) and without all these three variables (4). The coefficients of internet use differ a bit, but still show similar significant results as in table 3 column (4).

The outcomes seem to be statistically and economically significant. This is in line with the earlier discussed empirical literature (Freund and Weinhold, 2002; Clarke and Wallsten, 2006; Riker, 2014), that also shows a positive effect of internet use on trade openness or with estimates of comparable variables. However, Riker (2014) found a higher effect of 4.21 percentage points, when internet use increases with 1 percentage points. The effect might be smaller because the data used in this paper contains more recent years where internet use (t-1) becomes closer to 100% and that corresponds with a relatively lower level of trade openness for developed countries according to the scatterplot of appendix B figure A1.

Nevertheless, the results show a significant positive effect of internet use on trade openness. That is why it is possible to reject the first hypothesis:

Hypotheses 1: "*internet use has a negative effect on trade openness*".

It is hard to say how the use of internet affects the trade openness. The literature review showed possible explanations: The internet reduces search frictions, which stimulates commerce and trade (Dinerstein, et al. 2018), the internet creates new opportunities that could stimulate trade (International Telecommunication Union, 2020; World Bank, 2021), the internet increases

market integration with spillover effects to other sectors that stimulate economic activity (Jensen & Miller (2018), and decreases transaction costs that could increase international trade (Kauffman & Kumar, 2008; Venables, 2001). These regression results do not show which channel the use of internet affects trade openness.

Hypothesis 2

To investigate if there are differences between developed countries and developing countries, the sample is split into these two groups of countries according to The World Bank (2021), based on GDP per capita. It is important to note that GDP is part of the dependent variable trade openness and thus plays a role in if a country is part of the developed or developing sample. Table 4 shows the regression estimations with the split samples. In column (1) and (2) the effects for the developed countries are shown. It shows a coefficient of 0.368 when only internet use (t-1) is included in the regression and a coefficient of 0.071 when all control variables are included. This indicates that a 10 percentage points increase in internet use (t-1) leads to a significant increase of 0.71 percentage points in trade openness. This result is similar to the one including the whole sample.

However, the results are very different for developing countries. Column (3) even shows a negative effect for internet use (t-1) without control variables, namely a coefficient of -0.010. Column (4), which includes all control variables still shows a small increase with a coefficient of 0.004. The results of internet use (t-1) for developing countries are also insignificant. This means that it is not possible to conclude that internet use (t-1) has a positive effect of trade openness. Nonetheless, it is very interesting that the regression shows almost no effect of internet use (t-1) on trade openness. This might be in line with the findings of Clarke and Wallsten (2006), that when developing countries improve their access to the internet it would

result in more exports from the developing country to the developed countries, but not the other way around. So, developing countries might not benefit as much from internet use as developed countries. However, these results do not show an explanation why there is not an effect for developing countries.

Nevertheless, the results clearly show a stronger effect of internet use on trade openness for developed countries, which means that it is likely that we can reject the second hypothesis:

Hypothesis 2: "*internet use has a stronger effect on trade openness for developing countries than for developed countries.*"

This is in line with earlier literature which also found a stronger effect of internet use on trade (or trade openness) in developed countries than in developing countries (Clarke and Wallsten, 2006; Riker, 2014). So, the results seem to be economically significant. However, Riker (2014) showed that when internet use increases by 10 percentage points, trade openness increases by 10.21 percentage points for developed countries and by 1.67 percentage points for developing countries. These are much greater outcomes than in Table 4.

Table 4: the effect of internet use (t-1) on trade openness for developed and developing countries.

	1	2	3	4
Trade openness	Developed	Developed	Developing	Developing
Internet use (t-1)	0.368***	0.071**	-0.010	0.004
	(5.11)	(2.87)	(-0.15)	(0.11)
Trade openness (t-1)		0.849***		0.786***
		(43.94)		(25.79)
School enrolment		-0.007		0.059
		(-0.22)		(1.22)
Unemployment rate		0.599***		-0.054
		(4.02)		(-0.36)
Inflation		0.097*		0.002
		(2.21)		(0.30)
Tariff rate		0.136*		-0.214**
		(0.97)		(-2.66)
Fuel exports (% of total)		0.136*		0.093*
		(2.50)		(2.19)
GDP growth		0.733***		0.109
		(5.14)		(1.17)
Ln GDP per capita		1.576		-3.377*
		(1.13)		(-2.34)
FDI (% of GDP)		0.040*		0.313*
		(2.22)		(2.57)
Ln population		-11.51*		-7.121
		(-2.11)		(-1.57)
Constant	88.86***	171.0	77.29***	153.9*
	(27.52)	(1.86)	(92.15)	(2.21)
Number of observations	1130	908	2411	1066
Number of countries	50	48	114	88
Adjusted R^2	0.259	0.846	-0.000	0.669
Country and time fixed effects	YES	YES	YES	YES
Robust standard errors	YES	YES	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Trade openness is the dependent variable, internet use (t-1) is the independent variable, all other variables are used as controls.

Hypothesis 3

To estimate the short and long run effect of trade openness, extra lagged variables of the independent variable internet use are added to the regression. In table 5, the results of these dynamic regressions are shown. The short-term estimations, the variable internet use without lags does show a negative sign in the regressions without control variables (1) and (2). When control variables are included in column (3) and (4), internet use shows a small positive sign of respectively 0.016 and 0.029. This indicates that when internet use increases by 10 percentage points, trade openness increases on the short-term by respectively 0.16 and 0.29 percentage points. However, these results are not significant and cannot be interpreted.

When we calculate the long run impact in table 5 (column 1 and 2 without controls, column 3 and 4 with controls), the regression shows that when internet use increases with 10 percentage points, the trade openness increases on the long-term with respectively 1.15[1], 1.38[2], 4.49[3] and 4.84[4] percentage points. However, these results are not significant and cannot be interpreted. That is why it is not possible to reject the third hypothesis.

Hypothesis 3: "*the long run effect of internet use on trade openness is greater than the short run effect."*

Although insignificant results, the long-term effect tends to be higher than the short-term effects. This is in contradiction with the earlier findings of Lin (2015) who found the opposite.

[1] (-0.070 + 0.088) / (1 - 0.843) = 0.115
[2] (-0.051 + 0.049 -0.053 +0.077) / (1 - 0.840) = 0.138
[3] (0.016 -0.016 + 0.054 + 0.021) / (1 - 0.833) = 0.449
[4] (0.029 - 0.008 + 0.018 + 0.040) / (1 - 0.837) = 0.484

Table 5: effect of internet use on trade openness short run and long run.

	1	2	3	4
Trade openness	Coefficient	Coefficient	Coefficient	Coefficient
Trade openness (t-1)	0.843***	0.840***	0.833***	0.837***
	(44.34)	(42.07)	(43.17)	(44.65)
Internet use	-0.070	-0.051	0.016	0.029
	(-1.33)	(-0.92)	(0.24)	(0.40)
Internet use (t-1)	0.088	0.049	-0.016	-0.008
	(1.61)	(0.57)	(-0.19)	(-0.10)
Internet use (t-2)		-0.053	0.054	0.018
		(-0.62)	(0.92)	(0.31)
Internet use (t-3)		0.077	0.021	0.040
		(1.58)	(0.45)	(0.91)
School enrolment			0.019	0.017
			(0.74)	(0.65)
Unemployment rate			0.229*	0.298**
			(2.52)	(3.04)
Inflation			-0.014	0.0144
			(-0.78)	(1.31)
GDP growth			0.361***	0.392***
			(5.18)	(4.37)
Ln GDP per capita			-2.832***	-1.950*
			(3.54)	(-2.04)
FDI (% of GDP)			0.050**	0.055**
			(2.83)	(2.69)
Tariff rate				-0.113
				(-1.70)
Fuel exports (% of total)				0.124***
				(3.66)
Ln population				-10.81**
				(-3.26)
Constant	13.66***	14.01***	32.21***	197.8***
	(8.58)	(8.38)	(4.93)	(3.74)
Number of observations	3512	3449	2397	1897
Number of countries	164	164	148	136
Adjusted R^2	0.738	0.736	0.745	0.782
Country and time fixed effects	YES	YES	YES	YES
Robust standard errors	YES	YES	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Trade openness is the dependent variable, internet use is the independent variable, all other variables are used as controls.

Note: To interpret the long-term results, extra calculations must be made.

Robustness checks

To check whether the results are robust to alternative specifications, the tariff rate will be used as the dependent variable and another regression will be used with mobile phone subscriptions as the independent variable.

Tariff rate

According to Madsen (2009), the tariff rate can be used as a measure of (trade) openness. The average tariff rate is between 8% and 4% in the sample period and has been decreasing since 1994, as discussed in the data section. The tariff rate is a variable that does not change very often as it depends on government policy. This might lead to lower or inconsistent estimation coefficients of the independent variable.

In Table 6, the tariff rate is used as the dependent variable instead of trade openness. The regression contains robust standard errors and fixed effects estimations. Column 1 shows, without control variables, that when internet use (t-1) increases with 10 percentage points, the tariff rate decreases by 0.60 percentage points. Although when control variables are included in the regression the effect becomes smaller. In column 2, most control variables are added. Column 3 also includes the lagged tariff rate (t-1) as a control variable, and column 4 includes the variable trade openness. These regressions estimate that when internet use (t-1) increases by 10 percentage points, the tariff rate decreases with respectively -0.06, -0.03 and -0.01 percentage points. However, these regressions are not significant and could not be interpreted.

As a decrease in the tariff rate corresponds with a higher level of openness, these results are in line with our earlier findings in the main regressions, although they are not significant.

Table 6: the effect of internet use (t-1) on the tariff rate.

	1	2	3	4
Tariff rate	Coefficient	Coefficient	Coefficient	Coefficient
Internet use (t-1)	-0.060***	-0.006	-0.003	-0.001
	(-10.70)	(-0.69)	(-0.47)	(-0017)
Tariff rate (t-1)			0.026	0.026
			(0.93)	(0.94)
School enrolment		-0.056**	-0.048**	-0.047**
		(-3.25)	(-2.95)	(-2.87)
Unemployment rate		0.022	0.014	0.014
		(0.59)	(0.43)	(0.45)
Inflation		-0.003	-0.003	-0.003
		(-1.17)	(-1.29)	(-1.28)
Fuel exports (% of total)		-0.024	-0.018	-0.017
		(-1.53)	(-1.32)	(-1.24)
GDP growth		0.010	0.001	0.005
		(0.46)	(0.07)	(0.30)
Ln GDP per capita		-1.958***	-1.943***	-1.948***
		(-3.68)	(-3.97)	(-4.00)
FDI (% of GDP)		-0.000	-0.000	-0.000
		(-0.20)	(-0.16)	(-0.09)
Ln population		-5.703***	-4.808***	-4.999***
		(-3.79)	(-3.68)	(-3.57)
Trade Openness				-0.005
				(-0.68)
Constant	8.245***	119.9***	104.3***	107.8***
	(54.67)	(4.93)	(4.83)	(4.63)
Number of observations	2716	1920	1764	1760
Number of countries	159	136	135	135
Adjusted R^2	0.023	0.338	0.345	0.345
Country and time fixed effects	YES	YES	YES	YES
Robust standard errors	YES	YES	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Tariff rate is the dependent variable, internet use (t-1) is the independent variable, all other variables are used as controls.

Mobile phone subscriptions

The mobile phone, or mobile cellular telephone, subscription are subscriptions to a public mobile telephone service and provides access to public telephone networks. The variable shows the level of subscriptions per 100 people. Although this variable does not say anything about the internet use, it shows developments in communication infrastructure. Appendix B figure

A2, shows the number of mobile telephone subscriptions per 100 people between 1995 and 2019. Where the world average number was around 1 in 1995, it exceeded 100 in 2016. This indicates that people have multiple subscriptions, which is also shown in appendix B table A6, that shows the summary statistics. Where the maximum number is above 300 subscriptions per 100 people. The extended correlation matrix shows that (the lagged) mobile phone subscriptions variable is highly correlated with internet use. The coefficient, shown in appendix B table A7, is above 0.800.

Table 7 shows the regressions results with mobile phone subscriptions (t-1) as independent variable. The regression includes robust standard errors and fixed effects estimations. Column 1 shows without control variables, that when mobile phone subscriptions (t-1) increase by 10 percentage points, the trade openness increases by 0.85 percentage points. Although when control variables are included in the regression the effect becomes smaller. In column 2, most control variables are added, only the tariff rate, fuel exports and population are excluded. Column 3 included all control variables. These regressions estimate that when mobile phone subscriptions (t-1) increase with 10 percentage points, trade openness increases with respectively 0.31 and 0.33 percentage points. So, the significant results show that mobile phone subscriptions (t-1) indeed increase trade openness. This is in line with Jensen & Miller (2018) natural experiment on fishermen in India, that showed that mobile phones increased market integration, and this results in spillover effects to other sections. The regression results show it is slightly lower than the coefficients of internet use (t-1) in the main regression. Because the mean mobile phone subscriptions are higher than the mean level of internet use, the regression outcomes seem to be similar. This shows that the results are robust to this alternative specification.

Table 7: effect of mobile phone subscriptions on trade openness.

	1	2	3
Trade openness	Coefficient	Coefficient	Coefficient
Mobile phone subscriptions (t-1)	0.085**	0.031**	0.033**
	(3.35)	(3.13)	(2.74)
Trade openness (t-1)		0.852***	0.853***
		(50.63)	(45.14)
School enrolment		-0.006	-0.012
		(-0.24)	(-0.46)
Unemployment rate		0.342***	0.368***
		(3.91)	(3.60)
Inflation		-0.005	0.013
		(-0.46)	(1.34)
GDP growth		0.365***	0.371***
		(5.27)	(4.09)
Ln GDP per capita		-2.865**	-1.927
		(-2.99)	(-1.68)
FDI (% of GDP)		0.055***	0.049***
		(3.58)	(3.43)
Tariff rate			-0.102
			(-1.32)
Fuel exports (% of total)			0.127***
			(4.10)
Ln population			-8.414*
			(-2.56)
Constant	81.32***	31.57***	159.2**
	(58.44)	(3.97)	(2.90)
Number of observations	3560	2427	1892
Number of countries	164	148	136
Adjusted R^2	0.052	0.748	0.776
Country and time fixed effects	YES	YES	YES
Robust standard errors	YES	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Trade openness is the dependent variable, mobile phone subscriptions (t-1) is the independent variable, all other variables are used as controls.

VI. Conclusions

This paper investigates the effect of internet use on trade openness with panel data containing 164 countries between 1995 and 2017. Multiple OLS regressions estimations are used with robust standard errors, country and year fixed effects and different sets of control variables. With the given results the research question could be answered: "What is the effect of internet use on trade openness?"

The main results show that internet use has a positive significant effect on trade openness. A 10 percentage points increase in internet use will result in a 0.76 percentage points increase in trade openness. The positive relation is consistent with the existing literature, although Riker (2014) found a much higher effect of 4.21 percentage points increase in trade openness. Furthermore, this research shows that the effect is higher for developed countries than for developing countries. However, the results for developing countries were not significant. Nevertheless, the results were in line with the existing literature (Clarke & Wallsten, 2006), although the results were much higher in the paper of Riker (2014). The results of this paper's analysis might be smaller because it contains more recent data. The long run versus short run analysis did not estimate significant effects and cannot be interpreted, although the long term effects tend to be higher. Given these results, the internet might be an important determinant for globalization, as trade openness could be seen as a degree of globalisation of a country.

To interpret the main results as causal effects, internal validity must hold. Although this paper tries to deal with multiple endogeneity problems, by using fixed effects, adding omitted variables, and using lagged variables, internal validity could still be violated. Furthermore, different types of measurement error could bias the results. Therefore, the results should be watched with caution and should be interpreted as correlations more than a causal relationship.

For policy implications the results might still be useful as it shows that internet use has a positive effect on the trade openness of a country. Policy makers that want to open their country to more international markets, might consider more investments in internet related infrastructure. In this way they could make a cost efficient policy regarding the developments in communication infrastructure.

For further research I should suggest doing an analysis using an IV estimation. For example, the research of Hjort and Poulsen (2019) who used the arrival of submarine internet cables in Africa as an instrument for the internet while using a difference-in-difference estimation. Besides the IV estimation, I should suggest using an index with both tariff and nontariff barriers as dependent variable as a measure of openness. Furthermore, it could be interesting to know how internet use influences trade openness. This is because the theory in the literature review showed us that it could be due to less search frictions, lower transaction costs, market integration and new opportunities. Natural experiments, such as the one of Jensen & Miller (2018) might be helpful for this.

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Appendix

Appendix A

Control variables that were not discussed earlier:

The variable *school enrolment* measures the gross secondary school enrolment ratio of a country. According to Mankiw, et al. (1992) secondary school enrolment can be used as a proxy for human capital. They found a significant role of human capital measured by secondary school enrolment. Human capital might be relevant to use as a control variable as it could be correlated with both internet use and trade openness. The data is based on annual school surveys, so it may not reflect actual enrolment rates.

The *unemployment rate* shows the percentage of people that do not have paid work, are seeking for work and have taken action to find work in the past month compared to the total labour force. The labour force consists of paid jobs, self-employed- and unemployed people.

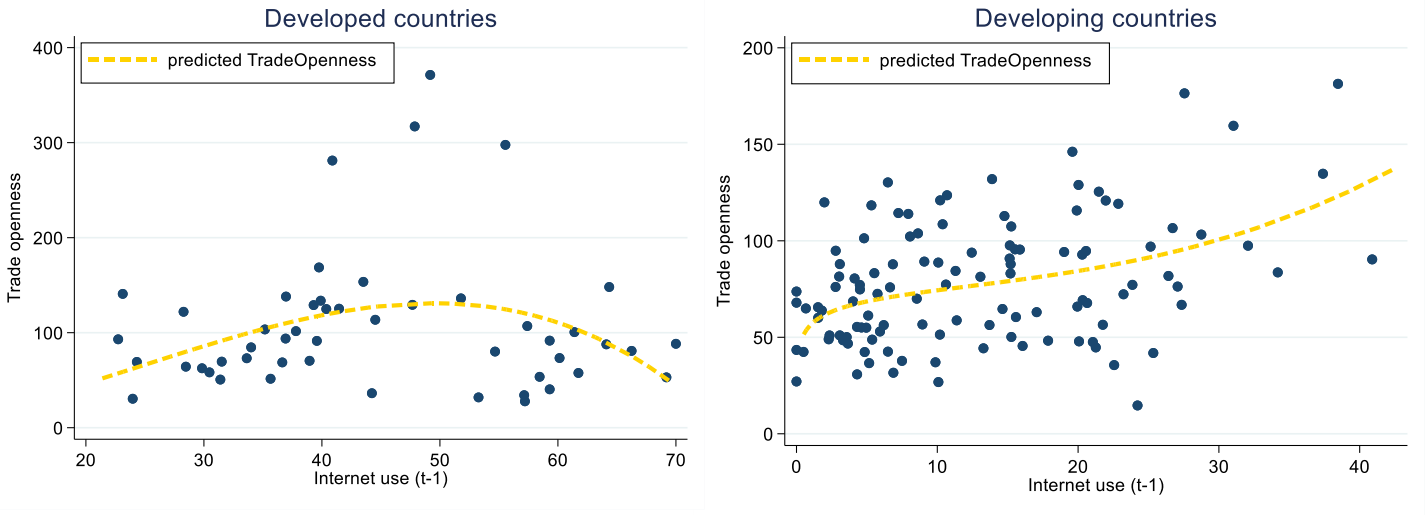
The *Inflation* is measured by the annual growth rate of the GDP deflator, which shows the price change rate in the economy. It is based on the current local currency of a country. The inflation rate might be associated with the macroeconomic stability of a country (Noorbakhsh, 2001). That is why it might be useful to add it as a control variable to the regression as it might correlate with both the independent as well as the dependent variable.

To control for the financial development the following variables are added: *GDP growth*, *real GDP per capita* and *foreign direct investment inflows* (FDI) as a percentage of GDP. The GDP growth is the annual GDP growth in percentage. The real GDP per capita is in natural logarithm and shows the amount of GDP divided by the population. The FDI inflows show the amount of foreign direct investment inflows as a percentage of the GDP. These variables are added as they might be correlated with internet use and trade openness.

To control for country size, the natural logarithm of the population is used. This is in line with Choi (2010), who stated that population can be used as a proxy for country size. Country size might influence both the dependent and independent variable.

Appendix B

Figure A1: Scatterplot between the average trade openness and average internet use (t-1) on country level for developing countries and developed countries.



Source: World development indicators (2021)

Table A1: The effect on internet use (t-1) on trade openness for Iceland and Luxembourg between 2015-2017.

	1
Trade openness	Coefficient
Internet use (t-1)	-2.404*
	(-19.67)
Constant	479.3****
	(40.31)
Number of observations	6
Number of countries	2
Adjusted R^2	-0.032
Country and time fixed effects	YES
Robust standard errors	YES
*** p<0.001, ** p<0.01, * p<0.05	
Note: The t-statistics are between the brackets	
Note: Trade openness is the dependent variable, internet use (t-1) is the independent variable,	

Table A2: Unit root test for trade openness

		Statistic	p-value
Inverse chi-squared (328)	P	858.159	0.000
Inverse normal	Z	-16.890	0.000
Inverse logit t (824)	L*	-17.140	0.000
Modified inv. Chi-squared	Pm	20.698	0.000

Table A3: Unit root test for internet use (t-1)

		Statistic	p-value
Inverse chi-squared (330)	P	941905	0.000
Inverse normal	Z	-17.564	0.000
Inverse logit t (829)	L*	-18.530	0.000
Modified inv. Chi-squared	Pm	23.818	0.000

Table A4: the effect of internet use (t-1) on trade openness with lagged control variables.

	1	2
Trade openness	Coefficient	Coefficient
Internet use (t-1)	0.040**	0.046**
	(3.07)	(3.14)
Trade openness (t-1)	0.840***	0.844***
	(44.15)	(51.92)
School enrolment (t-1)		0.011
		(0.42)
Unemployment rate (t-1)	0.446***	0.435***
	(5.22)	(4.20)
Inflation (t-1)	-0.008***	-0.024*
	(-3.74)	(-2.60)
Tariff rate (t-1)		0.083
		(0.99)
Fuel exports (% of total) (t-1)		0.044
		(1.19)
GDP growth (t-1)	0.014	-0.009
	(0.32)	(-0.16)
Ln GDP per capita (t-1)	-0.826	-0.321
	(-1.50)	(-0.39)
FDI (% of GDP) (t-1)	0.054**	0.054*
	(2.75)	(2.75)
Ln population (t-1)	-2.397	-8.336**
	(-1.46)	(-2.74)
Constant	54.20*	144.7**
	(2.17)	(3.04)
Number of observations	3234	1839
Number of countries	154	136
Adjusted R^2	0.736	0.769
Country and time fixed effects	YES	YES
Robust standard errors	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Trade openness is the dependent variable, internet use (t-1) is the independent variable, all other variables are used as controls.

Table A5: The effect of internet use (t-1) on trade openness with different sets of control variables.

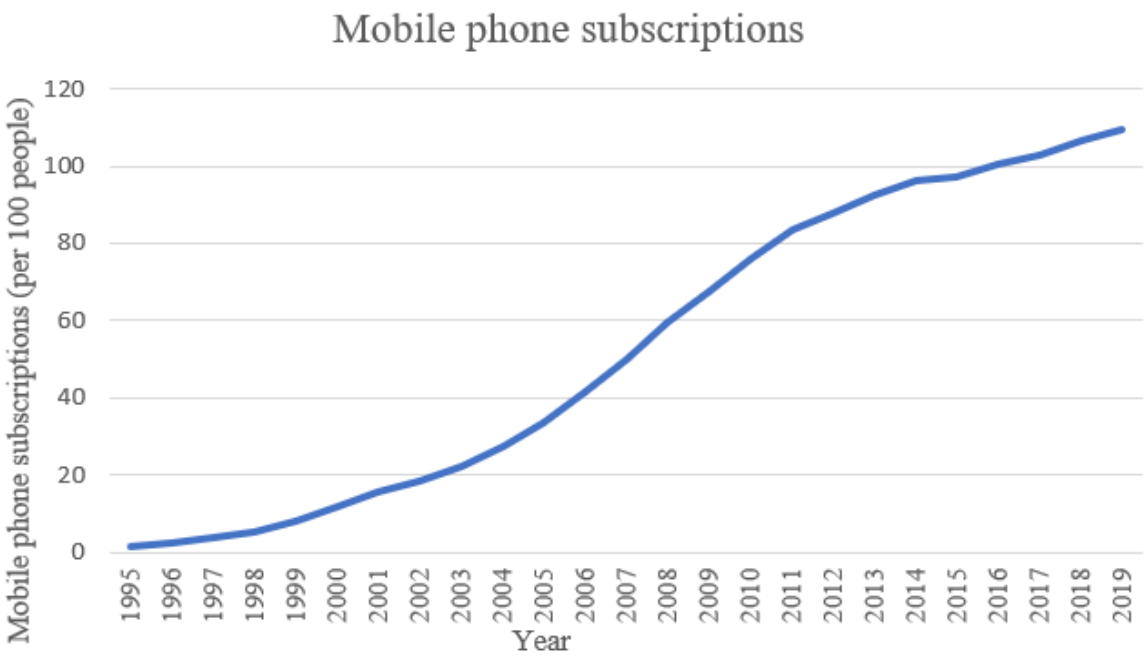
	1	2	3	4
Trade openness	Coefficient	Coefficient	Coefficient	Coefficient
Internet use (t-1)	0.065***	0.070***	0.084***	0.073***
	(3.94)	(4.70)	(5.06)	(4.87)
Trade openness (t-1)	0.848***	0.853***	0.832***	0.839***
	(48.41)	(52.51)	(39.72)	(46.98)
School enrolment	-0.011	0.038	0.021	0.017
	(-0.48)	(1.580	(0.79)	(0.71)
Unemployment rate	0.284**	0.294**	0.303***	0.241**
	(2.99)	(3.25)	(3.44)	(2.68)
Inflation	0.012	0.009	0.003	-0.015
	(1.13)	(1.05)	(0.32)	(-0.83)
Tariff rate	-0.030		-0.002	
	(-0.44)		(-0.26)	
Fuel exports (% of total)	0.119***	0.101***		
	(3.68)	(4.27)		
GDP growth	0.377***	0.366***	0.361***	0.362***
	(4.300	(4.97)	(4.48)	(5.35)
Ln GDP per capita	-2.179*	-2.353**	-1.669	-2.936***
	(-2.15)	(-2.90)	(-1.83)	(-3.63)
FDI (% of GDP)	0.045*	0.048**	0.045**	0.051**
	(2.43)	(2.88)	(2.70)	(2.83)
Ln population		-8.076**	-10.26**	
		(-3.13)	(-3.36)	
Constant	26.58**	153.00***	187.00***	32.35***
	(2.98)	(3.84)	(3.86)	(5.06)
Number of observations	1914	2197	2028	2441
Number of countries	136	144	145	146
Adjusted R^2	0.780	0.779	0.759	0.747
Country and time fixed effects	YES	YES	YES	YES
Robust standard errors	YES	YES	YES	YES

*** p<0.001, ** p<0.01, * p<0.05

Note: The t-statistics are between the brackets

Note: Trade openness is the dependent variable, internet use (t-1) is the independent variable, all other variables are used as controls.

Figure A2: Mobile phone subscriptions in the world between 1995 and 2019.



Source: World development indicators (2021).

Table A6: summary statistics of the variables of mobile phone subscriptions.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Mobile phone subscriptions	3774	57.518	52.160	0	328.790
Mobile phone subscriptions (t-1)	3609	55.129	51.426	0	321.452

Note: (t-1) means 1 year before period t.

Table A7: extended correlation matrix

1	**2**	**3**	**4**	**5**
Trade openness	Trade openness (t-1)	Internet use	Internet use (t-1)	School enrolment
6	**7**	**8**	**9**	**10**
Unemployment rate	Inflation	Tariff rate	Fuel export (% of total)	GDP growth
11	**12**	**13**	**14**	**15**
Ln real GDP per capita	FDI (% of GDP)	Ln population	Mobile phone subscriptions	Mobile phone subscriptions (t-1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14	0.345	0.355	0.789	0.777	0.516	-0.026	-0.111	-0.524	0.072	-0.168	0.618	0.117	-0.119	1.000	
15	0.338	0.348	0.811	0.802	0.508	-0.025	-0.109	-0.509	0.065	-0.197	0.610	0.113	-0.111	0.990	1.000