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Does the internet generate economic growth, international trade, or both?

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Abstract

Recent cross country panel data studies find a positive impact of internet use on economic growth and a positive impact of internet use on trade. The present study challenges the first finding by showing that internet use does not explain economic growth directly in a fully specified growth model. In particular openness to international trade variables seems to be highly correlated with internet use and the findings in the literature that internet use causes trade is confirmed here, suggesting that internet use impacts trade and that trade impacts economic growth. A simultaneous equations model confirms the positive and significant role of internet use to openness and the importance of openness to economic growth. Internet use has been shown to impact trade more in non-high income countries than in high income countries, whereas the impact of trade on economic growth is the same for both income groups.

JEL classification: C23, L86, F10, O40

Keywords: economic growth, internet, trade, panel

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I. Introduction

This paper is an empirical investigation on the relation between international trade, internet use and economic growth. Recent literature shows a positive and causal relation between internet use and international trade whereas other papers demonstrate a positive relation between internet use and economic growth. There is also a lively debate on the relation between international trade and economic growth and the mainstream finding in this debate concludes that trade positively impacts economic growth but particular results depend on econometric techniques, country sample, and time period. The main question addressed in this paper is whether internet use has a direct impact on economic growth or whether internet use impacts economic growth more indirectly through trade. Secondly the literature finds that internet use impacts international trade more in non-high income countries than in high income countries and we investigate this by employing the final empirical model as applied to the total sample of countries to high and on-high income countries separately.

The starting point is the literature on economic growth as pioneered by (Solow, 1956) and employed in empirical work by e.g. (Barro, 1991; Barro, 2003), (Quah, 1993; Quah, 1997), (Islam, 1995), (Bosworth and Collins, 2003) and many others. The next section elaborates on this by portraying a standard basic growth equation relating economic growth (as measured by the growth rate of per capita GDP) to per capita internet use and several control variables and allowing for long run growth rates to be country specific by including individual country intercepts. After a brief discussion of the data the first empirical analysis supports the initial view that economic growth is positively related to internet use as found by for instance (Choi and Hoon Yi, 2009). A more detailed analysis however shows that this conclusion has to be relaxed and that internet use does not seem to impact economic growth in a direct way. If standard control variables such as investment, government expenditure, rate of inflation and openness are included and also if time dummies are included to capture longitudinal variation, internet use does not seem to have a positive contribution to economic growth. Leaving out internet use re-establishes the traditional growth equation whereby, amongst others, openness as a measure of international connectedness of countries has a positive and significant impact on economic growth.

(Clarke and Wallsten, 2006), (Freund and Weinhold, 2004) and (Vemuri and Siddiqi, 2009) all study the impact of internet use on international trade and they all find a positive relation between internet use and trade, although not as strong for all regions. In the tradition of empirical trade models a gravity approach is employed using bilateral trade data.[1] So the natural question emerges whether internet use impacts economic growth or international trade and whether international trade impacts economic growth or internet use. Section 4 discusses a Granger causality analysis on this issue by using a VAR analysis on economic growth, international trade and internet use showing that internet use is Granger causing trade whereas per capita GDP does not and that the relation of internet use causing international trade is stronger than the other way around. This is somewhat relaxed by a similar analysis if time dummies are included but also here internet use is impacting trade more significantly than the other way around and international trade impacts economic growth more significantly than internet use. Combining the findings from the growth equation from section 3 and the Granger causality analysis suggest a direct relation between international trade and economic growth and a direct relation between internet use and international trade. Section 5 shows that indeed internet use has a positive impact on international trade as reported in the literature. The trade model includes amongst others the area size of countries which is fixed over time. This demands a model combining notions from a panel fixed effects model with time invariant variables. Three different approaches are investigated all leading to the same conclusion that internet use is positively affecting international trade. Finally, section 6 elaborates on this by suggesting a simultaneous equation model whereby both the growth rate of per capita GDP and openness, measured as imports plus exports as ratio of GDP, are explained. International trade is positively and significantly related to economic growth and internet use indeed appears to be positively and significantly related to openness. This leads to the suggestion that internet use is not impacting economic growth in a direct way but though international trade. (Clarke and Wallsten, 2006) and (Clarke, 2008) study the impact of internet use on international trade in developed and in developing countries and conclude that this effect is much more emphasized in developing countries than in developed countries. The second part of section 6 resembles their analysis by employing the simultaneous equation approach and finds that the impact of international trade on economic growth is not different at all between low and high income countries. However, that seems not

[1] (Clarke and Wallsten, 2006) employ a broad “quasi” bilateral trade setting by differentiating exports from countries to high income countries and to low income countries.

to be the case for the impact of internet use on international trade where we indeed find significant differences between high income and non-high income countries.

II. Economic Growth and internet use

The internet can be regarded as a truly general purpose technology and impacts society at various levels and in a vast range of activities ((Harris, 1998)).[2] Firms are able to communicate better, faster and at lower costs, reducing internal as well as external transaction costs and thus lowering production costs and enhancing productivity and generating economic growth. The internet facilitates the generation and spread of knowledge and new ideas tremendously which allows for an increased productivity of the research process and an increased diffusion of its products and outcomes. The internet also affects markets such as the labour market ((T. Ziesemer, 2002), (Stevenson, 2008)) and the product market ((Levin, 2011)) by reducing search costs and facilitating access to information. Conversely internet also impacts society in a less positive way as for instance online crime is spreading rapidly ((Moore et al., 2009)).

Models on endogenous growth theory focus on the importance of increasing returns, R&D activities, human capital, the generation and spread of new ideas, and the diffusion of new technologies in general on economic growth. ((Lucas, 1988; Romer, 1990; Aghion and Howitt, 1992)). In this context new communication technologies like the internet not only may reduce marginal costs of production processes but also may enhance the creation and spread of new ideas. This implies that the nature of the R&D process itself and the spread of the resulting knowledge has been changed by the use of new communication technologies like the internet ((Röller and Waverman, 2001; Czernich et al., 2011)). This suggests that the use of the internet not only induces temporary growth towards a higher level of the steady state, it also introduces the likelihood of permanent higher growth rates as the R&D process itself is affected. From that perspective it is highly relevant to test whether indeed internet use has an impact on the rate of economic growth. For this purpose we will include internet use in empirical growth models as to investigate its importance for economic growth.

[2] The term internet used here refers not only to the physical infrastructure but also to the applications running on top of this infrastructure such as world wide web, email, and file transfer.

Closely related to studying impacts of internet use on economic growth are studies on the impact of the broader concept of information and communication technologies (ICTs) on economic growth. In the latter domain many studies have indeed shown that ICTs have a positive impact on economic growth, on labour productivity growth and on total factor productivity growth ((Jorgenson et al., 2008; Ark et al., 2008; Oliner et al., 2008)). These studies are centred on growth accounting methodologies or on estimating extended production functions which all rely on stocks for ICT and non-ICT capital. In studying the impact of internet on economic growth this approach is less obvious since there are no measures of the stock of internet capital and, more important, internet as a general purpose technology is highly interconnected with many other activities such that a separation becomes less obvious but also less meaningful. The focus of this paper is on the impact of internet use and our approach is closely related to approaches in empirical endogenous growth models.

The economic growth model employed here stems from (Barro, 1991) who shows that the basic neoclassical model as proposed by e.g. (Solow, 1956) and (Koopmans, 1963) should be relaxed by introducing conditional convergence entailing that the growth rate of a country depends on its initial deviation of per capita GDP from its own steady state level and thus implying that poor countries will not grow faster per se but that the growth rate depends on the distance between the initial situation and its (individual) steady state level of per capita GDP. As new technologies are not readily available in all countries or cannot be employed to their full extent differences in technological adoption and in the knowledge base may also lead to different growth rates, even if there exist diminishing marginal returns from single factors of production like capital. So whereas the Solow model explains absolute convergence –all countries grow to a single steady state– (Barro, 1991) and (Barro and Sala-I-Martin, 1991) adopt the notion of conditional convergence where steady state growth levels may differ between countries and depend on the country's technological potentials. Both the Solow model as the model employed by Barro are based on exogenous technological change. As a variant of the AK-model, which is the most simple model explaining positive economic growth in a steady state, (Acemoglu and Ventura, 2002) develop a model that can explain convergence in growth rates by linking growth to international trade. This path will be further explored below.

Many studies in the realm of empirical economic growth models and those contributing to the discussion on economic convergence are based on the impact of new technologies, human capital and diffusion of knowledge on growth and convergence and most employ models where growth of GDP per capita is explained by various factors like savings, education, government intervention, and international trade as to differentiate between technological potentials of countries which define steady state growth levels and the dynamics towards steady states (see e.g. (Barro, 1991), (Barro, 2003), (Quah, 1993), and (Bosworth and Collins, 2003)).

The basic model employed here is in line with (Barro, 1991) and (Barro, 2003) postulating a generalized growth equation as:

$$\hat{y}_{i,t} = \alpha + \sum_{l} \bar{x}'_{i,t-l}\bar{\beta}^{(l)} + V_{i,t} \quad (1)$$

where $V_{i,t} = \mu_i + \nu_t + \varepsilon_{i,t}$ and where $\hat{y}_{i,t}$ denotes the growth rate of per capita GDP (y) of country i at time t and $\bar{x}_{i,t}$denotes a multidimensional vector of explanatory and control variables. $\bar{\beta}^{(l)}$denotes a vector of coefficients of which its elements are assumed to be identical for all countries but could have an individual dimension in a more general setup. Next to the remainder idiosyncratic disturbance term ($\varepsilon_{i,t}$), the error term $V_{i,t}$ may contain an individual effect (μ_i) and/or a time effect (ν_t) leading to a one-way or two-way error component model, respectively. The literature on empirical growth analysis listed above includes the lagged level of GDP per capita, investment as ratio to GDP, government expenditures as ratio to GDP, the level of inflation, openness, human capital variables, and life expectancy as explanatory variables. Lagged GDP per capita reflects the convergence hypotheses and is expected to have a negative sign as low income countries are expected to show higher growth rates and thus are expected to catch up relative to high income countries, ceteris paribus. Higher rates of investment (as ratio to GDP) are expected to have a positive impact on per capita GDP growth since a higher value of the investment ratio raises the steady state level of per capita output resulting into higher growth rates, at least in the short and medium run. Investment may also be seen as carrier of new technologies (the embodiment hypothesis) leading to increased economic growth. Government expenditures include amongst others non-productive expenditures that can distort private decisions and thus are expected to have a negative impact on per capita growth of GDP. The openness ratio as measured by imports plus exports as ratio of GDP is expected to catch the benefits coming from international trade. These benefits can have different sources as international trade may reflect that a country is being linked to and integrated in the international community and therefore having access to new knowledge and to new technologies. On the other hand openness indicates access to foreign markets and may increase market size (and therefore benefits from further specialisation). In the latter case one would expect that small countries may gain more from trade since trade may increase market size relative to the home market relative more substantial in small countries than in large countries with a larger home market. Higher levels of human capital are associated with more efficient production processes –higher steady state levels of per capita GDP– and the ability to adopt and use more advanced technologies and thus to have a positive impact on catching up. Enrolment rates into education have been studied in empirical growth models by e.g. (Krueger and Lindahl, 2001) and, albeit in a different setting by (Ranis et al., 2000), and show to have a positive and significant impact on economic growth. The inflation rate is added as a measure of macroeconomic stability and thus is expected to have a negative sign on per capita economic growth.

In order to determine the impact of internet use on economic growth next section implements equation (1) empirically using per capita internet use as additional variable. In most empirical implementations of growth equations fairly long time series are employed and in many cases averaged data are used to cancel out temporary effects and business cycles. Typical is to use averaged data over periods of five years and covering a time period from 1960 (or earlier) onwards. In order to analyse the impact of internet use on economic growth it is not straightforward to apply this strategy since data on internet use are for most countries only available from 1995 and onwards resulting in one or two data points for most countries if we would use five yearly averaged data. Using lags as instruments or including growth rates is nearly impossible in such case and this paper therefore employs yearly data covering a time period from 1990 onwards. This incorporates a risk that also cyclical effects enter the analysis but by using time dummies we try to cancel out influences of cycles at a global level.

III. Data and first estimation results

Data for initially 213 countries were collected from the World Bank 2010 database on World Development Indicators from 1990 until 2008 which also includes data from the International Telecommunication Union. Not all series are equally available for all countries and for the entire time period and the employed dataset includes 162 countries. This unbalanced dataset includes time series length varying between 1 to 18 data points per variable of a country. Table 1 summarizes the data and shows that the number of data points (N) varies considerable for different variables with an average series length between 14 and 19 data points. Most restrictive is data on internet use with an average time series length of 15 years where most missing data are observable in the early nineties.[3]

[Insert Table 1 about here]

In this table the overall statistics refer to the entire sample of N observations whereas the between statistics refer to the country averages. The within statistics are based on the deviations from the country averages but corrected for the overall average. If the between standard deviation and the within standard deviation are about equal, which is the case for e.g. gross fixed capital formation as percentage of GDP (investment ratio) the longitudinal variation per country is about the same as the cross section variation on country averages. In other words this implies that when drawing investment ratio data for two countries randomly from the dataset the difference between these data points is nearly equal to the difference when drawing two randomly selected years for the same country. The between and within variations for per capita internet use and for government final consumption ratio are also approximately equal. On the other hand per capita GDP and more obviously population and land area show small within variations as compared to between variations. Below we will come back to these differences of between and within variations.

The measure on internet use is defined here per capita and stems from the International Telecommunication Union (ITU) where a user is defined as a person that has accessed the internet in the last 12 month and which includes access through all devices. In many cases this number is based on household surveys but may also be based on estimates by ITU where no survey data are available. See e.g. (United Nations, 2011). Other studies employ the number of internet hosts (Clarke and Wallsten, 2006) or domain names (Freund and Weinhold, 2004) as proxy for internet use but that measure might be biased because one single host (i.e. a computer connected to the internet) might be used by more people. Earlier studies report estimates of 2.5 to 4 users per hosts, a number

[3] Initially also net barter terms of trade, life expectancy, fertility rates are employed but these variables did not yield satisfactory results and are not displayed in the table.

which might be higher in newly emerging countries such as those in Africa (International Telecommunication Union, 1997) and therefore biasing estimates for these countries.

Per capita internet use is on average 12% over the entire sample, ranging from 0% to 90%. The fact that within and between variations are not that different for per capita internet use does not consequentially mean that there is no path dependency. It highlights here that the variation of internet use over the years from 1990 until 2008 is about equal to the variation of the average use over countries. Countries with high proportions of internet users per capita (above 80%) in the second half of the 2000's are Denmark, Finland, Island, the Netherlands, Norway, and Sweden. In 32 countries the per capita internet use is below 5% in 2008 from which 23 are located in Sub-Saharan Africa and from which 19 countries belong to the group of low income countries, 12 are lower middle income countries and one is a high income country (Equatorial Guinea).[4] Figure 1 on the diffusion of internet users displays the number of countries for which the percentage of internet users has passed various thresholds. 19 countries report a percentage of internet users of strictly larger than zero in 1990 and this numbers grows very fast to 114 countries in 1995 and to 160 countries in 1999. Using higher thresholds shows that one country (Island) passed the 5% threshold in 1994 and 59 countries had passed this threshold six years later. In 2008 in 15 countries the number of internet users exceeded 75%. Worldwide per capita internet diffusion started at a low 0.05% in 1990 and increased towards 6.8% in 2000 and has reached almost the 25% level in 2008. The growth rate of the percentage of internet users is still increasing in 2008 implying that the (global) inflection point is not reached.[5]

[Insert Figure 1 about here]

Figure 2 depicts the relation between (the log of) per capita internet use and (the log of) per capita GDP for 162 countries in 2000 and in 2008. The fast diffusion of internet use becomes apparent by the upwards shift of the data points and which is highlighted by the linear regression lines applied to both years. In this log-linear relation the constant

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[4] These 32 countries are BGD, BEN, BFA, BDI, KHM, CMR, CAF, TCD, COG, CIV, DJI, GNQ, ETH, GHA, GIN, GNB, IND, LSO, MDG, MWI, MLI, MRT, MOZ, NPL, NIC, NER, PNG, RWA, SLE, SLB, TZA, and YEM.

[5] In 2010 the percentage of internet users has increased to 30.5% and the annual growth rate is still increasing.

term increased between 2000 and 2008 whereas the slope decreased. The latter suggests a decreasing income elasticity of internet use over time but may also reflect the S-shaped diffusion process where the first difference of the growth rate of per capita internet use is positive for countries which are in the early phases of the diffusion process and where it is negative for countries which are in the later phases of the diffusion process. A linear regression on the first difference of the growth rate of per capita internet users on the log of per capita GDP shows a positive slope until 2002 and a negative slope afterwards and indicates indeed that the growth rate of internet users has declined in high income countries relative to the growth rate of internet users in low income countries.[6] Figures 1 and 2 show that the diffusion of internet follows the traditional S-shaped diffusion curve and that there is a clear positive relation between internet users and per capita GDP. Before 2003 high income countries showed to have higher growth rates of per capita internet users than low income countries whereas that has been reversed in most recent years such that –on average– the absolute difference of per capita internet users between high income and low income countries has become smaller in most recent years. The relation between internet use and economic growth is less obvious as can be seen from Figure 3. Although a linear regression between GDP growth per capita and per capita internet use shows a positive and significant slope the graph clearly shows that such simple model is far from complete.[7] The main objective of this section is to investigate the impact of internet use on economic growth in a fully specified growth model.

[Insert Figure 2 about here]

[Insert Figure 3 about here]

In a related analysis (Choi and Hoon Yi, 2009) use an empirical growth model in which they employ per capita internet use, investment as ratio to GDP, government expenditure as ratio to GDP and the level of inflation as explanatory variables. Using the same dataset as we do but covering a time span from 1991 to 2000 they find a highly

[6] A regression of the first differences of the growth rate of per capita internet users on the log of per capita GDP indeed shows a positive and significant slope in 1994, 1995, 1996, 1997, 1998 and in 2002 and a negative and significant slope in 2003 and 2005 (and non-significant in the other years between 1992 and 2008).

[7] Regressing the growth rate of per capita GDP on per capita internet use shows a slope of 0.015 with an standard error of 0.005 ($p<1\%$).

positive and significant effect of internet use on economic growth. Using the same time period and using the same variables the results of (Choi and Hoon Yi, 2009) can be reproduced fairly well. Table 2, model (a) resembles their OLS results but now using the extended time span and adding lagged per capita GDP, openness and schooling enrolment as additional variables.[8] The investment ratio has a positive and significant impact on economic growth and both inflation and government expenditure ratio are significant and have a negative impact, all as expected. Lagged per capita GDP is significant and negative suggesting that countries with lower initial per capita GDP grow faster such that on average there is convergence. Secondary school enrolment rates and openness to international trade are also positive and significant.[9] Per capita internet use is significant and positive as also reported by (Choi and Hoon Yi, 2009). So from model (a) in Table 2 one would learn that internet use has a significant and positive contribution to economic growth additional to the impact of other variables that are included. Including time dummies to capture global movements in economic growth and thus to control for longitudinal variation dramatically changes the picture of the relation between per capita internet use and economic growth and the coefficient on per capita internet use becomes insignificant whereas the order of magnitude and the significance of all other explanatory variables remain unchanged (see model b in Table 2). A Wald test on joint significance of time dummies clearly rejects the null that the coefficients are jointly equal to zero (last row in Table 2). From Table 1 the within standard deviation of per capita internet use is slightly higher than the between standard deviation although the difference between these standard deviations is not very substantial implying that the longitudinal variation is comparable in size with the cross-section variation. Compared to internet use the figures on inflation show a more considerable difference where the within standard deviation is much larger than the between standard deviation. Nonetheless this difference the coefficient on inflation remains stable when introducing time dummies whereas the coefficient of internet use becomes highly insignificant when comparing models (a) and (b).

[8] Next to the variable indicated here also life expectancy at birth, fertility rate and some institutional factors such as corruption index and rules of law were initially included but did not give significant results.

[9] To check for multicollinearity problems initially all independent variables are regressed on all (remaining) independent variables in a fixed effects model and no adjusted r-squared proved to exceed 0.9.

The panel structure of the dataset allows for random and fixed effects estimation and the Sargan-Hansen test as well as the Hausman test show that the fixed effects model has to be preferred. In models (c) to (e) the random effects variant of the panel model is firmly rejected indicating that the disturbance terms are correlated with country effects. [10] Model (c) is comparable to (Choi and Hoon Yi, 2009) but includes the same additional explanatory variables as before but also here excludes time dummies. Even in this case the coefficient of per capita internet use of the growth rate of per capita GDP becomes insignificant. So a fixed effects model that captures country specific effects by country dummies but without using time dummies cannot reject the hypothesis that internet use does not impact economic growth. This again contradicts the findings of (Choi and Hoon Yi, 2009). Model (d) includes time dummies which are jointly significant different from zero. The fixed effect estimate in (c) and (d) suggest a larger negative value of the lagged per capita GDP, so indicating a stronger convergence, and also the effect of trade on GDP growth is increased and highly significant whereas the effect of education has become insignificant different from zero if time dummies are included in model (d). As before the per capita internet variable remains insignificant. Both models show some autocorrelation as reported in the last but one row of Table 2.[11]

[Insert Table 2 about here]

Extending the analysis by allowing for two-year lagged per capita GDP to capture higher order dynamic effects does not change these conclusions as reported by model (e). The long-run coefficient of lagged per capita GDP remains negative, significant, and of the same order of magnitude. Also all other independent variables remain significant and of the same order of magnitude. Per capita internet use remains insignificant suggesting

[10] The robust test on overidentifying restrictions as proposed by (Wooldridge, 2002) p 190-191 is displayed as Sargan-Hansen Chi-squared statistics including the corresponding p-value and shows that fixed effects are never redundant and is to be preferred over the random effects model. In all cases the standard Hausman tests on non-robust estimates of the equivalent models maintain the same conclusions (not shown in tables).

[11] Autocorrelation is computed using the test for serial correlation in panel data as described by (Wooldridge, 2002) and (Drukker, 2003).

that indeed internet use is not contributing to economic growth in this extended but still simple model. Note that the autocorrelation remains in model (e), however.[12]

The above suggests that using a fixed effects model and including standard control variables as found in the empirical growth literature there is no significant impact of internet use on economic growth. Also when including time dummies more to control for longitudinal variation the positive impact of internet use on economic growth as found by (Choi and Hoon Yi, 2009) –and as replicated as model (a) in Table 2– vanishes.[13]

Since the model basically includes a lagged dependent variable and thus is subject to the Nickell bias (see (Nickell, 1981)) and suffers from some autocorrelation even in the case where one and two year lagged dependent variables are used, the model is re-estimated by using GMM techniques. Model (f) in Table 2 shows the results of system GMM estimations using two and three year lagged variables as GMM instruments ((Blundell and Bond, 1998)). The system GMM approach estimates the equation in levels as well as in first differences simultaneously and accounts, amongst others, for first order serial correlation. See (Bond et al., 2001) for a system GMM approach on growth models including a discussion of its properties. Main concerns in GMM estimation are related to validity of instruments and to over-identification of the model. The choice of instruments is determined analogous to (Roodman, 2009a) and (Roodman, 2009b) by keeping the number of instruments below the number of countries, by not rejecting the validity of instruments but not too strong (Hansen J-statistic roughly between 5% and 25%), and by assuring validity of GMM instruments in the level equations and of IV instruments. The latter refers to the time dummies only. The resulting coefficients of one and two year lagged per capita GDP and the combined long-run coefficient –so adding up the short run effects– is in model (f) between the required upper and lower bounds as resulted from the OLS and FE estimates, respectively. This reassures the validity of using the system GMM technique and the number of instruments employed. Internet use remains insignificant in model (f) and seems to confirm the belief that internet use is not

[12] A Newey-West estimate of model (d) using STATA's newey2 command shows standard errors which are all slightly below the ones as reported in the table such that both internet use and schooling become significant at 10% level.

[13] To check for non-linear effects a combined logs, lags and squares analysis on internet use in model (c) does not improve the results and does not change this conclusion.

directly impacting economic growth in a fully specified growth model. Compared to the fixed effects estimations in models (c) to (e) lagged per capita GDP is strongly reduced and closer to the OLS results as reported in models (a) and (b). All other coefficients are significant and are of the same order of magnitude. The impact of openness to international trade is in the GMM model closer to the fixed effects results in model (e) than to the OLS results in models (a) and (b).

These findings imply that per capita internet use does not have a positive impact on economic growth. This strongly contrasts the findings of (Choi and Hoon Yi, 2009) who report a positive and significant impact of internet use on economic growth. Using an extended version of their model by including standard explanatory variables as found in the empirical growth literature (e.g. (Barro, 1991) and (Barro, 2003)) internet use disappears as a significant factor. The model is consistent with the findings in the literature that the growth rate of per capita GDP depends negatively on lagged per capita GDP, negatively on both government expenditure and inflation and positively on the investment ratio, on openness and on education. From this we can conclude that internet use does not impact economic growth, at least not in a direct way.

From the above we can conclude that international trade, here measured by the openness ratio, has a positive impact on economic growth. (Clarke and Wallsten, 2006), (Freund and Weinhold, 2004) and (Vemuri and Siddiqi, 2009) all study international trade and internet use in gravity based models and they all find a positive and causal relation between internet use and trade. Since we find a strong and positive relation between international trade and economic growth, this naturally leads to the question whether internet use leads to trade or the other way around and how both affect economic growth. Before turning to a trade equation including internet use next section discusses the results of a panel Granger causality analysis on internet use, International trade, and economic growth.

IV. Granger causality on openness, internet use and growth

The above analysis suggests that international trade (openness) has a positive impact on economic growth and that the impact of internet use on economic growth disappears in one way and in two way fixed effects models whereas openness remains significant in all cases. The literature on the relation between trade and internet use suggests a positive and causal relation running from internet use to openness. To further develop an understanding of the interrelationship between economic growth, international trade and internet use a Granger causality test is employed in this section. Starting point is a standard VAR representation:

$$y_{i,t} = \sum_{l=1}^{L_{\gamma}} \gamma^{(l)}\, y_{i,t-l} + \sum_{l=1}^{L_{\beta}} \beta^{(l)}\, x_{i,t-l} + V_{i,t} \tag{2}$$

where $V_{i,t} = \alpha_i + \varepsilon_{i,t}$, where $\varepsilon_{i,t}$ are i.i.d $(0, \sigma^2)$ and where $x_{i,t}$ denotes a vector of explanatory variables and where the lag length (L_x) can vary for each right hand side variable. This equation is estimated using a fixed effects model for all three relevant variables namely the log of per capita GDP, per capita internet use and openness ratio.[14] To determine the number of lags in equation (2) the following procedure is adopted (cf. (Greene, 2002), pp. 589). The model is estimated several times using different lag lengths for the lagged dependent variable and for each explanatory variable. The model that minimized the Akaike information criterion (AIC) is selected as the best performing model.[15] Some experiments showed that using lags between 1 and 4 years where sufficient to determine the optimal lag structure as the AIC increased rapidly in the case of lag lengths of 3 and 4 years. The model is thus estimated 12 times –all possible combinations of lag lengths up to 4 years for each of the 3 variables– and the left upper panel in Table 3 reports the F-statistics and the p-values along with the number of lags of the three equations in a fixed effects model without time dummies.

[Insert Table 3 about here]

In all cases the lagged dependent variable is highly significant different from zero. The left upper panel also suggests that per capita internet use is Granger causing openness ratio (first row) and that the reverse has to be rejected (second row). Per capita GDP is causing per capita internet use (second row) and also here the reverse has to be rejected (third row). Finally openness ratio causes per capita GDP (third row) and per capita GDP is not causing openness ratio. The upper left panel therefore clearly indicates the

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[14] Initially also country specific slope coefficients were allowed along the lines pointed out by (Hoffmann et al., 2005). The results firmly reject openness Granger causing internet use and cannot reject internet use Granger causing trade at the 1% level. Since country specific slope coefficients are not employed below, this finding is left for further research.

[15] Minimizing the Bayesian information criterion (BIC) resulted in exactly the same lag structures.

directions of causality where internet use is causing openness, openness is causing per capita GDP, and per capita GDP is causing internet use. Including time dummies –which are jointly significant at 1%-level in all cases– as to capture longitudinal variation changed the analysis in the previous section dramatically. The lower left panel reports the Granger causality test when time dummies are included. In a first step also here the most optimal lag lengths is determined using the AIC criterion and also here the BIC pointed to the same optimal structure. The resulting optimal lag length per independent variable is identical to the model without time dummies. The results change somewhat as internet use is not highly significant in explaining openness (p-value of 8.6%) but the reverse that openness is explaining internet use is even far less significant. So if there is a relation between per capita internet use and openness ratio then internet use is more likely causing openness than the other way around. The third row in the lower left panel of Table 3 suggests that all variables are impacting per capita GDP disallowing to attain causality conclusions. So the inclusion of time dummies changes the significance of the causality relations somewhat and thus weakening the main conclusions, but certainly not reversing them such that overall conclusion that internet use is causing openness and that openness is causing economic growth persists.

As the three equations used in this analysis might not be independent from each other in the sense that the error terms might be correlated, the same analysis is redone using Zellner's seemingly unrelated regression technique (SUR). The right panels in Table 3 report the same analysis but now based on a SUR estimate. Also here in a first step the optimal lag structure is determined by estimating the model using lags between one and three years in all possible variants and selecting the optimal lag structure by minimizing the AIC.[16] The model without time dummies as reported in the upper right panel of Table 3 shows much lower variation for all coefficients. The same causal relation is found as indicated by the upper left panel of Table 3 but at much lower thresholds of p-values. To some extent this holds also true if time dummies are included and the lower right panel in Table 3 resembles the results as found before and indicates that internet use is more likely to cause openness than the other way around.[17]

[16] Also here minimizing BIC leads to the same optimal lag structure.

[17] The non-reported Breusch-Pagan test on the null of independent equations indicates with p-values of 0.0000 and 0.0077 for the upper right and lower right model, respectively, that the equations are not independent and that the SUR results are to be preferred.

Summarizing the standard Granger causality analysis the above indicates that internet use is causing international openness and that both openness and internet use cause per Capita GDP. In the latter relationship the coefficient on openness appears to have a higher level of significance than the coefficient on internet use. Combined with the previous conclusion that in a fully specified growth equation current internet use is not significantly impacting economic growth whereas openness to international trade does, the general view emerges that internet might impacting growth through international trade and that it does not have a direct impact on economic growth. To investigate this further next section reports on the relation between internet use and international trade.

V. Internet use and international trade

The results presented so far suggest that internet use is not directly impacting economic growth but possibly indirectly via trade. This section elaborates on this by showing that internet use indeed is positively related to openness, if corrected for many factors such as per capita GDP, area size and population size.

From a theoretical perspective (Fink et al., 2005), (Harris, 1998) and (J. E. Anderson and van Wincoop, 2004) all elaborate on the notion that using the internet for data transfer and communication lowers transaction costs in lowering both fixed and variable costs but also in improving the quality of communication, both stimulating trade and specialisation. As long internet use is growing these costs are decreasing which increases international trade and thus we expect a positive relation between internet use and international trade and we also expect that this effect is larger for smaller countries because of expected decreasing marginal returns to market size. (Grossman and Rossi-Hansberg, 2008) elaborate on the notion that the internet, mobile telephony and technologies such as teleconferencing have dramatically decreased the cost of offshoring and thereby increased the trade in intermediate products and services, called “trade in tasks” as they refer to. They show that these costs reductions and increased trade in tasks have effects that are similar to factor augmenting technological progress. The impact of ICT in general and that of internet use in particular on international trade has been studied empirically by e.g. (Freund and Weinhold, 2004), (Clarke and Wallsten, 2006), (Clarke, 2008), and (Vemuri and Siddiqi, 2009). Employing bilateral trade data in most cases international trade is explained by internet use and many control variables, most based on gravity models including distance between countries, both country’s

GDP, and extended with income per capita and sometimes other measures like institutional quality, trade barriers and dummies for oil exporting countries. Distance is found to be negatively related to bilateral trade whereas the economic masses have a positive impact (e.g. (Freund and Weinhold, 2004)). Internet use is shown to have a positive impact on bilateral trade also if the endogeneity is investigated by employing institutional based instrumental variables thereby controlling for the possibility that a positive relation between trade and internet use is caused by the fact that a part of trade statistics includes trade in ICT equipment and ICT services which could cause for illegitimate conclusions (c.f. (Clarke and Wallsten, 2006)). Here we employ openness to international trade which measures country's total imports plus exports as ratio of GDP and not bilateral trade data because the purpose of this paper is to investigate the connection between internet use, international trade and economic growth and not so much between internet use and trade only. This also comes close to (Clarke and Wallsten, 2006) since they use quasi bilateral trade data by distinguishing trade within and between low and high income groups of countries and thus not employ country-to-country bilateral data as the other studies do. Openness is explained by internet use and control variables which include per capita GDP, area, area squared and population. Initial experiments with net barter terms of trade did not give significant results and are not included here. Per capita GDP indicates productivity and wealth and is expected to have a positive sign. Both area and population are indicators of country size. Small countries are likely to trade more since their internal market is small and the likelihood of having natural resources is reduced thus we expect a negative sign for area and for size of population. The squared value of area is included to account for a non-linear specification and the relation appears to be U-shaped in most cases. The model includes area and area squared which are both time invariant.[18] This obviously interferes with a fixed effects approach since a within estimator would sweep out the time invariant variables. In the literature two closely related approaches are employed in such cases. The Hausman-Taylor model ((Hausman and Taylor, 1981)) and the approach based on (Mundlak, 1978), both being actually developed to overcome endogeneity problems due to unobserved individual effects. Hausman and Taylor split the set of explanatory variables in endogenous and exogenous variables indicating that endogenous variables

[18] As reported in the description of the data the statistics on area and not exactly time invariant as there are some very minor changes for a very limited number of countries. To allow for the Hausman-Taylor analysis what follows in this section these minor changes are averaged out.

are country specific and thus correlated with the individual effect μ_i, cf. equation (1). An instrumental variable model is used to get around the time invariant endogeneity problem by using the time variant variables twice namely as averages and as differences from these averages. Here the Hausman-Taylor approach is employed next to a model where the time variant variables are split into group averages and differences from these averages. The latter model is then estimated both by OLS and a random effects model. Finally a system GMM approach is used since that approach uses simultaneously both a first differenced equation and a level equation without individual fixed effects. Although the time invariant variables sweep out in the first differenced equation the level equation still allows for identification of time invariant variables.[19] As before time dummies are included and tested on joint significance using a standard Wald test. This leads to four model variants, two in which the data are split into group averages and within differences, one employing the Hausman-Taylor approach, and one employing a system GMM technique.

[Insert Table 4 about here]

In all four cases the impact of internet use on openness is positive and significant as reported in Table 4. Especially the coefficient of the within difference of internet use in the random effects model (model (b)) is consistent in both size and precision with the Hausman-Taylor (c) and GMM estimate (d). The coefficient on group averages seems high as is the standard error. From Table 1 we have learned that the within variation of per capita internet use is larger than the between variation suggesting that indeed Hausman-Taylor and GMM estimates are more influenced by within differences of internet use than by between country differences. The impact of per capita GDP on openness is less strong having only a significant coefficient in the OLS and GMM estimates where the GMM coefficient is more close to the group average estimate than to the within difference coefficient. Contrary to per capita internet use the between variation in per capita GDP is much larger than the within variation (cf. Table 1) and the results suggest that the estimate on the impact of per capita GDP on openness ratio is more driven by between differences than by within differences. In summary the results clearly suggest that both per capita internet use and per capita GDP are positively related to openness. Finally, larger countries both in area as in population size trade less

[19] In the system GMM approach the current and lagged values of the number of telephones lines and the number of mobile phone users, both per capita, are used as additional instruments.

than smaller countries but this is (partly) offset by the positive squared term of area leading to an U-shaped relation between trade and area.[20]

The results obtained by employing the system GMM estimator confirms the other results after using sufficient but not too many lags as instruments as to keep various statistics within their boundaries as before. Following (Clarke and Wallsten, 2006), (Clarke, 2008), and (Czernich et al., 2011) internet use as explanatory variable might be endogenous in the trade equation which should be accounted for. The GMM model presented here also includes the number of telephone lines per capita and the number of mobile subscribers per capita as additional instruments to capture possible endogeneity of internet use. Leaving out the number of telephone lines per capita and the relative number of mobile subscribers does not change the results significantly and leads to the same qualitative conclusions, however.

The results presented here confirm the view as reported in the literature and demonstrate a positive and significant impact of internet use on international trade. The previous finding in the Granger causality analysis that indeed internet use is impacting economic growth through international trade is thereby reinforced. As both relations might interact such that residuals are correlated and might bias this conclusion a simultaneous equation model approach can be employed. Next section elaborates on this and confirms by using 3SLS simultaneous model approaches that indeed internet use is impacting trade and that trade is impacting economic growth.

VI. Simultaneous Equation Model

The analysis so far suggests that openness is positive and significant in explaining economic growth and that internet use explains openness to international trade. Both findings call for a simultaneous equation model by combining both relations as to take possible correlation between the residuals into account. Various approaches can be followed and we explored a seemingly unrelated regression (SUR), a two stage least squares (2SLS) and a three stage least squares (3SLS) approach where the models may contain a level equation only or a combined level and first difference equation mimicking the system GMM estimation as presented above though being based on a

[20] Simulation using the obtained coefficients on area and using actual area size distribution indeed shows a U-shaped relation where the effect is larger for very small as well as for very large countries.

3SLS variance-covariance estimate and leaving aside the dynamic instruments which are typical for GMM techniques.[21] The SUR takes only the correlation between the error terms of both equations into account and models with and without time and country dummies are explored. In all SUR estimates both dummies appeared to be each jointly significant in the growth equation and not significant in the trade equation. The SUR results are highly comparable with the results presented as model (c) in Table 2 and model (a) in Table 4 and are not displayed. Here we focus on the 3SLS results combining the model specification of the economic growth equation from Table 2 with the model specification of the trade equation from Table 4 into a simultaneous equation model. This also implies that the trade equation is modelled in two different ways. One in which the data on internet use and on per capita GDP are split into group averages and within differences and one in which the original data are used. As before the inclusion of time invariant variables such as area does not allow for country dummies or a fixed effects approach in the trade equation but this limitation is compensated by estimating the model both in levels and in first differences for the two equations simultaneously. This not only comes close to a system GMM approach but also allows for a (semi-) fixed effect approach in the trade equation where the time invariant variables are excluded in the first difference equation. In this section we estimate four equations simultaneously namely the growth equation in levels, the growth equation in first differences, the trade equation in levels and the trade equation in first differences where an additional restriction is imposed that the estimated coefficients of the first difference equations are equal to the coefficients of the corresponding level equations.

Since the growth equation is estimated both in levels and in first differences the dependent variable in the level equation is the log of the level of per capita GDP and not the growth rate of per capita GDP as before. This, however, does not fundamentally change the model since the lagged dependent variable is included in both cases. As instruments one-year lags are included for all independent variables and for the trade equation we initially also included the number of fixed telephone lines per 100 inhabitants and the number of mobile subscriptions per 100 inhabitants as additional instrument for internet use. These additional instruments did not change the results however and are not included in the tables displayed here. Table 5 presents the results where models (a) and (b) employ the group averages and within differences in the trade

[21] See (T. H. W. Ziesemer, 2011) for a simultaneous equation system GMM approach.

equation and where models (c) and (d) use the non-transformed data. The presented coefficient on the lagged dependent variable in the growth equation is redefined to make it fully comparable to the results presented before where the growth of per capita GDP was employed as explanatory variable. In a first stage the economic growth equation is equipped with both time dummies and country dummies and the trade equation with time dummies. In all models and various versions thereof the time dummies and country dummies are each jointly significantly different from zero in the growth equation whereas the time dummies are highly insignificant in the trade equation and the latter are excluded from the models presented here. Also in a first stage internet use is included in the growth equation using lagged terms as instruments but internet use proved to be highly insignificant in all cases and is not included in the growth equation in the table.

[Insert Table 5 about here]

Models (a) and (c) in Table 5 display the results for the full sample of countries and the models are comparable to the models presented in tables 2 and 4 above. The coefficient of the lagged per capita of GDP is similar to the fixed effects results as reported in Table 2, model (d) but stronger negative as compared to Table 2, model (e), implying that the convergence effect is stronger.[22] The coefficients on the investment ratio, inflation and openness are also slightly stronger compared to earlier results. Partly this can be explained by the stronger negative estimate of lagged per capita GDP since that leads to smaller long-run effects of other independent variables, ceteris paribus. To compensate for this effect, the coefficients of the remaining variables have to be more sizeable. The results of the trade equation in model (a) are more comparable to the previous results. The effect of the group averages of per capita internet use on the openness ratio is now slightly reduced but still significantly different from zero and the impact of the group average of per capita GDP is reduced and has become insignificant. The impact of the within difference of internet use on openness is comparable to the random effects results in Table 4 but smaller than the OLS results in that table. This reinforces the believe that this effect is overestimated in the OLS results. The coefficients of area, area squared and the population size are nearly the same as before. Note that the first difference model of the trade equation only contains the first differences of the within

[22] Estimating the model with SUR and with 2SLS leads to the same order of magnitude.

differences and that these are also the only instrumented variables. Model (c) presents the results of a comparable model but now the non-transformed data on internet use and per capita GDP are employed in the trade equation.[23] The models are also here estimated simultaneously as level equations and in first differences where the first differences equation does not contain time invariant variables. The coefficients of the growth equation in model (c) are highly comparable with those obtained in model (a) except for the impact of inflation on economic growth which is stronger in model (c). In the trade equation the coefficients of land area and population size are the same as in model (a) and the same as found before.

The results of the trade equation are displayed in the bottom panel of Table 5. The model is being estimated using lagged explanatory variables as instruments and initially also some additional instruments to capture endogeneity of internet use. Current and lagged values of the number of telephone lines per capita and the number of mobile cellular subscriptions per capita are added as additional instruments, both as deviation from their respective group averages in line with the within difference of internet use. Including these additional instruments did not change the results and the table here reports the results without these additional instruments. The impact of internet use on openness ratio is less strong in model (a) as compared to models (a) and (b) in Table 4 whereas the impact of per capita GDP has become insignificant. The coefficients of the non-transformed data are in between the coefficients of the transformed data as expected and here the coefficient of internet use is stronger compared to Table 4. Note that the time dummies are jointly insignificant in the trade equation in Table 5 and are excluded whereas they are included (and jointly significant) in models (c) and (d) in Table 4. This might affect the impact of internet use on trade and a brief analysis shows that it actually does. If time dummies are included in the trade equation the coefficient of the group average of per capita internet use is not affected nor its precision. However, the coefficient on the within difference is reduced from 0.125 to 0.088 whereas the standard error remains (about) the same such that the p value is increased above 10%. In the non-transformed estimate as reported by model (c) the inclusion of time dummies in the trade equation decreased the coefficient from 0.386 to 0.296 which remains significant at the 1% level as before. This implies that the inclusion of time

[23] The model is also estimated using mobile phone per capita and number of fixed telephone lines per capita as instruments for internet use (instead of lagged internet use) and the results where the same and not reported here.

dummies in the trade equation decreases the coefficient of per capita internet use on openness but that its remains highly significant in the non-transformed model. In the model employing transformed data this effect is of course entirely attributed to the within difference but the coefficient on the group average variable remains highly significant. Note that although the estimation results do not show dramatic changes in the results, the Breusch-Pagan test on independence of each equation is firmly rejected in all cases implying that the simultaneous equation approach has to be preferred above single equation models thereby increasing the efficiency and using all information available.

The results of the combined growth and openness equations in a 3SLS framework confirm the suggestion that internet use is positively impacting openness and that openness is positively impacting economic growth. By splitting per capita GDP and per capita internet use into group averages and deviations from these group averages it is possible to estimate group specific effects combined with area and area squared as time invariant variables in a 3SLS framework. Coefficients related to group averages of per capita internet use seem stronger than coefficients on the within group differences. This might suggest that the specification ignores some dynamic effects but also leaves the possibility that global increases in international trade and increases in internet use coincide and that the correlations are partly spurious. The significance of the within difference of internet use on openness however suggests that there is a causal relation between internet use and international trade. These findings are consistent with the findings of (Freund and Weinhold, 2004) and of (Clarke and Wallsten, 2006) and also here we employ a 3SLS approach as to capture possible endogeneity issues and correlation between the error terms of both equations.

From these results we can conclude that the growth model and the trade model are interrelated and that and the simultaneous equation approach seems to amplify the coefficients related to the growth equation and also increases the impact of internet use on trade. The direct impact of internet use on economic growth is highly insignificant and not reported in the tables.[24] To illustrate the impact of internet use on trade and consequently on economic growth we employ the results obtained from model (c). If

[24] For instance in adding internet use to the growth equation of model (c) in Table 5 yields a coefficient for internet use of -0.002 (0.014) with a p-value of 0.88, so highly insignificant which again confirms the belief that internet use is not directly impacting economic growth because otherwise 3SLS would have improved the efficiency.

internet use is increased by 10 percentage points, the openness ratio will, according to this model, increase by 3.9 percentage points which again leads to an increase of per capita GDP growth by 0.17 percentage points. This is the same as measured by the direct effect of internet use on economic growth in Table 2, model (a) and as found by (Choi and Hoon Yi, 2009) but the above analysis shows that the impact of internet use on economic growth is not a direct one but runs through international trade.

Difference between high and non-high income countries

(Clarke and Wallsten, 2006) and (Clarke, 2008) investigate the impact of internet on trade in developed and developing countries and conclude that internet improves export performance in developing countries but not in developed countries. (Clarke and Wallsten, 2006) argue that this finding is intuitive first because internet access and internet use is very common among enterprises in high-income countries and that differences in internet use is more related to the consumers behaviour than to enterprises, and second that internet access is less common in developing countries and being connected to the internet gives enterprises in developing countries a greater (relative) advantage. To further investigate the differences between developed and developing countries in the relation to internet use, trade and economic growth we have split the sample in high income and non-high income countries and have re-estimated the model as presented above.[25] Models (b) and (d) in Table 5 show the results of that analysis where, as before, a 3SLS approach is used employing both level equations and first differences. The models can be estimated for the two subsets of countries but also in one model by pre-multiplying all independent variables by dummies for the group of high income and non-high income countries. Both results are statistically the same and here we report the dummy approach as to determine the significance of the difference in coefficients between the income groups.

Focusing first on the growth equation in the top panel of Table 5 the results of model (b) are highly comparable model (d) and for most coefficients there is no significant difference between high income and non-high income countries as reported by the p-values of the null hypothesis that both coefficients are equal. The only exception is the impact of the government expenditure ratio on per capita GDP growth which is stronger

[25] The group of high income countries are the 47 countries listed below Table 1. The group of non-high income countries comprise low income, lower middle income and upper middle income countries.

in high income countries. (Barro, 2003) distinguishes high income and non-high countries in his analysis on the determinants of economic growth using a 3SLS approach but using decennial data covering the period 1965 to 1995. He finds that the for non-high income countries the convergence effect is less strong, that the impact of investment is less strong and that the impact of inflation is less strong. Stronger effects for non-high income countries are government expenditure ratio, openness ratio and school enrolment. Except for the government expenditure ratio where we find a less strong effect for non-high income countries we find similar differences. Barro finds that only the coefficient on the inverse of life expectancy is significantly different between non-high income and high income countries, a variable that is not included in our analysis since life expectancy did not turn out to be significant in our overall analysis. The significant difference for government expenditure was not found by Barro.

In the trade equation the results differ more between high income and non-high countries and most tests using the null that both coefficients are equal are rejected at a 5% level. The left panel at the bottom of Table 5 shows that the coefficient on the group average of internet use is much higher for non-high income countries than for high income countries and that the difference is highly significant. This seems to be comparable to the findings of (Clarke and Wallsten, 2006) who use the number of internet hosts per 100 inhabitants as explanatory variable and exports as share of GDP as dependent variable in a 2SLS analysis but who also find that the coefficient on internet hosts is insignificant for high income countries and positive and strongly significant for non-high income countries. Considering the analysis on non-transformed data in the right panel at the bottom of Table 5 this conclusion becomes more subtle. Internet use is positive and significant for both income groups but larger for non-high income countries and the difference between high income and non-high countries is still significant at a 5% level. The effect of per capita GDP on openness is positive and significant for high income countries in our analysis whereas it is not significant in the non-transformed analysis and even negative and significant for the group average estimate for non-high income countries. A positive coefficient of per capita GDP on the openness ratio suggests that higher per capita income will lead to more trade. The negative coefficient for the group average for non-high income countries suggests that this is not true for these countries on average. However, since the coefficient of the within difference of per capita GDP for non-high income countries is positive and significant the perception emerges that in comparing countries in the group of non-high income countries a higher income decreases trade whereas within these countries the longitudinal effect indicates that higher per capita GDP increases trade. The results for the non-transformed data in the right panel at the bottom of Table 5 show that the effect of per capita GDP on trade is insignificant for non-high income countries. Finally the coefficients of high income and non-high income countries concerning the impact of area, area squared and population size are highly comparable between the left and right panels. Remarkable are the differences between the income groups and the impact of area and of population size on openness ratio much more pronounced in high income countries. The physical size of countries seems to be much more important for trade in high income countries than in non-high income countries. This suggests that market size is much more important for smaller high income countries than it is for smaller non-high income countries which can be related to the importance of specialisation in high income countries. (Clarke and Wallsten, 2006) find similar results on area whereas their coefficient on population size is not significant.

Comparing the (first round) measured impact of internet use on economic growth through trade for high and non-high income countries we find that a 10%-point increase in internet use leads to 3.12%-point increase in openness ration in high income countries and a 5.3%-point increase in non-high income countries. Translated into economic growth this leads to an increase of 0.15%-point in high income countries and 0.27%-point increase in non-high income countries. The impact of an increase of internet use on economic growth through international trade is thus much more emphasized in non-high income countries than it is in high income countries. As suggested by (Clarke and Wallsten, 2006) this might be caused by relative high internet penetration in high income countries where most firms will use the internet somehow or other such that the impact of even further growth is limited whereas higher internet penetration rates gives competitive advantage for non-high income countries.

VII. Conclusions

This paper challenges the findings that internet use has a direct and positive impact on economic growth if measured in an empirical economic growth model and applied on a large panel of countries. Initially the positive impact of internet use on growth is confirmed but by using a fully specified growth model the positive significant impact of internet use on growth disappears. Also if taking account for longitudinal variation by including time dummies the conclusion is weakened or even reversed. Accounting for dynamic effects by employing a system GMM approach confirms these findings. International trade is however impacting economic growth in all models and the literature gives theoretical arguments and provides empirical support that higher internet penetration leads to more international trade. A Granger causality analysis between internet use, international trade and per capita GDP does not lead to strong conclusions in all cases. Estimated without time dummies internet use impacts international trade significantly stronger than the other way around but this seems less strong but still positive when using times dummies. The relation between international trade, per capita GDP and internet use is further investigated by explaining trade by internet use and a set of control variables. The finding of the literature of a positive impact of internet use on international trade is firmly confirmed here. Since some explanatory variables are time invariant a quasi-fixed effects model is employed here, next to a more standard Hausman-Taylor approach. So international trade seems to impact economic growth and internet use in turn seems to impact international trade. Finally both findings are combined by employing a 3SLS simultaneous equation approach which confirms these findings.

Based on the entire sample a 10 percentage points increase of per capita internet is estimated to lead to a 3.9 percentage points increase of the openness ration which in turn will lead to a 0.17 percentage points increase of economic growth. We also distinguish between low and high income countries and find no differences in the economic growth equation for these two groups of countries. The differences between low and high income countries is substantial in the trade equation where the impact of internet use for non-high income countries is much higher than it is for high income countries. Comparing the (first round) measured impact of internet use on economic growth through trade for high and non-high income countries we find that a 10 percentage points increase in internet use leads to 3.12 percentage points increase in openness ration in high income countries and a 5.3 percentage points increase in non-high income countries. Translated into economic growth this leads to an increase of 0.15 percentage points in high income countries and 0.27 percentage points increase in non-high income countries. The impact of an increase of internet use on economic growth through international trade is thus much more emphasized in non-high income countries than it is in high income countries. So the ultimate impact of an increase of internet use by 10 percentage points on economic growth is worldwide 0.17 percentage points but even 0.27 percentage points for non-high income countries.

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Figure 1. Number of countries for which the percentage of internet users exceeds various thresholds (left axis) and worldwide percentage of internet users (right axis)

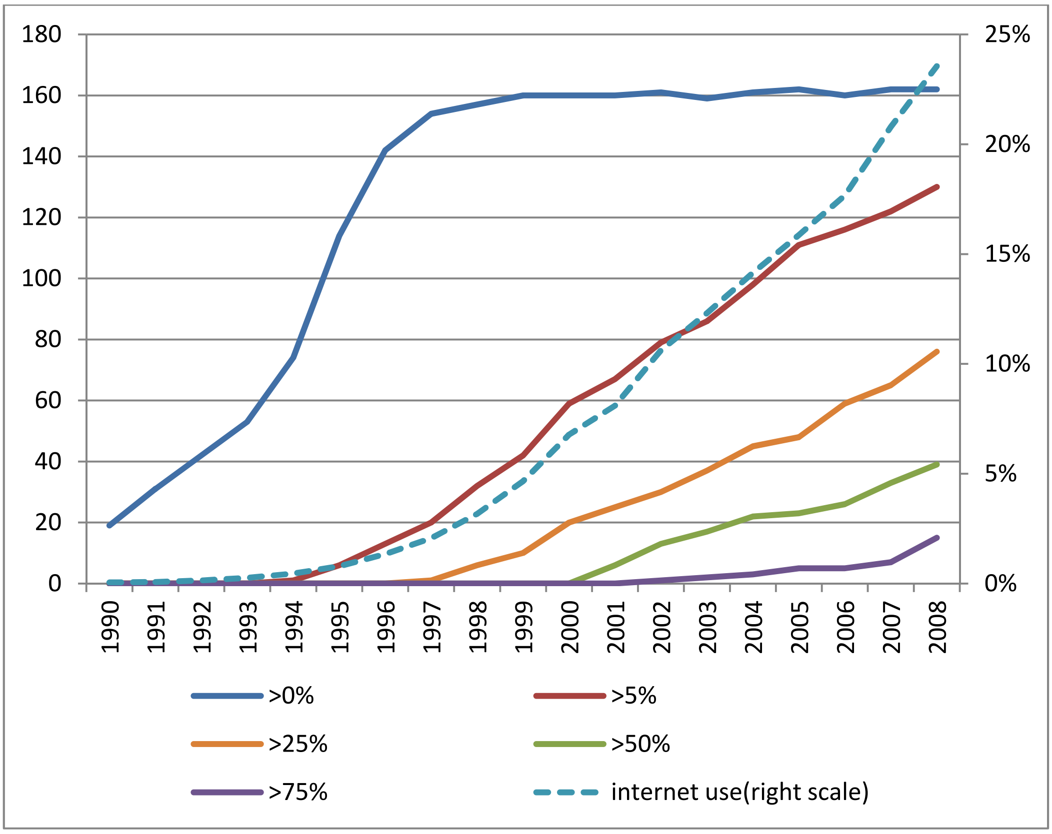

Figure 2. Per capita GDP and internet use

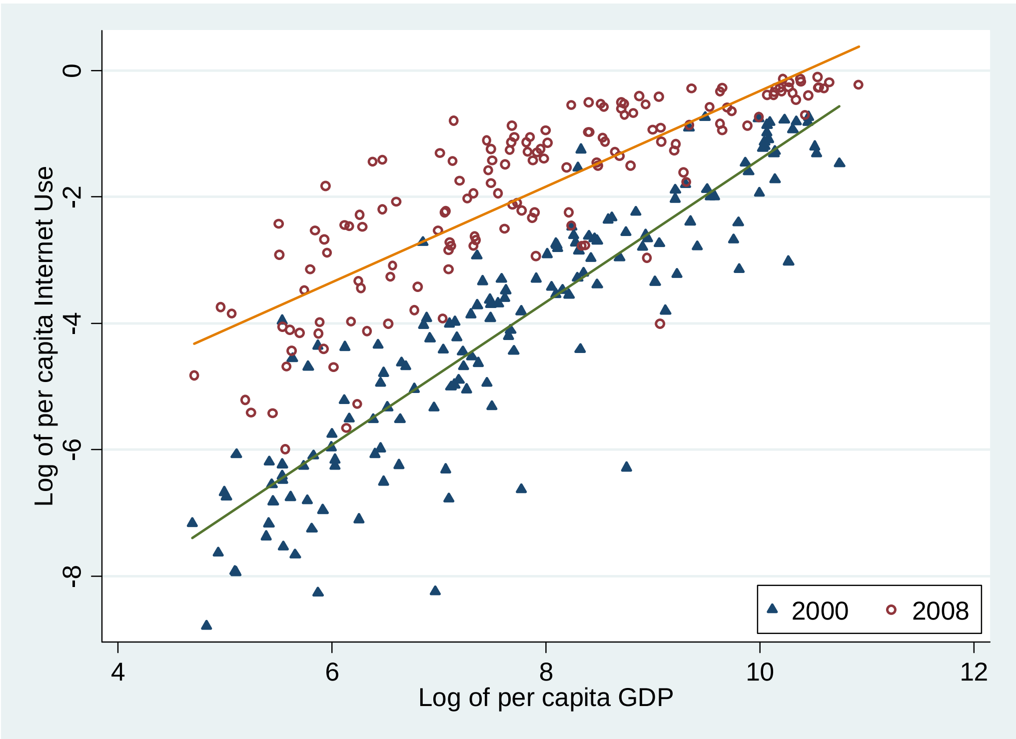

Figure 3. Internet use and growth of per capita GDP

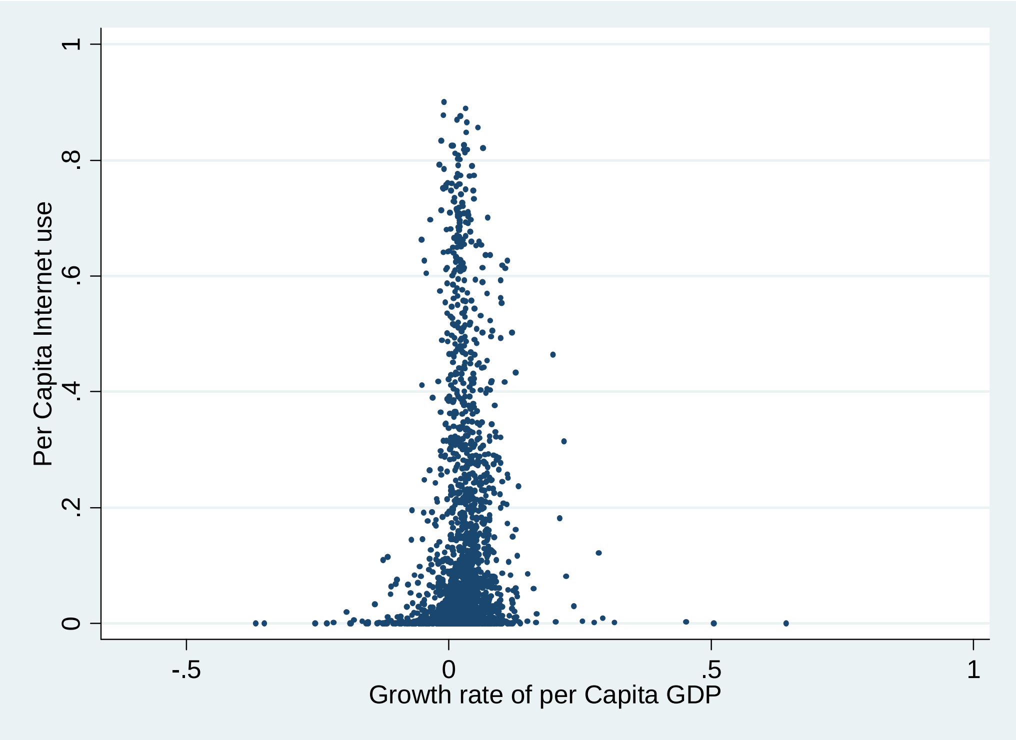

Table 1. Summary of the data

Variable		Mean	Std. Dev.	Min	Max	Observations
lgdppc	overall	7.67	1.57	4.63	10.94	N = 3,020
	between		1.57	4.79	10.67	n = 162
	within		0.19	6.34	9.15	T-bar = 18.6
dlgdppc	overall	0.02	0.06	-0.63	0.64	N = 2,858
	between		0.02	-0.03	0.15	n = 162
	within		0.05	-0.63	0.54	T-bar = 17.6
openness	overall	0.87	0.49	0.11	4.38	N = 2,985
	between		0.49	0.21	4.06	n = 162
	within		0.17	-0.24	2.13	T-bar = 18.4
iupc	overall	0.12	0.19	0.00	0.90	N = 2,442
	between		0.11	0.00	0.44	n = 162
	within		0.15	-0.32	0.63	T-bar = 15.1
infl	overall	0.36	5.08	-1.00	244.11	N = 2,859
	between		1.36	0.00	15.05	n = 162
	within		4.90	-14.51	229.42	T-bar = 17.6
gcfgdp	overall	0.23	0.09	-0.24	1.14	N = 2,976
	between		0.07	0.09	0.52	n = 162
	within		0.06	-0.21	0.85	T-bar = 18.4
govgdp	overall	16.11	6.30	2.29	83.16	N = 2,972
(x100)	between		5.44	4.85	29.94	n = 162
	within		3.31	-0.43	76.76	T-bar = 18.3
school	overall	0.72	0.32	0.06	1.62	N = 2170
	between		0.30	0.06	1.51	n = 160
	within		0.08	0.38	1.08	T-bar = 13.6
lpop	overall	15.61	1.92	10.60	21.00	N = 3,075
	between		1.93	10.69	20.94	n = 162
	within		0.10	15.14	16.29	T-bar = 19.0
area	overall	74.17	199.12	0.00	1639.00	N = 3,078
	between		199.70	0.00	1639.00	n = 162
	within		0.00	74.17	74.17	T = 19
mob100	overall	22.28	34.91	0.00	188.2981	N = 3,078
	between		17.41	0.32	67.44973	n = 162
	within		30.29	-42.82	160.2816	T = 19
tell100	overall	18.16	18.95	0.00	74.46233	N = 3,078
	between		18.46	0.10	66.6186	n = 162
	within		4.528	-.51	50.17876	T = 19

Notes: N denotes the total number of observation, n the number of groups, T-bar the average length of time series if some years for some countries are missing, and T the number of years if all data are available. The overall statistics are based on N country-years observations (x_{it}). The between statistics are computed on the country averages ($\bar{x}_i$) and are based on n observations. The within statistics are computed on the deviations of the actual data from the country averages but corrected for global average ($x_{it} - \bar{x}_i + \bar{\bar{x}}$) and are based on N observations. (In some cases there were minor variations in the area statistics per country and these are removed as to allow for Hausman-Taylor estimates).

Brief description of the data:

lgdppc	Logarithm of per capita GDP (constant 2000 US$)
dlgdppc	Growth rate of per capita GDP (log based)
openness ratio	Trade (% of GDP) defined as imports plus exports of goods and services
iupc	Per capita internet use
infl	Inflation, consumer prices (annual %)
gcfgdp	Gross capital formation (% of GDP)
govgdp	General government final consumption expenditure (% of GDP)
school	Secondary School Enrolment (% gross)
lpop	Logarithm of population, total
area	Land area (sq. km)
tell100	Number of telephone lines per 100 people
mob100	Mobile cellular subscribers, per 100 people

Data on the number of internet users come from the International Telecommunication Union (ITU) and is defined as: "The estimated number of internet users out of total population. This includes those using the internet from any device (including mobile phones) in the last 12 months. A growing number of countries are measuring this through household surveys. In countries where household surveys are available, this estimate should correspond to the estimated number derived from the percentage of internet users collected. (If the survey covers percentage of the population for a certain age group (e.g., 15-74 years old, the estimated number of internet users should be derived using this percentage, and note indicating the scope and coverage of the survey should be provided). In situations where surveys are not available, an estimate can be derived based on the number of internet subscriptions." (source: ITU). Gross secondary school enrolment is the ratio of secondary school enrolment of males, regardless of age, to the male population of the age group that officially corresponds to the secondary level of education.

List of countries included[26]

Low income countries (33): BGD(12), BEN(10), BFA(11), BDI(16), KHM(11), CAF(13), TCD(12), ETH(14), GMB(14), GHA(14), GIN(14), GNB(12), KEN(14), KGZ(11), LAO(9), MDG(13), MWI(11), MLI(12), MRT(11), MOZ(13), NPL, NER(10), RWA(12), SEN(14), SLE(2), TJK(8), TZA(11), TGO(15), UGA(14), VNM(13), YEM(8), ZMB(15), ZWE(12)
Lower middle income countries (43): ALB(14), ARM(15), AZE(13), BLZ(12), BTN(10), BOL(14), CMR(11), CPV(12), CHN(16), COG(12), CIV(14), DJI(7), ECU(17), EGY(16), SLV(13), GEO(14), GTM(14), GUY(13), HND(14), IND(17), IDN(15), IRN(14), JOR(14), LSO(11), MDA(14), MNG(14), MAR(14), NIC(8), PAK(13), PNG(13), PRY(13), PHL(15), SLB(10), LKA(15), SDN(15), SWZ(14), SYR, THA, TON(14), TUN(15), UKR(16), VUT(12), WBG(6)
Upper middle income countries (39): DZA(15), ARG(17), BLR(15), BIH(3), BWA(14), BRA, BGR(16), COL(15), CRI(17), DMA(13), DOM(14), FJI(16), GAB(13), GRD, JAM(4), KAZ(15), LVA(13), LBY(9), LTU(13), MKD(14), MYS(16), MUS(13), MEX, NAM(6), PAN(15), PER(15), POL, ROM(16), RUS(16), SRB(5), SYC(13), ZAF, KNA(13), LCA(13), VCT(14), SUR(11), TUR(16), URY(15), VEN(17)
High income countries (47) : ATG(10), AUS, AUT, BHS(13), BHR(14), BRB(8), BEL, BRN(13), CAN(17), HRV(16), CYP(17), CZE(15), DNK, GNQ(11), EST(16), FIN, FRA, DEU(17), GRC, HKG, HUN, ISL, IRL(17), ISR, ITA, JPN(17), KOR, KWT(12), LUX(17), MAC(15), MLT(13), NLD, NZL(16), NOR, OMN(8), PRT, QAT(6), SAU(14), SGP(8), SVK(15), SVN(16), ESP, SWE, CHE(17), TTO(14), GBR, USA(17)

[26] In total 162 countries are included. If less than 18 data points are available the number of observations is indicated between brackets.

Table 2. Estimates of the basic model

Dep var: growth rate of per capita GDP	(a) OLS	(b) OLS	(c) FE	(d) FE	(e) FE	(f) System GMM
Log per capita GDP, one year lagged	-0.008 (0.001)***	-0.007 (0.001)***	-0.0416 (0.020)***	-0.063 (0.025)**	0.198 (0.073)***	0.314 (0.080)***
Log per capita GDP; two years lagged					-0.288 (0.066)***	-0.327 (0.078)***
(Log per capita GDP; long run, (F-test))	-0.008 (68.84)***	-0.007 (31.09)***	-0.0416 (4.18)**	-0.063 (6.17)**	-0.090 (22.75)***	-0.013 (4.47)**
Per capita internet use	0.016 (0.004)***	-0.005 (0.006)	0.018 (0.012)	-0.017 (0.013)	-0.010 (0.009)	0.015 (0.022)
Investment/GDP ratio	0.130 (0.016)***	0.122 (0.015)***	0.185 (0.029)***	0.173 (0.027)***	0.137 (0.024)***	0.169 (0.053)***
Government expenditure/GDP ratio	-0.002 (0.000)***	-0.001 (0.000)***	-0.002 (0.001)***	-0.002 (0.001)***	-0.001 (0.000)***	-0.001 (0.000)*
Inflation	-0.008 (0.002)***	-0.007 (0.002)***	-0.008 (0.002)***	-0.007 (0.003)***	-0.005 (0.002)***	-0.009 (0.001)***
Openness ratio	0.008 (0.002)***	0.008 (0.002)***	0.040 (0.009)***	0.032 (0.008)***	0.023 (0.006)***	0.018 (0.008)**
Secondary school enrolment	0.045 (0.005)***	0.045 (0.005)***	0.066 (0.016)***	0.023 (0.017)	0.024 (0.014)*	0.053 (0.020)***
time dummies	no	yes	no	yes	yes	yes
Adjusted R2	0.228	0.275	0.222	0.278	0.361	
Sargan-Hansen against RE: chi2-value (p-value)			53.87 (0.000)	58.5 (0.000)	135.8 (0.000)	
Observations/Groups/Instruments	1682	1682	1682/158	1682/158	1648/158	1380/153/134
AB test for AR(2) in differences: z-val (p-val)						0.678
Hansen J-test: chi2-value (p-value)						0.139
Diff-in-Hansen test GMM instr. for levels						0.408
Diff-in-Hansen test IV instr.						0.551
F autocorrelation (p-value)			73.4 (0.000)	88.9 (0.000)	108.4 (0.000)	
Wald test time dummies equal zero: F-val (p-val)		6.68 (0.000)		8.35 (0.000)	11.26 (0.000)	7.34 (0.000)

Notes: Robust standard errors are displayed in parentheses and significance levels are given as ***, ** and * for p-values below 0.01, 0.05 and 0.1, respectively. The robust test on overidentifying restrictions as proposed by (Wooldridge, 2002) p 190-191 is in models (d) en (e) displayed as Sargan-Hansen against RE Chi-squared statistics including the corresponding p-value and shows that the fixed effect model is to be preferred over the random effects model. The standard Hausman tests on non-robust estimates of the equivalent models maintain the same conclusions. The latter test is used in model (f). Panel System GMM estimation uses a two-step difference GMM estimator using a robust estimation of the covariance matrix such that the resulting standard-error estimates are consistent in the presence of any pattern of autocorrelation and heteroskedasticity [(Windmeijer, 2005)]. AB test indicates Arrelano-Bond test for autocorrelation in differences and thus for invalidity of lagged variables as instruments (rejected here). GMM type instruments are used for lagged log of per capita GDP using 2 to 6 lags, and for openness ratio and investment ratio using 1 to 2 lags. One year lagged IV instruments are used for remaining variables. Hansen J-test shows the robust test of overidentification as joint validity of the instruments. The Difference-in-Hansen test for GMM instruments reports the joint validity of GMM-style instruments for levels (accepted here). A similar test statistic is given for IV instruments (accepted here). (Also Difference-in-Hansen test of all individual GMM instruments show their validity but are not reported here). Autocorrelation in the one but last row is in models (c) to (e) computed using the test for serial correlation in panel data as described by (Wooldridge, 2002) and (Drukker, 2003). Long run effect is tested with a standard Wald test and the F value is reported within brackets using the same significance intervals as the p-values. GMM model is estimated using Stata's xtabond2 ((Roodman, 2009b)).

Table 3. Granger causality test on individual equations

dependent variable	*separate equations* independent variable: Openness ratio	Per capita internet use	Log of per capita GDP	*SUR estimate* independent variable: Openness ratio	Per capita internet use	Log of per capita GDP
Excluding time dummies:				Excluding time dummies:		
Openness ratio	495.22 (1)	22.53 (1)	0.69 (1)	3379.89 (1)	61.78 (1)	5.42 (1)
	0.0000	0.0000	***0.4076***	0.0000	0.0000	**0.0200**
Per capita internet use	4.03 (1)	13471.7 (1)	44.48 (1)	10.35 (1)	32187.82 (1)	102.95 (1)
	0.0465	0.0000	0.0000	0.0013	0.0000	0.0000
Log of per capita GDP	8.44 (2)	6.60 (1)	3895.43 (2)	59.98 (1)	7.71 (1)	21828.33 (1)
	0.0003	**0.0111**	0.0000	0.0000	0.0055	0.0000
Including time dummies:				Including time dummies:		
Openness ratio	455.46 (1)	2.98 (1)	4.32 (1)	3405.65 (1)	6.60 (1)	33.05 (1)
	0.0000	***0.0863***	**0.0393**	0.0000	**0.0102**	0.0000
Per capita internet use	0.96 (1)	9116.95 (1)	14.05 (1)	1.81 (1)	23773.56 (1)	23.95 (1)
	0.3280	0.0000	0.0002	***0.1790***	0.0000	0.0000
Log of per capita GDP	7.04 (2)	13.17 (1)	1728.23 (2)	39.92 (1)	22.27 (1)	15129.96 (1)
	0.0012	0.0004	0.0000	0.0000	0.0000	0.0000

Notes: First line denotes F-statistic and the number of lags is in brackets. Second line denotes p value of H0: all coefficients of that particular variable are equal to zero. P-values between 1% and 5% in bold, above 5% in bold-italic. The left panels display estimation results employing panel fixed effects using robust standard errors (employing the Huber/White/sandwich estimator for estimating the variance-covariance matrix). The number of lags is determined in a first stage using lags between 1 to 4 years for each variable separately and choosing the best performing lag structure that minimizes the Akaike Information Criterion (AIC) (Minimizing BIC gives same models in all cases). The model is estimated with (top panels) and without (bottom panels) time dummies. Time dummies are jointly significant at the 1%-level in all cases. The right panels show results using Zellner's seemingly unrelated regression (SUR) including country dummies. For the SUR estimates the number of lags is determined in a first stage by minimum Akaike Information Criterion (AIC) using 1 to 3 lags for each variable (Minimizing BIC gives same results). A Breusch-Pagan test of independence of the three equations cannot reject the H0 that the equations are independent (p-values of 0.000 and 0.008 for the right top and right bottom panel, respectively).

Table 4. Trade and internet use

Dep var: openness ratio (export plus imports as ratio of GDP)	(a) OLS	(b) Random effects	(c) Hausman-Taylor	(d) System GMM
Per capita internet use			0.167(0.029)***	0.133(0.081)*
group average	0.695(0.135)***	0.735(0.429)*		
within difference	0.356(0.097)***	0.160(0.035)***		
Log per capita GDP			0.017(0.021)	0.057(0.032)*
group average	0.017(0.009)**	0.030(0.030)		
within difference	0.246(0.043)***	-0.028(0.063)		
Area	-0.105(0.009)***	-0.108(0.041)***	-0.100(0.055)*	-0.092(0.040)**
Area squared	0.007(0.001)***	0.007(0.004)*	0.007(0.004)	0.006(0.002)**
log of population size	-0.105(0.009)***	-0.115(0.033)***	-0.096(0.022)***	-0.090(0.021)***
time dummies	no	yes	yes	yes
r2	0.296	0.291		
Obs/Groups/Instr.	2364	2364/162	2364/162	2364/162/128
AB-test AR(1): z-val (p-val)				0.77 (0.439)
AB-test AR(2): z-val (p-val)				-1.43 (0.154)
Hansen J-test for joint validity of instruments: chi2-value (p-value)				110.77 (0.307)
Hansen test incl GMM instr.				20.01 (0.986)
Dif-in-Hansen exog IV instr.				24.88 (0.252)
Wald test time dummies equal to zero: F-value (p-value)	0.64 (0.867)	65.97 (0.000)	124.10 (0.000)	131.56 (0.000)

Notes: Model (a) is estimated with Heteroskedasticity and Autocorrelation (HAC) robust standard errors (Bartlett). Wald test of time dummies is based on same model incl. time dummies and estimates of the model including time dummies do not differ significantly from the ones presented here. Random effects model (b) is estimated with robust standard errors and uses group average and within differences for per capita GDP and for per capita internet use. In Hausman-Taylor model (c) log per capita GDP per capita and per capita internet use are treated as endogenous variables, area and area squared are time invariant variables. System GMM estimation uses a two-step difference GMM using a robust estimation of the covariance matrix such that the resulting standard-error estimates are consistent in the presence of any pattern of autocorrelation and heteroskedasticity ((Windmeijer, 2005)). GMM type instruments are used for log GDP per capita and internet users per capita all variables using 2 lags. The current and lagged values of the number of telephone lines per capita and the number of mobile phone users per capita are used as two different instruments for internet use. (Note that no lag dependent variable is used). Hansen J-test shows the robust test of overidentification. Standard errors are displayed in parentheses and significance levels are given as ***, ** and * for p-values below 0.01, 0.05 and 0.1, respectively.

Table 5. 3SLS regression results on simultaneous model

Growth equation *Dep var: growth rate of GDP per capita*	(a) all	(b1) high income	(b2) non-high income	p-value high=low	(c) all	(d1) high income	(d2) non-high income	p-value high=low
Log per capita GDP, lagged	-0.095(0.007)***	-0.109(0.017)***	-0.102(0.009)***	0.69	-0.093(0.008)***	-0.105(0.017)***	-0.100(0.009)***	0.76
Investment/GDP ratio	0.184(0.016)***	0.237(0.043)***	0.166(0.023)***	0.15	0.190(0.020)***	0.243(0.044)***	0.164(0.023)***	0.11
Government expenditure/GDP ratio	-0.001(0.000)***	-0.003(0.001)***	-0.001(0.000)**	0.01	-0.002(0.000)***	-0.003(0.001)***	-0.001(0.000)***	0.01
Inflation	-0.016(0.002)***	-0.033(0.024)	-0.024(0.004)***	0.71	-0.031(0.004)***	-0.036(0.024)	-0.025(0.004)***	0.66
Openness ratio	0.042(0.006)***	0.050(0.009)***	0.053(0.010)***	0.78	0.044(0.007)***	0.049(0.009)***	0.051(0.010)***	0.85
Secondary school enrolment	0.044(0.011)***	0.022(0.016)	0.038(0.018)**	0.50	0.048(0.011)***	0.023(0.016)	0.039(0.018)**	0.51
Trade equation *Dep var: openness ratio*								
Per capita internet use:					0.386(0.050)***	0.306(0.055)***	0.533(0.104)***	0.05
group average	0.477(0.167)***	0.061(0.216)	2.189(0.340)***	0.00				
within difference	0.125(0.058)**	0.026(0.074)	0.084(0.126)	0.69				
Log per capita GDP:					0.013(0.008)	0.069(0.021)***	0.017(0.013)	0.01
group average	0.005(0.013)	0.045(0.023)*	-0.044(0.017)***	0.00				
within difference	0.458(0.047)***	0.757(0.113)***	0.278(0.066)***	0.00				
Area	-0.099(0.016)***	-0.685(0.079)***	-0.051(0.022)**	0.00	-0.101(0.017)***	-0.711(0.080)***	-0.068(0.022)***	0.00
Area squared	0.006(0.001)***	0.073(0.009)***	0.003(0.002)*	0.00	0.006(0.001)***	0.076(0.009)***	0.004(0.002)**	0.00
log of population size	-0.101(0.007)***	-0.110(0.011)***	-0.084(0.008)***	0.03	-0.099(0.007)***	-0.112(0.011)***	-0.087(0.008)***	0.04
Breusch-Pagan LM Diagonal Covariance Matrix Test (3sls) (6 degrees of freedom)	513.7 (0.000)***	481.9 (0.000)***			442.4 (0.000)***	421.7 (0.000)***		
Nr Observations (obs in income group)	1278	(481) 1278 (797)			1278	(481) 1278 (797)		

Notes: Standard errors are displayed in parentheses and significance levels are given as ***, ** and * for p-values below 0.01, 0.05 and 0.1, respectively.
All models are estimated using three-stage least squares (3SLS) and employ level equations as well as first differences of the same models, so estimating 4 equations simultaneously and constraining the coefficients of the level equations to be equal to the coefficients of accompanying first difference equations. The growth equations include time dummies as well as country dummies which are both each jointly significantly different from zero in all six models using a Wald test. Time dummies in the openness equations where jointly insignificantly different from zero in all cases and are not included. In a first stage internet use was also included in the growth equation but did not lead to significant estimates. The models for high and non-high income countries include time dummies for each income group and are estimated simultaneously by pre-multiplying all right hand side variables with dummies for high and non-high income countries. Instruments are two years lagged log of per capita GDP; lagged investment ratio; lagged government expenditure ratio; lagged openness ratio; lagged inflation rate; two years lagged first difference of log of per capita GDP, lagged first difference of investment ratio; lagged first difference of internet use per capita. Models (a) and (b) also use lagged within difference of log of per capita GDP, and lagged within difference of internet use per capita as additional instruments and models (c) and (d) use lagged internet use and the lagged first difference of internet use as additional instruments. Since level and first difference equations are both estimated the dependent

variable in the growth equation is defined in levels in the level equation but recalculated in first differences to make the resulting coefficients comparable with previous tables. The Breusch-Pagan LM Diagonal Covariance Matrix is based on (Shehata, 2012) using a H0 that all equations are independent. High-income countries refer to the group of 47 high-income countries as listed in the data description. Non-high income countries refer here to the 115 countries listed in the data description as low, lower middle and upper middle income countries. The p-values reflecting the H0 that the coefficients for the high income countries are equal to the coefficients for the non-high incomes countries are based on a Wald test.

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