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The effect of the Internet on economic growth: Counter-evidence from cross-country panel data.

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Abstract

Choi and Yi (2009) found evidence that the Internet stimulated economic growth in the 1990-2000 period using cross-country panel data. When extending the period to 2015, similar regressions indicate negative and significant effects of the Internet on growth.

Keywords: Internet, Growth, Panel data.

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1. Introduction

The effects of *Information and communications technologies* (ICT) on economic growth have been the subject of much research.[1] Supplemented with the internet, ICT has transformed production processes in most industries in many countries. ICT is omnipresent. The Internet provides all users everywhere with access to unlimited amounts of information and contact with any other user anywhere. ICT is a general purpose technology (see e.g. Quah, 2003). ICT is network technology. Utility and productivity effects from use of ICT increase with the number of users. Prices for ICT goods have decreased dramatically (Jorgenson, 2005).

Despite the obvious important effects of ICT for the economy and for society in general, growth effects from ICT have been hard to find in macro data. Trend growth rates have been falling for decades. This is denoted the *Solow-paradox*.[2]

In the 1990s, US growth rates increased. Many attributed this to ICT (see e.g. Cordona *et al*, 2013). The interpretation was that "Computers are now everywhere in our productivity statistics" (Acemoglu *et al*, 2014).

Since the 1990s, the Internet has supplemented ICTs. Diffusion of the Internet has been fast. Included in the World Bank's *World Development Indicators* are data for the share of countries' populations that have used the Internet during the last year (World Bank, 2017).[3] Almost half of world's population is now (2018) internet users. The share of internet users varies between countries. In 2015, 96 per cent of Danes were internet users. In Eritrea, about 1 per cent reported to have used the Internet in 2015. There is also much time variation in the period from 1990 to 2015. Diffusion has varied considerably between countries.

Choi and Yi (2009) used the above data to investigate growth effects from the Internet. They found positive and significant effects from the Internet on economic growth. A one percentage point increase in the share of internet users was associated with an increase in the growth rate of about 0.05 percentage point. This result was robust to econometric specification. Choi and Yi reported results from pooled OLS, random effects, fixed effects, time fixed effects and panel GMM regressions. All results indicated significant growth effects from the Internet of about the same size.

In this paper results from similar regressions are reported. For the same period that was studied by Choi and Yi, the results are almost identical. For the 1990-2015 period, however, growth effects from the Internet are negative and significant. They are strongly so for the post 2000 period.

The next section present the empirical specification and data used. Results are presented in section 3. Section 4 concludes with a short discussion.

2. Data and empirical specification

Choi and Yi extend a standard panel data growth regression (as in Barro, 1997) with the share of internet users in countries' populations. The dependent variable is countries' yearly growth

[1] See e.g. surveys by Maurseth (2017), Brynjulfsson and McAfee (2014) or Cardona *et al.* (2013).
[2] Solow (1987) marked «You can see the computer everywhere but in the productivity statistics».
[3] The data are collected by the World Telecommunication Union.

rates in GDP per capita. They include as explanatory variables countries' investment rates, government expenditures as shares of GDP and inflation rates. They do not, however, include lagged GDP per capita in their regressions. Their regression equation is

1) $$Growth_{it} = \alpha_0 + \alpha_1 Internet_{it} + \alpha_2 Investment_{it} + \alpha_3 Government_{it} + \alpha_4 Inflation + u_{it}$$

where $u_{it}=\eta_i+v_t+\varepsilon_{it}$. η_i is an individual country fixed effect, v_t is a year dummy and ε_{it} is assumed idependently and identically distributed among country-years. Subscript *it* denotes country *i* in year *t*.

In order to re-run these regressions, data from *World Development Report* was downloaded. GDP per capita (PPP) in constant 2011 USD were used to measure GDP per capita. Gross fixed capital formation as share of GDP was used to measure investments. Government expenditures are included to indicate potential tax distortions.[4] Inflation is increase in consumer price indexes and is included to indicate macroeconomic instability. These data were supplemented with the share of internet users across countries and over time.[5]

In total 171 countries are included in the regressions. The panel is unbalanced due to data coverage, but also because some countries disappears from the dataset and some countries gain independence.

3. Results

Results are reported in table 1. Equation 1 was estimated with the same estimation methods as in Choi and Yi: a) pooled ordinary least squares (OLS), b) individual random effects, c) individual fixed effects, d) time fixed effects, e) individual random effects and time fixed effects and f) a panel generalized method of moments (GMM). The GMM estimation takes into account endogeneity by using lagged levels of all the variables as instruments. This model was estimated with STATA's *xtdpd* command that allows GMM models to be run without the lagged endogenous variable as explanatory variable (as in Choi and Yi). The *xtdpd* commands also avoid loss of observations due to lagging variables. Table 1 reports results from the 1990-2000 period (as in Choi and Yi), for the entire 1990-2015 period as well as for the 2000-2015 period.

<u>Insert table 1 here</u>

For the GMM estimations, an important assumption is zero second order autocorrelation. This was tested with the Arellano-bond test. For the 1990-2000 period, the null hypothesis was not rejected. But there were signs of second order autocorrelation for later periods.

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[4] The variable is *General government final consumption expenditure*. Choi and Yi do not mention that if government expenditures are counter cyclical, they will tend to correlate negatively with yearly growth rates.

[5] The raw data for the share of internet users in populations are reported with missing values for many countries in the first years. In the cases were the first non-missing numbers were less than five per cent and the previous numbers were missing, these were substituted with zeros. Intermediate missing observation were substituted with the average of the value the period before and the period after the missing observation. These were few cases.

Therefore, also a dynamic panel data (DPD) model which included lagged growth rates as explanatory variables was estimated. Results are reported in the first column in Table 2. The second column reports results when also time dummies were included. The modelling procedure gives a large number of instruments. A question is whether the overidentification restrictions are valid. This was tested with the Sargan test for validity of the overidentifying restrictions. The null-hypothesis was not rejected for any of the models.

To check for robustness, auxiliary models were estimated. Table 2 also reports these results. The third column is for a model with both fixed individual and time fixed effects. The fourth column is for a model in which the share of services in GDP was included to control for Baumol's disease (Baumol, 1967). The fifth column reports results from a GMM model with time fixed effects included.

Insert table 2 here

The results give support to Choi and Yi's findings for the 1990-2000 period. The coefficients for the share of internet users are positive and significant and of about the same size as in Choi and Yi. Column 1 in table 1 indicate that when the internet-user ratio increases by 1 % point, the growth rate increased by 0.073 % point (Choi and Yi's estimate was 0.057 % point). The auxiliary regressions (table 2) give similar results. The exception is for fixed effects regressions with time fixed effects included (the coefficient is significant at the ten percent level) and when the lagged dependent variable was included. For latter, the coefficient is significant only when time fixed effects were included.

The coefficients for investments, government expenditures and inflation are positive (significant), negative (most often significant) and negative (most often not significant), respectively.

The results change when the period is extended to 2015. For this period, the coefficients for the share of internet users are negative and significant in all regressions. Separate regressions for the 2001-2015 period resulted in even larger negative effects. Results for government consumption (sign and significance), investments (significance) and inflation (sign and significance) are not robust to econometric specification. Inclusion of services did not alter the results.

Also other models were estimated, but results are not reported here. A dummy for USA and EU countries for 2007-09 was included (to test whether the financial crisis influenced on the results). Interaction terms with GDP and openness to trade were included. Lagged (log of) GDP per capita was included to capture convergence. The results for the effects of the Internet were the same as those reported in tables 1 and 2 (in terms of sign and significance).

4. Conclusions

Choi and Yi concluded that they "found evidence that the Internet plays a positive and significant role in economic growth ..". In this paper I have extended the time period to 2015. The results are the opposite of those found by Choi and Yi. Gordon (2002) compared the promises of the computer with other important innovations in the 20th century and concludes that (p. 50):

"It is quite plausible that the greatest benefits of the computer lie a decade or more in the past, not in the future."

I hesitate to conclude that my findings lend support to Gordon. Regressions, even fixed effects panel data regressions or panel GMM data regressions, reveal correlations, not causation. Several studies using more disaggregated data or appropriate instrument variables indicate varying effects from the Internet at firm or industry levels, or for smaller samples of countries (as e.g. Acemoglu *et al.* (2014), Czernich *et al.* (2011) and Akerman *et al.* (2015)). Acemoglu *et al.* conclude that "Prior declarations of the death of the Solow Paradox may have been premature." The findings presented here support their conclusion.

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Table 1

	Pooled OLS	Random effects	Fixed effects	Time dummies	Random effects with time dummies	Panel GMM
1990-2000						
Internet	7.353*** (1.173)	7.253*** (1.261)	5.327*** (1.211)	6.238*** (1.284)	6.037*** (1.407)	4.446** (1.957
Investment	0.178*** (0.042)	0.174*** (0.014)	0.141*** (0.030)	0.177*** (0.041)	0.174*** (0.123)	0.081** (0.035)
Government	-0.131*** (0.028)	-0.165*** (0.037)	-0.423*** (0.100)	-0.122*** 0.027)	-0.142*** (0.034)	-0.647*** (0.154)
Inflation	-0.0009 (0.0006)	-0.0007* (0.0004)	-0.0005 (0.0004)	-0.0009* (0.0005)	-0.0008* (0.0004)	-0.0003 (0.0002)
R^2	0.22	0.22	0.13	0.24	0.24	
N	1386	1386	1386	1386	1386	1386
1990-2015						
Internet	-0.736*** (0.282)	-1.167*** (0.283)	-1.456*** (0.309)	-0.931** (0.360)	-1.855*** (0.506)	-3.333*** (0.922)
Investment	0.165*** (0.025)	0.161*** (0.021)	0.155*** (0.027)	0.165*** (0.026)	0.159*** (0.023)	0.096 (0.091)
Government	-0.080*** (0.018)	-0.104** (0.046)	-0.184*** (0.068)	-0.074*** (0.018)	-0.078** (0.035)	-0.426 (0.378)
Inflation	-0.0007** (0.0003)	-0.0006** (0.0002)	-0.0006** (0.0002)	-0.0006*** (0.0003)	-0.0006*** (0.0002)	-0.0001 (0.0001)
R^2	0.13	0.13	0.11	0.19	0.20	
N	3781	3781	3781	3781	3781	3781
2001-2015						
Internet	-1.987*** (0.344)	-2.983*** (0.497)	-5.034*** (0.845)	-1.343*** (0.377)	-5.357*** (1.969)	-6.175*** (0.970)
Investment	0.144*** (0.000)	0.147*** (0.030)	0.143*** (0.039)	0.145*** (0.023)	0.138*** (0.047)	0.195*** (0.034)
Government	-0.057*** (0.020)	-0.058* (0.033)	-0.086 (0.070)	-0.054** (0.021)	-0.020 (0.062)	0.081 (0.056)
Inflation	-0.0003*** (0.0000)	-0.0002*** (0.0000)	-0.0002*** (0.0000)	-0.0003*** (0.0001)	-0.0002*** (0.000)	0.0003 0.0002
R^2	0.09	0.08	0.07	0.16	0.15	
N	2395	2395	2395	2395	2395	2395

Note: Results for constants and year dummies are not reported. *, ** and *** denotes significance at 10%, 5% and 1% levels, respectively. Standard errors are heteroscedasticity robust. Standard errors for GMM model are calculated as proposed by Windmeijer (2005). Instruments for differenced equation in GMM model are $Growth_{t-2,t-3}$, $Internet_{t-2,t-3}$, $Investment_{t-2,t-3}$, $Government_{t-2,t-3}$, $Inflation_{t-2,t-3}$. Chi2 from Sargan tests for overidentifying (p-value): 96.11 (0.09), 169.93 (0.99), 164.49 (0.14) for 1990-2000, 1990-2015 and 2001-2015 estimations, respectively. Arellano-Bond test for 2. order autocorrelation (p-values): 0.18, 0.01, 0.01 for 1990-2000, 1990-2015 and 2001-2015 estimations, respectively.

Table 2

	DPD with lagged end.	DPD with lagged end. and time dummies	Fixed effects with time dummies	Fixed effects with services	Panel GMM with time dummies
1990-2000					
L.growth	0.196*** (0.047)	0.177*** (0.050)			
Internet	0.840 (2.571)	5.891*** (2.147)	3.621* (2.078)	4.539*** (1.438)	5.814** (2.679)
Investment	0.002 (0.051)	-0.045 (0.061)	0.135*** (0.030)	0.812 (0.521)	0.009 (0.033)
Government	-0.826*** (0.254)	-0.565** (0.265)	-0.383*** (0.097)	-0.403*** (0.115)	-0.282 (0.217)
Inflation	-0.0001 (0.0001)	-0.0001 (0.000)	-0.0004 (0.0004)	-0.0004 (0.0004)	-0.0002 (0.0002)
Services				0.003 (0.046)	
R^2			0.15	0.05	
N	1254	1254	1386	1219	1386
1990-2015					
L.growth	0.145** (0.059)	0.128** (0.058)			
Internet	-3.370*** (0.930)	-2.589*** (0.641)	-3.492*** (0.829)	-1.766*** (0.423)	-5.217** (2.350)
Investment	0.066 (0.083)	0.098** (0.041)	0.147*** (0.034)	0.123*** (0.023)	0.131*** (0.036)
Government	-0.395 (0.405)	-0.095 (0.208)	-0.129** (0.062)	-0.195*** (0.066)	-0.061 (0.167)
Inflation	-0.000 (0.0002)	0.000 (0.0001)	-0.0005*** (0.0002)	-0.0006*** (0.0002)	0.0000 (0.0001)
Services				0.013 (0.028)	
R^2			0.18	0.06	
N	3648	3648	3781	3420	3781
2001-2015					
L.growth	0.111 (0.069)	0.104 (0.073)			
Internet	-5.658*** (0.945)	-11.978*** (2.898)	-5.357*** (1.969)	-9.033*** (1.520)	-6.175*** (0.970)
Investment	0.117** (0.050)	0.201*** (0.039)	0.138*** (0.047)	0.166*** (0.034)	0.195*** (0.034)
Government	-0.221 (0.198)	0.134 (0.082)	-0.020 (0.062)	-0.124* (0.072)	0.081 (0.057)
Inflation	0.0001 (0.0002)	0.0002 (0.0001)	-0.0002*** (0.0000)	-0.0002*** (0.0000)	0.0003 (0.0002)
Services				-0.016 (0.052)	
R^2			0.15	0.01	
N	2394	2394	2395	2201	2395

Note: Results for constants and year dummies are not reported. *, ** and *** denotes significance at 10%, 5% and 1% levels, respectively. Standard errors are heteroscedasticity robust. Standard errors for GMM and DPD model are calculated as proposed by Windmeijer (2005). Instruments for differenced equation in GMM and DPD model are $Growth_{t-2,t-3}$, $Internet_{t-2,t-3}$, $Investment_{t-2,t-3}$, $Government_{t-2,t-3}$, $Inflation_{t-2,t-3}$. Chi2 from Sargan tests for overidentifying (p-value): 74.27 (0.34), 169.93 (0.99), 164.49 (0.14) for 1990-2000, 1990-2015 and 2001-2015 estimations, respectively. Arellano-Bond test for 2. order autocorrelation (p-values): 0.18, 0.01, 0.01 for 1990-2000, 1990-2015 and 2001-2015 estimations, respectively.