Trade, Internet and economic growth: a cross country panel analysis

Paper prepared for the first ICTNET workshop
Parma, Italy on the 16-17 of December 2010

Huub Meijers, 2010
Draft Version

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 equation. In special openness and trade variables seem 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 impact 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.

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I. Introduction

Over the last decades the worldwide adoption of Information and Communication Technologies (ICTs) has reached an enormous momentum and the diffusion of the Internet as a prominent component of these technologies shows extraordinary figures. At the dawn of the Net around 1993 when the first graphical browser was introduced far less than 1% of worldwide population had access to the Internet. In 1995 this number has grown to 2% increasing further to nearly 8% at the turn of the century. In 2008 on average about 30% of world population has access to the Internet.[1,2] Together with the rise of ICT and the Internet the number of studies on the economic and broader impact of these technologies witnessed a similar spectacular growth, especially on the relation between economic performance and ICT. Though the first studies on this relation did not give a clear cut picture and was subject to a heated debate on the productivity paradox –see for overviews e.g. Brynjolfsson (1993) and Triplett (1999)– it is well established by now that ICTs have a positive and significant impact on economic growth at various levels of aggregation ranging from regions and countries (see e.g. van Ark et al. (2008), Jorgenson et al. (2008) and Stiroh et al. (2008)) to firm or even process levels (see e.g. Bharadwaj et al. (2000), Melville et al. (2004), Banker et al. (2006) and Karimi et al. (2007)). The literature is mostly restricted to developed countries or to individual countries or specific cases and a more general global analysis is rather scarce. Some notable exceptions are Jorgenson and Vu (2005), No and Yoo (2008), Choi and Yi (2005), and Clarke (2008) and the broader literature on the digital divide though this latter focuses more on the diffusion of new technologies like the Internet than on its (economic) impact. With the exception of the studies mentioned here

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[1] Data from International Telecommunication Union, see Table 1 for an overview and short glossary of terms.

[2] As physical network the Internet was already established in the early 1970s as successor of ARPANET which in turn was established in the late 1960s. The introduction of the World Wide Web (Berners-Lee, 1990) and the graphical browsers brought the Internet to the interest of the broader public.

the literature on the relation between investments in ICT in general and in the Internet in particular and economic growth is mainly concentrated on developed countries. The present paper focuses on a more global view on empirical evidence of the impact of ICT and the Internet in particular on economic growth.

[Insert Figure 1 about here]

Figure 1 depicts the relation between per capita Internet use and per capita GDP for 162 countries in 2000 and in 2008. The fast diffusion of Internet use combined with a modest growth of per capita GDP becomes apparent and is highlighted by the linear regression lines in both years. The figure also suggest a decrease of the slope of this relation through time indicating a relative fast catch up of low income countries regarding Internet use. The relation between Internet use and economic growth is less obvious as can be seen from Figure 2. Although a simple regression line shows a positive and significant slope, a visual inspection of the graph clearly shows that such simple model is far from complete and that other aspects are relevant.[3] The main objective of this study is to investigate the impact of Internet use on economic growth in a fully specific growth model.

[Insert Figure 2 about here]

Starting point is the literature on economic growth as pioneered by Solow (1956) and employed in empirical work by e.g. Barro (1991, 2003), Quah (1993, 1997), Bosworth and Collins (2003) and many others. Next section elaborates on this by portraying the 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. 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 Yi (2005). A more

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[3] Regressing the growth rate of per capita GDO on per capita Internet use shows a slope of 0.015 with an standard error of 0.005 (p<1%).

careful 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 if time dummies are allowed capturing longitudinal variation, Internet use does not seems to have a positive contribution to economic growth. In some cases even a significant and negative effect is measured. Leaving our 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 models and they all find a positive relation between Internet use and trade, although not as strong for all regions. In the tradition of gravity models this is done in a bilateral trade setting.[4] This positive relation, albeit in a non-bilateral trade setting, is studied also here in section 5. Before turning to that, section 4 briefly discusses a Granger causality analysis on economic growth, International trade and Internet use showing that in levels 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 in growth rates where the relation between the growth of international trade on economic growth and on Internet use is stronger than the relation between the growth rate of Internet use and trade, though the latter remains significant at 10%. Combining the findings from the growth equation and the Granger causality analysis suggest a direct relation between international trade and economic growth and a relation between Internet use and 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 physical size of countries which is fixed over time.

[4] 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.

This demands for a model combining notions from a panel fixed affects model with time invariant variables and 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. Finally, a brief summary and some limitations close this paper.

II. Basic Growth Model including Internet use

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 (1965) should be relaxed by introducing conditional convergence. 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, 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 to international trade. This path will be further explored below.

So many studies in the realm of empirical economic growth models and the discussion of convergence are based on the impact of new technologies, human capital and diffusion of knowledge on growth and convergence and most employ growth equations where the growth of GDP per capita is related to 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 stead states (see e.g. Barro (1991, 2003), Quah (1993), Bosworth and Collins (2003)).

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

(1)

where and where denotes the growth rate of per capita GDP ( ) of country *i* at time *t* and denotes a multidimensional vector of explanatory and control variables. 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 ( ), the error term may contain an individual effect ( ) and/or a time effect ( ) leading to a one-way or two-way error component model, respectively. A critical aspect of equation (1) is obviously the choice of explanatory and control variables, here all captured by the term . The standard literature on empirical growth analysis 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, life expectancy and population size as explanatory variables. Lagged GDP per capita reflects the convergence hypotheses and is expected to have a negative sign as low income countries are assumed to show higher growth rates and thus 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, ceteris paribus. Investment may also be seen as carrier of new technologies (the embodiment hypothesis) leading to higher economic growth figures. Government expenditures include amongst others non productive expenditures and are assumed to distort private decisions and thus are expected to have a negative impact on per capita growth rates. 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 openness and being linked to 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) such that small countries may increase market size by international trade resulting in higher growth rates. 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. 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. Life expectancy is used as an indicator of health and the quality of human capital and is expected to appear with a positive sign.

Next section is devoted to the empirical implementation of equation (1) using per capita Internet use next to the above mentioned controls variables in order to determine the impact of Internet use on economic growth. In general the empirical implementation of growth equations is often done by using long time series and in most cases by using averaged data to cancel out temporary effects and business cycles. Typical is using five yearly averaged data and 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 since 1995 or even later resulting in one or two data points for most countries. Using lags as instruments or including growth rates is nearly impossible in case of such short time dimensions. Therefore the present analysis starts from 1990 onwards and employs yearly data.

III. Data and first estimation results

Data for initially 213 countries were collected from the Worldbank 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. For most what will follow the dataset includes 162 countries. This unbalanced dataset includes time series length varying between 1 to 18 data points per variable. Table 1 summarizes the data and shows that the number of countries 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.[5]

[Insert Table 1 about here]

In a related analysis Choi and Yi (2009) 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 data for 207 countries from 1991 to 2000 (but actually employing a subset leading to 1004 datapoints) they find a highly positive and significant effect of Internet use on economic growth. Using the same time period the results of Choi and Yi (2009) can be reproduced fairly well. Table 2a models (a) and (c) resemble their results but now using the extended time span and adding lagged per capita GDP and openness as additional variables.[6] Compared to the shorter time span the OLS results and the

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

[6] 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 the fixed effect model 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).

panel fixed effect results change somewhat but Internet use still shows to be a positive and significant factor.[7] Also investment ratio is positive and inflation and government expenditure ratio is significant and negative. All as expected. Including time dummies to capture global movements in economic growth and thus to control for longitudinal variation dramatically changes the picture and the impact of per capita Internet use on economic growth becomes either insignificant (model b) or even negative and significant (model d) whereas order of magnitude and significance of other explanatory variables remain unchanged. A Wald test on joint significance of time dummies clearly rejects the null that the coefficients are jointly equal to zero. In both models (c) and (d) the random effects variant of the panel models is firmly rejected indicating that the disturbance terms are correlated with country effects. The above implies that using more control variables as suggested by the literature on empirical economic growth models and by controlling for longitudinal variation the positive impact of Internet use on economic growth vanishes.

Since the model employed here basically includes a lagged dependent variable and thus is subject to the Nickel bias the model is re-estimated by using GMM techniques. Models (e) and (f) in Table 2a show the results of first differenced and system GMM estimations, respectively, using two and three year lagged variables as GMM instruments. Main concerns in GMM estimation are related to validity of instruments and to overidentification of the model. The choice of instruments is determined analogous to Roodman (2006 and 2009) 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 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. In both cases per capita Internet use is insignificant and seems to confirm the belief that Internet use is not directly impacting economic growth in a fully specified growth model.

[7] Inclusion of openness as additional variable also reduces the coefficient of Internet use such that this coefficient is much lower than the one as reported by Choi and Yi (2009).

Note however that in both GMM estimates the coefficient of the lagged dependent variable is not in the required interval as determined by the OLS and fixed effects estimates as upper and lower bound, respectively. Also the Arrelano-Bond test for AR(2) in differences points to endogeneity and thus to invalidity of the instruments. Note also that both OLS and two-way fixed effects panel model shows severe autocorrelation pointing to missing explanatory variables (including missing dynamics) in the model.

[Insert Table 2a about here]

The results suggest missing (lagged) explanatory variables and to reassure the conclusion that Internet use is not directly impacting economic growth more variants of the growth equation are tested and Table 2b reveals the results of this search. Next to the variable indicated here also rates of population with primary, secondary and tertiary schooling, life expectancy at birth, fertility rate and some institutional factors such as corruption index and rules of law were included but did not give significant results. The models (a)-(c) in Table 2b include one and two years lagged value of the log of per capita GDP and the current, one and two years lagged value of per capita Internet use, next to the investment ratio, government expenditure, lagged inflation and lagged openness ratio. All models include time dummies which are all jointly significant in the Wald test. In the fixed effects estimates the long run lagged dependent variable is about -0.1which is roughly in line with model (d) in Table 2a. The results of the fixed effects AR(1) model seem striking but taking account for the autoregressive term being equal to 0.37 the long run coefficient of the lagged and two years lagged dependent variable comes close to those reported in model (a). The control variables show similar results compared to Table 2a except for lagged inflation which is not significant any more. The GMM results reported as model (c) give the same picture as in Table 2a and now the coefficients of the lagged dependent variable are within the range between OLS and Fixed effects models and the Arrelano-Bond test statistics on autocorrelation of the idiosyncratic disturbance term confirm the validity of the instruments.[8] Note that as in Table 2a the long run value of the log of per capita GDP is slightly below but insignificantly different from zero in the GMM model whereas clearly negative and significant in the fixed effects model. The result challenges the convergence hypotheses in these cases. The long run impact of per capita Internet use on economic growth is negative and significant in the fixed effects models and insignificant in case of GMM as reported by the Wald test on the sum of Internet coefficients being equal to zero. Avoiding the one year lagged dependent variable results in the fixed effects model reported as (d) in Table 2b which again confirms the picture that Internet use has a negative impact on economic growth. Finally excluding Internet use in the equation leads to models (e) and (f) where all control variables are included with lagged values to exclude even further possible endogeneity. The results remain of same magnitude and significance.

[Insert Table 2b about here]

These findings suggest that per capita Internet use does not have a positive impact on economic growth and that it in some cases even has a negative impact. This strongly contrasts the findings of Choi and Yi (2009). However, the analysis also shows a positive and significant impact of openness on economic growth and the literature reports a positive, significant and causal relation between Internet use and openness. Clarke and Wallsten (2006), Freund and Weinhold (2004) and Vemuri and Siddiqi (2009) all study International trade and Internet use in gravity like models and they all find a positive relation between Internet use and trade, although not as strong for all regions. 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 briefly discuses the results of a panel Granger causality analysis between Internet use, International trade, and economic growth.

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[8] OLS results are not reported but the coefficients (p-values) of the one and two years lagged dependent variables are 0.361 (0.0.37) and -0.362 (0.037), respectively.

IV. Granger causality on openness, Internet use and growth

The analysis so far suggests that international trade (openness) can empirically explain economic growth and that the impact of Internet use on economic growth disappears if time dummies are included whereas openness remains significant. The literature on the relation between trade and Internet use suggests a positive and causal relation running from Internet use to openness. This is based on bilateral trade data employing gravity models of international trade and variants thereof. Here the openness ratio has been used so far in the analysis so as a primary investigation a standard Granger causality test is employed to further develop the understanding of the relation between openness, Internet use and growth. Starting point is a VAR representation:

(2)

where , where are i.i.d and where denotes a vector of explanatory variables. 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 the openness ratio measured as imports plus exports as ratio of GDP.[9] The length of time series in the dataset is limited to a maximum of 19 years with an average value of just over 15 years so using long lags is not possible and thus reduces somewhat the power of the analysis. Per equation first the maximum lag length L is determined by starting at an arbitrary lag length equal to $L=5$ and reducing the lag length until all coefficients at that maximum lag level are jointly significant. This is tested by a standard Wald test. Second a Wald test is carried out for joint significance of all lags per explanatory variable. This is repeated for all three dependent variables and carried out for levels as well as for growth

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[9] 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.

rates. The latter is included to overcome possible problems due to cointegration though formal testing of such relations cannot be carried out due to short length of time series.

[Insert Table 3 about here]

Focussing first on the levels equations shows that Internet use is Granger causing openness but also the other way around though the first effect seems to be stronger, see Table 3. The level of the log of per capita GDP does not seem to impact openness but all other level equations do not have sufficient power to confirm or to reject causality relations. Employing levels for openness and Internet use but growth rates of per capita GDP in the lower panel of Table 3 shows that the growth rate of per capita GDP is Granger causing openness but not per capita Internet use and the relation between Internet use causing growth of per capita GDP is less strong compared to international trade causing economic growth, which confirms the analysis from the previous section. Finally using growth rates for all three variables does not discriminate between the causal relations though the growth of per capita GDP does not strongly cause the growth rate of Internet use and the growth rate of Internet use does not strongly cause the growth rate of the openness ratio. The conclusions that can be drawn from this analysis are somewhat limited and in many cases a Granger causality test cannot discriminate between possible causal relations. In levels the relation between Internet use causing openness ratio is much stronger than the other way around but this is reverse if analysed in growth rates.

V. Internet use and international trade

The results presented so far suggest that Internet use is not directly related to 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, physical country size and population size. The impact of ICT in general and Internet use in particular on International trade has been studied by e.g. Freund and Weinhold (2004), Clarke and Wallsten (2006), Clarke (12008), 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 the gravity model including distance between counties, 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. Internet use is shown to have a positive impact on bilateral trade also if the causality is taken into account by employing instrumental variables (Clarke and Wallsten, 2006). Here only openness is taken into account which measures country's total imports plus exports as ratio of GDP and not bilateral trade data. This 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, country size, country size squared and population size. 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 size 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 expecting a negative sign. 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 (nearly) time invariant. 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 are country specific and thus correlated with the individual effect , 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. Although the time invariant variables sweep out in the first differenced equation the level equation still allows for identification of time invariant variables.[10] As before time dummies are included and tested on joint significance using a standard Wald test.

[Insert Table 4 about here]

In all four cases the impact of Internet use on openness is positive and significant. Especially the within estimator in the random effects model is highly consistent in both size and precision with the Hausman-Taylor and GMM estimate. The coefficient on group averages seems high as is the standard error. The impact of per capita GDP on openness is less strong having only a significant coefficient in the OLS and Hausman-Taylor estimates. In both cases the positive sign is as expected. Finally, larger countries both in physical area as in population size trade less than smaller ones but this is offset by the positive squared term leading to an U-shaped relation between trade and physical country size.[11]

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

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[10] 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.

[11] 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.

various statistics within their boundaries as before. 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 dramatically and leads to the same qualitative conclusions.

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 as measured by the openness ratio. The initial finding 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. As a final analysis next section elaborates on this and confirms by using a 3SLS simultaneous model approach that indeed Internet use is impacting trade and that trade is impacting economic growth.

VI. Simultaneous Equation Model

The analysis so far suggests that a) openness is positive and significant in explaining economic growth and b) Internet use explains openness ratio. Both findings call for a simultaneous equation model by combining both relations as to take possible correlation between the residuals into account. The approach combines the findings of above and uses the model specification of the economic growth equation from Table 2b, combined with the model specification of the trade equation from Table 4 into a simultaneous model using a three stage least squares approach. The growth equation is equipped with both time dummies and country dummies, so basically using a two-way Least Squares Dummy Variables approach which is numerically fully identical to a fixed effect model as indicated as model (e) in Table 2b. Instrumental variables are used to deal with possible endogeneity problems. The openness equation is equivalent to model (a) in Table 4 with lagged values as additional instruments to capture endogeneity problems and is in line with the single equation 3SLS approach of

Barro (1991, 2003). The simultaneous model is first estimated by using time dummies also for the openness equation but a standard Wald test shows that these time dummies are jointly highly insignificant. The same model is re-estimated without using time dummies in the openness equation and the results of both models are reported in Table 5. The upper panel of Table 5 reports the 3SLS results of the growth equation which reproduces the fixed effects model (e) from Table 2b fairly well. The convergence effect is slightly stronger as is the effect of investment on growth. The negative effect of government expenditure on growth becomes insignificant though the coefficient remain about the same. The impact of inflation on growth is about the same as before as is the precision of the estimate. In both model (a) and model (b) the openness effect in the simultaneous model is stronger compared to the single equation results as obtained in Table 2b. Both time dummies and country dummies are each jointly highly significant as before.

[Insert table 5 about here]

The results of the openness equation are displayed in the lower panel of Table 5 and broadly resemble the results from Table 4. Both models with and without time dummies are reported. The main difference between both models is that the model including time dummies the within difference of per capita Internet use is not significant. A Wald test on the joint significance of time dummies firmly rejects the null such that model (b) has to be preferred. In that model also the within difference of per capita Internet use is significant with a p-value of 6%.[12] The model is being estimated using lagged explanatory variables as instruments as well as some additional instruments to capture endogeneity for 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

[12] The p-value of 6.3% is not shown in the table.

the within difference of Internet use. Leaving out these additional instruments did not alter the results dramatically.

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 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).

VII. Brief summary and limitations

This paper challenges the findings that Internet use has a direct and positive impact on economic growth if measured in an empirical economic growth equation 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 and taking account for longitudinal variation by including time dummies the conclusion is weakened or even reversed. Adopting a more dynamic model specification including an autoregressive regression model confirms this finding. International trade is however impacting economic growth in all models and the literature reports findings 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. Estimated in levels Internet use impacts international trade stronger than the other way around but this seems to be reversed when using a growth specification. 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.

An interesting question not addressed yet in this paper is whether the relations found here also hold true for groups of countries. Clarke and Wallsten (2006) for instance find that trade from low income to high income countries benefit from Internet use by low income countries and that this is not found for high income countries. This poses the question whether the simultaneous model results indeed hold true for all income groups. Second the impact of Internet use on the rapid diffusion of knowledge on thus to innovative process itself is not studied here. As is known from the (endogenous) growth literature non-decreasing marginal returns from human capital can be an important source to explain permanent economic growth. From that perspective Internet use and human capital and its joint effect could be a different approach to the same basic question. Finally the diffusion of Internet is not explained in this framework. Adding Internet diffusion as a third equation in the simultaneous model would also shed more light on the causal relation between economic growth, international trade and Internet use thereby completing the entire model.

VIII. References

Acemoglu, D., and J. Ventura (2002), “The World Income Distribution”, Quarterly Journal of Economics, 117, 659-694

Ark, Bart van, Mary O’Mahony and Marcel P. Timmer (2008), “The Productivity Gap between Europe and the United States: Trends and Causes”, Journal of Economic Perspectives, Vol. 22, Number 1, 25-44

Banker, R.D., Bardhan, I.R., Chang, H. & Lin, S. (2006), “Plant information systems, manufacturing capabilities, and plant performance”, MIS Quarterly, 30 (2), 315-337

Barro, Robert J. (1991), “Economic growth in a cross section of countries”, Quarterly Journal of Economics, 407-443

Barro, Robert J. (2003), “Determinants of Growth in a Panel of Countries”, Annals of Economics and Finance, 4, 407-443

Barro, Robert J., and X. Sala-i-Martin (1991), “Convergence across States and Regions”, Brookins papers on Economic Activity, 1, 107-182.

Berners-Lee, T. And R. Cailliau (1990), “WorldWideWeb: Proposal for a HyperText Project”, CERN, http://www.w3.org/Proposal.html (accessed December 2010)

Bharadwaj, A.S. (2000), “A resource-based perspective on information technology capability and firm performance: an empirical investigation”, MIS Quarterly, 24 (1), 169-196

Bosworth, Barry P. And Susan M. Collins (2003), “The Empirics of Growth: an Update”, Brookings Papers on Economic Activity, 2, 113-179

Brynjolfsson, E. (1993), “The Productivity Paradox of Information technology”, Communication of the ACM, 36 (12), 67-77

Chinn, Menzie D; Fairlie, Robert W., (March 2004), “The Determinants of the Global Digital Divide: A Cross-Country analysis of computer and Integer Penetration”, Center Discussion paper No. 881, Economic Growth Center, Yale University

Choi, Changkyu and Myung Hoon Yi (2009), “The effect of the Internet on economic growth: Evidence from cross-country panel; data”, Economics Letters, 105, 39-41

Clarke, George R. G. and Scott Wallsten (2006), “Has the Internet Increased Trade? Developed and Developing Country Evidence", Economic Inquiry, 44, 465-485,

Clarke, George R.G. (2008), “Has the Internet increased exports for firms from low and middle-income countries?”, Information Economics and Policy, 20, 16-37

Drukker, D. M. (2003), “Testing for serial correlation in linear panel-data models”, Stata Journal, (3)2, 168-177

Freund, Caroline L. and Diana Weinhold (2004), “The effect of the Internet on international trade”, Journal of International Economics, 62, 171-189

Hausman, J.A. and W.E. Taylor (1981), “Panel data and unobserved individual effects”, Econometrica, 49, 1377-1398

Hoffman, Robert, Chew-Ging Lee, Bala Ramasamy and Matthew Yeung (2005), “FDI and Pollution: A Granger Causality Test unsing Panel data”, Journal of International Development, 17, 311-317

Jorgenson, Dale W. And Khuong Vu (2005), “Information technology and the World Economy”, Scandinavian Journal of Economics, 107(4), 631-650

Jorgenson, D.W., Ho, M.S. & Stiroh, K.J. (2008), “A Retrospective Look at the U.S. Productivity Growth Resurgence”, Journal of Economics Perspectives, Vol. 22, Number 1, 3-24

Karimi, J., Somers, T.M. & Bhattacherjee, A. (2007), “The impact of ERP implementation on business process outcomes: A factor-based study”, Journal of Management Information Systems, Vol.24, Iss.1, 101-134

Koopmans, T.C. (1965), “On the Concept of Optimal Economic growth”, Cowles foundation for Research in Economics at Yale University, New Haven , U.S.A..

Melville, N., Kraemer, K. & Gurbaxani, V. (2004), “Information technology and organizational performance: An integrative model of IT business value”, MIS Quarterly, Vol.28, Iss.2, 283-322

Mundlak, Y. (1978), “On the pooling of time series and cross-section data”, Econometrica, 46, 69-85

Noh, YH. and K. Yoo (2008), “Internet, inequality and growth”, Journal of Policy Modeling, 30, 1005-1016

Oliner, S.D., Sichel, D.E. & Stiroh, K.J. (2008), “Explaining a productive decade”, Journal of Policy Modeling, 30, 633-673

Quah, D. (1993), “Galton’s fallacy and Tests of the Convergence Hypothesis”, Scandinavian Journal of Economics, 95, 427-444

Quah, D. (1997), “Empirics for Growth and Distribution: Polarization, Stratification and Convergence Clubs”, Journal of Economic growth, 2, 27-59

Roodman, D. (2006). “How to Do xtabond2: An introduction to "Difference" and "System" GMM in Stata”, Working Paper 103, Center for Global Development, Washington

Roodman, D. (2009), “Practitioners’ Corner. A Note on the Theme of Too Many Instruments”, Oxford Bulletin of Economics and Statistics, 71, 1, 135-158

Solow, Robert M. (1956), “A Contribution to the Theory of Economic Growth”, Quarterly Journal of Economics, LXX, 65-94

Triplett, J.E. (1999), “The Solow Productivity Paradox: What do Computers do to Productivity”, Canadian Journal of Economics, 323 (2), 309-334

Vemuri, Vijay K. and Shahid Siddiqi (2009), “Impact of Commercialization of the Internet on International trade: A panel Study using the extended Gravity Model”, The International Trade Journal, Vol. XXIII, 4, 458-484

Wallsten, Scott (2005), “Regulation and Internet Use in Developing Countries”, Economic Development & Cultural Change, Vol. 53 Issue 2, 501-523

Windmeijer, F. (2005). “A finite sample correction for the variance of linear efficient two-step GMM estimators”. Journal of Econometrics, 126, 25-51.

Wooldridge, J.M. (2002), Econometric Analysis of Cross Section and Panel Data, Cambridge, MA: MIT Press.

Figure 1. Per capita GDP and Internet use

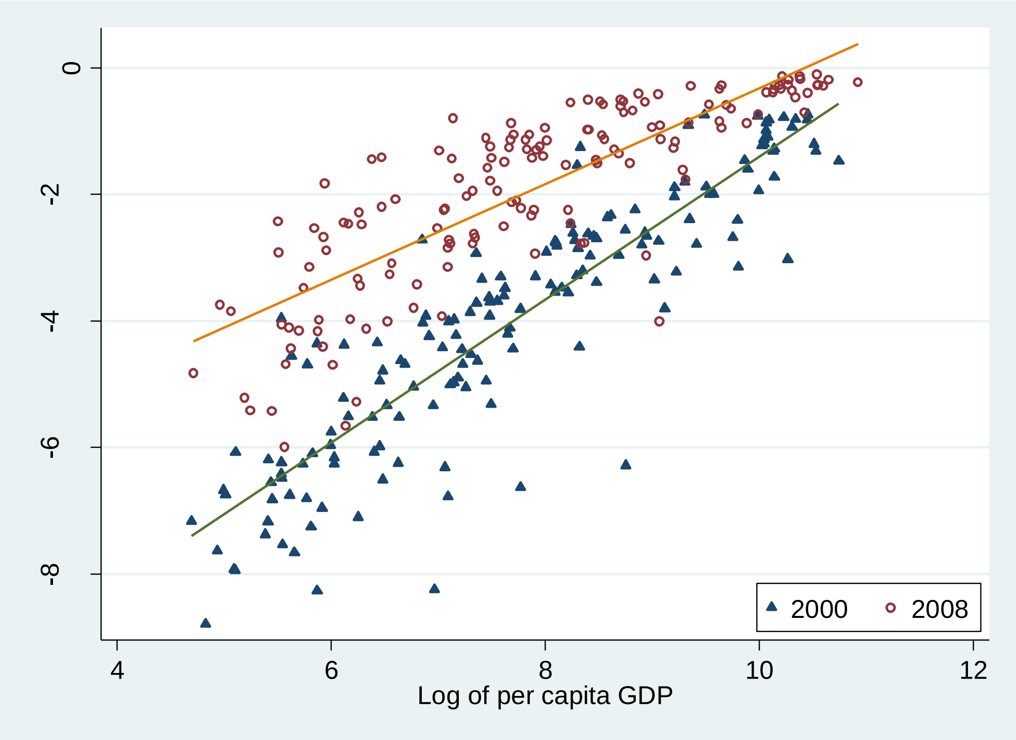

Figure 2. Internet use and growth of per capita GDP

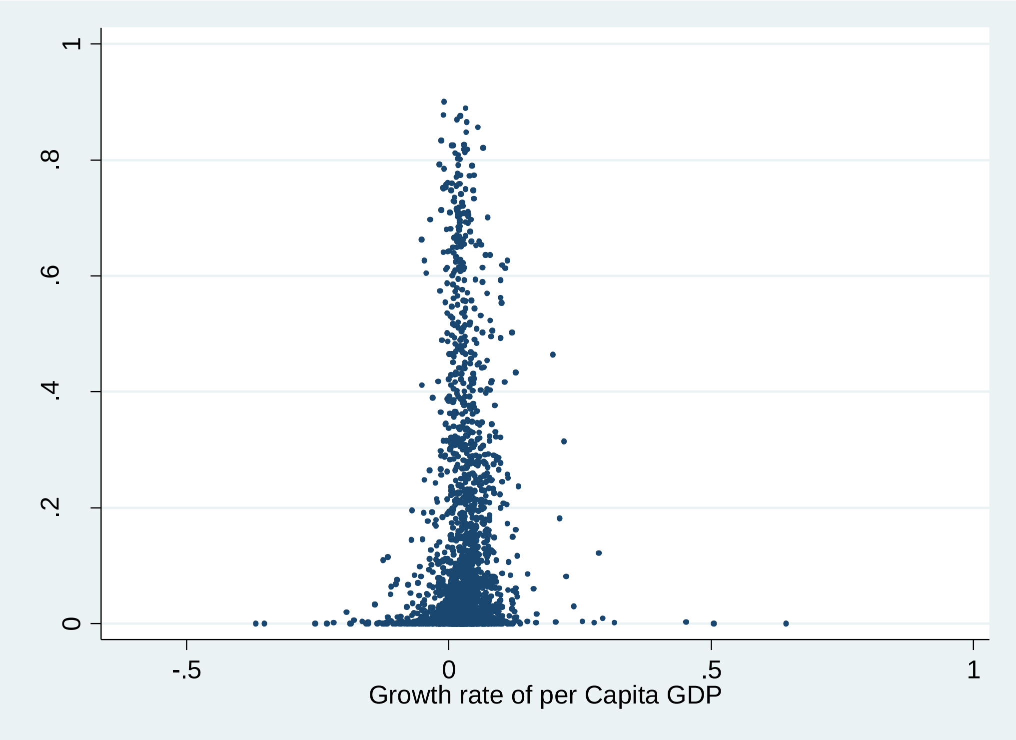

Table 1. Summary of the data

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
	between		5.44	4.85	29.94	n = 162
	within		3.31	-0.43	76.76	T-bar = 18.3
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 = 19.0
Tellines	overall	18.16	18.95	0	74.46	N = 3078
	between		18.46	.10	66.62	n = 162
	within		4.52	-.51	50.18	T-bar = 19
Mobile	overall	22.28	34.91459	0	188.30	N=3078
	between		17.41259	.3198387	67.45	n = 162
	within		30.29	-42.82	160.28	T-bar = 19

* N: total number of observation, n: number of groups, T-bar: average length of time series

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)
Lpop	Logarithm of population, total
area	Land area (sq. km)
Tellines	Number of telephone lines per 100 people
Mobile	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)

List of countries included[13]

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)

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

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)

Table 2a. Estimates of basic model

Dep var: growth rate of GDP per capita	(a) OLS	(b) OLS	(c) FE	(d) FE	(e) GMM	(f) System GMM
Log per capita GDP, lagged	-0.001 (0.001)	0.001 (0.001)	-0.046 (0.015)***	-0.081 (0.017)***	-0.218 (0.033)***	0.007 (0.005)
Per capita Internet use	0.020 (0.007)***	-0.005 (0.008)	0.025 (0.008)***	-0.021 (0.007)***	-0.028 (0.029)	-0.040 (0.024)
Investment/GDP ratio	0.181 (0.035)***	0.173 (0.036)***	0.206 (0.030)***	0.194 (0.029)***	0.255 (0.130)*	0.140 (0.041)***
Government expenditure/GDP ratio	-0.001 (0.000)***	-0.001 (0.000)***	-0.002 (0.001)***	-0.002 (0.001)***	-0.001 (0.001)**	-0.001 (0.000)***
Inflation	-0.004 (0.002)**	-0.004 (0.002)**	-0.005 (0.002)***	-0.005 (0.001)***	-0.005 (0.004)	-0.004 (0.002)*
Openess ratio	0.005 (0.003)*	0.004 (0.003)*	0.049 (0.010)***	0.034 (0.009)***	0.024 (0.013)*	0.003 (0.003)
time dummies	no	yes	no	yes	yes	yes
r2	0.173	0.210	0.179	0.251		
Sargan-Hansen against RE: chi2-value (p-value)			20.410 (0.002)	36.200 (0.039)		
Obs/Groups/Instr.	2200/161	2200/161	2200/161	2200/161	1910/161/129	2118/162/157
AB test for AR(2) in differences: z-value (p-value)					-1.840 (0.022)	-2.290 (0.022)
Hansen J-test for joint validity of instruments: chi2-value (p-value)					127.490 (0.086)	147.140 (0.190)
Diff-in-Hansen test GMM instr. For levels						8.770 (0.947)
Diff-in-Hansen test IV instr.					18.930 (0.650)	13.580 (0.916)
F autocorr. (p-value)			103.658 (0.000)	127.081 (0.000)		
Wald test time dummies equal to zero: F-value (p-value)		7.44 (0.000)		10.47 (0.000)	11.57 (0.000)	7.45 (0.000)

The robust test on overidentifying restrictions as proposed by Wooldridge (2002) p 190-191 is 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 if time dummies are included. In all cases the standard Hausman tests on non-robust estimates of the equivalent models maintain the same conclusions (test are not included in tables). Panel 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 validity of lagged variables as instruments (rejected here). GMM type instruments are used for all variables (except time dummies) using 2 to 3 lags. Hansen J-test shows the robust test of overidentification. The Difference-in-Hansen test for GMM instruments reports the joint validity of GMM-style instruments for levels (accepted here). A similar test statistics is given for IV instruments (here the time dummies only). (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 computed using the test for serial correlation in panel data as described by Wooldridge (2002) and Drukker

(2003). Standard errors are displayed in parentheses and significance levels are given as *** for p-values below 0.01, ** for 0.05 and * for 0.1. GMM models are estimated using Stata's xtabond2 (Roodman 2006).

Table 2b. Estimates of basic model

Dep var: growth rate of per capita GDP	(a)	(b)	(c)	(d)	(e)	(f)
	FE	FE, AR(1)	System GMM	FE	FE	System GMM
Log per capita GDP, lagged	0.083 (0.059)	-0.242 (0.222)***	0.311 (0.042)***			0.228 (0.061)***
two years lagged	-0.182 (0.051)***	0.106 (0.022)***	-0.311 (0.042)***	-0.105 (0.017)***	-0.080 (0.019)***	-0.232 (0.062)***
Per capita Internet use	0.062 (0.019)***	0.047 (0.025)*	0.075 (0.037)**	0.061 (0.019)***		
one year lagged	-0.025 (0.026)	-0.013 (0.032)	-0.026 (0.050)	-0.018 (0.024)		
two years lagged	-0.063 (0.018)***	-0.082 (0.026)***	-0.064 (0.033)*	-0.070 (0.018)***		
Investment/GDP ratio	0.192 (0.034)***	0.212 (0.022)***	0.148 (0.044)***	0.204 (0.030)***	0.125[a)] (0.033)***	0.194 (0.054)***
Government expenditure/GDP ratio	-0.002 (0.001)***	-0.002 (0.000)***	-0.001 (0.000)***	-0.002 (0.001)***	-0.001[a)] (0.001)*	-0.002 (0.001)***
Inflation, lagged	-0.003 (0.003)	0.001 (0.001)	-0.002 (0.002)	-0.003 (0.003)	-0.005 (0.002)***	-0.008 (0.005)
Openess ratio, lagged	0.035 (0.008)***	0.047 (0.008)***	0.028 (0.017)	0.039 (0.007)***	0.034 (0.012)***	0.021 (0.011)*
time dummies	yes	yes	yes	yes	Yes	yes
r2	0.271	0.241		0.264	0.202	
Sargan-Hansen against RE: chi2-value (p-value)	443.00 (0.000)	1066.01 (0.000)		216.57 (0.000)	243.82 (0.000)	
Obs/Groups/Instr.	1957/161	1796/160	1816/162/161	1957/161	2473/160	2446/161/147
AB test for AR(2) in diff: z-value (p-value)		-0.160 (0.873)				-0.64 (0.523)
Hansen J-: chi2-value (p-value)		148.280 (0.205)				139.72 (0.159)
Diff-in-Hansen test GMM instr.			49.180 (0.914)			23.660 (0.943)
Diff-in-Hansen test IV instr.			2.670 (0.849)			0.590 (0.442)
F autocorr. (p-value)	139.75 (0.000)			4.466 (0.036)		
Wald test time dummies jointly zero: F-val (p-val)	12.90 (0.000)	17.99 (0.000)	10.52 (0.000)	11.57 (0.000)	16.20 (0.000)	7.24 (0.000)
Wald test ∑Internet use=0: F-value (p-value)	7.37 (0.007)	13.91 (0.000)	1.04 (0.309)	6.79 (0.010)		
Rho AR(1)		0.3674			0.192	
Bhargave Durbin Watson		1.789			1.632	
Baltagi-Wu LBI		1.996			1.843	

a) Investment/GDP ratio and government expenditures one year lagged. Other notes: see Table 2a

Table 3. Granger causality

	MaxLag	iupc>tradegdp	lgdppc>tradegdp
Level	2	23.45 (0.000)	1.69 (0.184)
Growth rates	3	2.17 (0.090)	8.48 (0.000)
		tradegdp>iupc	lgdppc>iupc
Level	4	5.46 (0.000)	16.51 (0.000)
Growth rates	4	5.75 (0.000)	2.28 (0.058)
		tradegdp>lgdppc	iupc>lgdppc
Level	4	6.79 (0.000)	4.34 (0.002)
Growth rates	4	8.58 (0.000)	7.38 (0.000)
		iupc>tradegdp	dlgdppc>tradegdp
Level	**5**	**7.85 (0.000)**	**4.61 (0.000)**
		tradegdp>iupc	dlgdppc>iupc
Level	4	6.39 (0.000)	1.89 (0.110)
		tradegdp>dlgdppc	iupc>dlgdppc
Level	5	7.80 (0.000)	2.16 (0.072)

Models are estimated using a fixed effects estimator. Maxlag is determined by starting at lag length equal to 5 and reducing (if needed) the lag length until all coefficients at this longest lag are jointly significant at 5% level. x>y denotes x is Granger causing y. The table lists F-statistics and the p-values. Variables included are: iupc: Per Capita Internet use; tradegdp: openness ratio; lgdppc: log of per capita GDP. dlgdppc stands for the growth rate of per capita GDP.

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
Log per capita GDP			0.054 (0.020)***	0.038 (0.031)
group average	0.017 (0.014)	-0.006 (0.028)		
within difference	0.255 (0.080)***	0.063 (0.052)		
Per capita Internet use			0.243 (0.027)***	0.336 (0.077)***
group average	0.666 (0.220)***	1.152 (0.413)***		
within difference	0.392 (0.161)**	0.246 (0.035)***		
Area	-1.047 (0.146)***	-1.157 (0.397)***	-1.394 (0.569)**	-0.954 (0.377)**
Area squared	0.001 (0.000)***	0.001 (0.000)**	0.001 (0.000)**	0.001 (0.000)***
log of population size	-0.088 (0.008)***	-0.072 (0.030)**	-0.061 (0.022)***	-0.088 (0.021)***
time dummies	no	yes	yes	yes
r2	0.296	0.291		
Obs/Groups/Instr.	2364	2364/162	2364/162	2364/162/127
AB-test AR(1): z-val (p-val)				0.23 (0.816)
AB-test AR(2): z-val (p-val)				-1.68 (0.093)
Hansen J-test for joint validity of instruments: chi2-value (p-value)				119.55 (0.141)
Hansen test incl GMM instr.				19.34 (0.989)
Dif-in-Hansen exog IV instr.				21.48 (0.369)
Wald test time dummies equal to zero: F-value (p-value)	.86 (0.618)	52.25 (0.000)	82.76 (0.000)	6.37 (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, land and land 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 *** for p-values below 0.01, ** for 0.05 and * for 0.1.

Table 5. 3SLS regression results on simultaneous model

Dep var: growth rate of GDP per capita	(a) 3SLS	(b) 3SLS
Log per capita GDP, two years lagged	-0.137 (0.010)***	-0.138 (0.009)***
Investment/GDP ratio, lagged	0.148 (0.026)***	0.146 (0.026)***
Government expenditure/GDP ratio, lagged (*E-03)	-0.127 (0.313)	-0.173 (0.305)
Inflation, lagged	-0.003 (0.001)***	-0.003 (0.001)***
Openness ratio, two years lagged	0.120 (0.030)***	0.093 (0.028)***
time dummies	yes	yes
country dummies	yes	yes
Wald test time dummies equal to zero: Chi2-value (p-value)	116.29 (0.000)	265.86 (0.000)
Wald test country dummies equal to zero: Chi2-value (p-value)	1140.14 (0.000)	1182.13 (0.000)
Dep var: openness ratio		
Log per capita GDP:		
group average	0.014 (0.011)	0.011 (0.011)
within difference	0.401 (0.080)***	0.509 (0.064)***
Per capita Internet use:		
group average	0.774 (0.153)***	0.709 (0.152)***
within difference	-0.016 (0.079)	0.123 (0.066)*
Area	-1.072 (0.134)***	-1.065 (0.134)***
Area squared	0.001 (0.000)***	0.001 (0.000)***
log of population size	-0.081 (0.006)***	-0.084 (0.006)***
time dummies	yes	no
country dummies	no	no
Wald test time dummies equal to zero: Chi2-value (p-value)	14.38 (0.570)	--
Nr Observations	1951	1951

Notes: Estimation is by three-stage least squares for both equations simultaneously. Model (a) includes time dummies in both equations, model (b) only time dummies in the growth equation. Instruments are log of per capita GDP two years lagged; investment ratio two years lagged; government expenditure as ratio of GDP: two years lagged; inflation rate lagged; log of per capita GDP: group average and within difference: lagged; Internet use per capita: group average and within difference: one and two years lagged. Standard errors are displayed in parentheses and significance levels are given as *** for p-values below 0.01, ** for 0.05 and * for 0.1.