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Measuring the Effect of Internet Adoption on Paper Consumption

Luis Andrés
Alejandro Zentner
Joaquín Zentner

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Sustainable Development Department
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Abstract

A large fraction of the total supply of paper is produced with technologies that have serious adverse consequences on the environment and cause significant health problems, such as cancer. This paper reports on how Internet adoption affects paper consumption. The study used country-level panel data on Internet penetration and paper consumption disaggregated into various paper categories. The empirical strategy is to use fixed-effect models to study whether countries with faster Internet penetration growth have experienced faster declines in paper consumption. The analysis finds that Internet penetration significantly decreases aggregate paper consumption. Further, the estimates show that Internet growth reduces consumption for the paper categories that are more likely to be affected by the diffusion of the Internet (paper used to print newspapers and books and magazines), whereas the growth of the Internet does not have a statistically significant impact on a paper category unlikely to be affected by the Internet (such as sanitary paper).

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Measuring the Effect of Internet Adoption on Paper Consumption

Luis Andrés, Alejandro Zentner, and Joaquín Zentner[1]

Key words: Internet adoption, paper consumption, contamination, fixed effect model
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[1] Luis Andrés is Lead Economist in the sustainable Development Department for the South Asia Region at World Bank, Alejandro Zentner is Associate Professor of Managerial Economics of the Naveen Jindal School of Management at University of Texas at Dallas, and Joaquín Zentner is a PhD student at the Universidad Catolica Argentina. They are grateful to Marianne Fay for her comments and suggestions. Financial support from the World Bank Research Support Budget (RSB) is gratefully acknowledged.
Authors' email addresses are: landres@worldbank.org, azentner@utdallas.edu, and joaquinzentner@hotmail.com .

I. Introduction

A large fraction of the total supply of paper is produced using technologies that have serious adverse consequences on the environment and human health. For example, in the United States the pulp and paper industry ranks third in air, water, and land pollution, following the chemical and primary metals industries (National Pollutant Release Inventory, 1996). The pulp and paper industry also represents the fourth-largest global industrial energy user (6.4 EJ in 2005) as well as a significant source of greenhouse gas emissions.[2] Paper production generates greenhouse gas emissions both directly via the production process and indirectly via greenhouse gas emissions associated with the off-site generation of steam and electricity used by paper mills (Energy Information Administration, 2009). Furthermore, the dioxins released in the production of paper increase the likelihood of contracting various types of cancer (Thompson et al. 2001; Sumathi and Hung 2006, World Health Organization 2010).[3]

State agencies and non-governmental organizations have invested substantial effort and resources in order to ameliorate the negative effects that paper production imposes on both the environment and human health. These efforts have mainly focused on promoting the development and use of cleaner production technologies as well as changing and enforcing regulations (e.g., the Clean Air Act in the United States). However, paper production and therefore pollution may also fall when the demand for paper decreases, and then it becomes important to examine the factors affecting paper consumption.

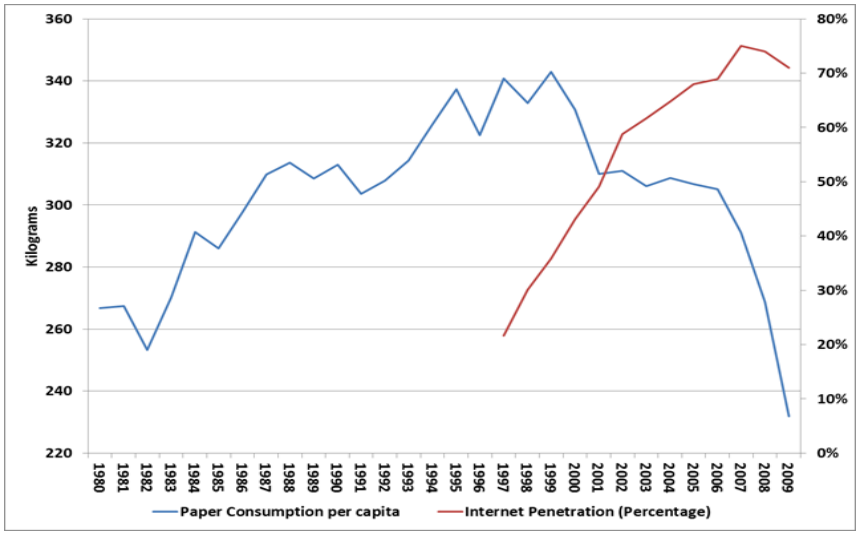
In this paper we focus on examining how Internet adoption affects paper consumption. There are various ways by which the Internet may displace paper consumption. For example, reading online newspapers and magazines, adopting

[2] http://www.iea.org/publications/freepublications/publication/Indicators_2008.pdf
[3] http://www.who.int/mediacentre/factsheets/fs225/en/

paperless billing, online advertising substituting for mail advertising, online phonebooks replacing physical phonebooks, the use of email, eBooks, and electronic documents are all likely to displace paper consumption.

As a first approximation, examining trends in paper consumption reveals interesting patterns. A long-term increasing paper consumption trend in the United States came to an end by 1999, and has been followed by a deep paper consumption decline (see Figure 1). This figure shows that the decline in paper consumption coincides with a period of fast diffusion of the Internet in the United States, but can we attribute the decline in paper consumption to the increase in Internet adoption? In this paper we seek to measure the causal impact of the increase in Internet adoption on paper consumption.

Figure 1. Internet Penetration and Paper Consumption in the United States

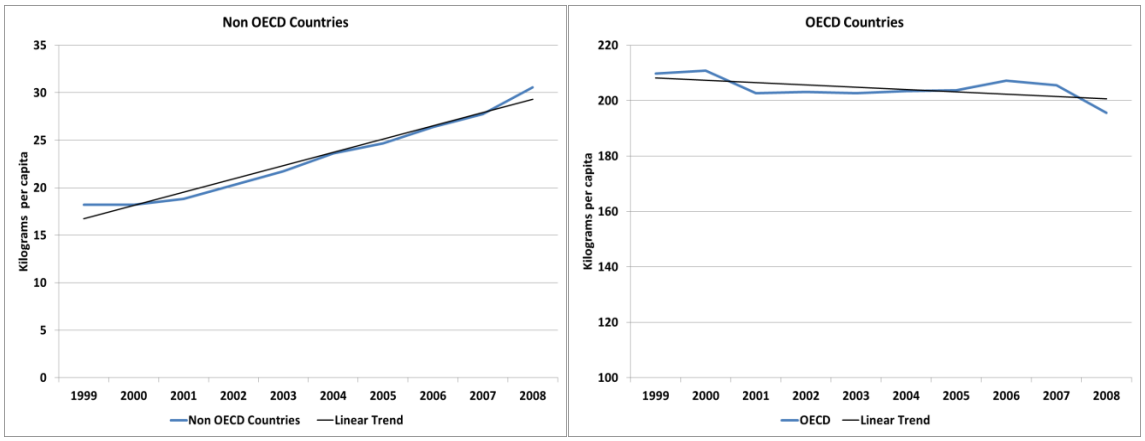


Source: Food and Agriculture Organization of the United Nations (paper consumption) and International Telecommunication Union (Internet penetration). The decrease in the Internet penetration rate following year 2008 might be due to the financial crisis.

It is also revealing to examine paper consumption trends for other countries. When examining paper consumption for other countries we can establish a divide between the consumption trends in more developed versus less developed countries. For example, in Figure 2 we show the average consumption trends for OECD versus non-

OECD countries. The figure shows a clear upward trend in paper consumption for non-OECD countries, while the consumption for OECD countries shows a slightly decaying trend. The different trends in Figure 2 for more and less developed countries may also suggest that Internet diffusion has reduced paper consumption because Internet penetration has grown faster in more developed countries.

Figure 2. Paper Consumption in OECD and non-OECD Countries[4]



In this paper we use country-level panel data on paper consumption and Internet penetration for ten years of data in order to study how the advent of the Internet affected paper consumption. By using a fixed effect model we examine whether countries with faster Internet penetration growth have experienced faster declines in paper consumption, and we find that Internet penetration significantly decreases

[4] The data used in Figure 2 come from the Food and Agricultural Organization of the United Nations and the International Monetary Fund. Because our panel is unbalanced, in order to facilitate the interpretation of the yearly evolution of paper consumption, Figure 2 uses balanced panels of countries. Our sample of OECD countries includes data from Australia, Austria, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Mexico, Norway, New Zealand, Netherlands, Poland, Portugal, Spain, Sweden, Turkey, United Kingdom, and United States. Our sample of non-OECD countries includes data from Albania, Algeria, Angola, Argentina, Bangladesh, Belarus, Bolivia, Brazil, Bulgaria, Cameroon, China, Colombia, Congo, Costa Rica, Croatia, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Russia, Philippines , Guatemala, Honduras, India, Indonesia, Iran, Jamaica, Jordan, Kenya, Latvia, Lebanon, Lithuania, Macedonia, Madagascar, Malaysia, Morocco, Mozambique, Myanmar, Nepal, Nigeria, Pakistan , Panama, Paraguay, Peru, Romania, Singapore, Sri Lanka, the Republic of Korea, Sudan, Syria, Thailand, Tanzania, Tunisia, Uganda, Ukraine, Uruguay, Venezuela, Vietnam, and Zambia. If we exclude the United States from the list of OECD countries this group of countries shows a slightly positive upward trend, which is much smaller in size than the large upward trend for non-OECD countries.

aggregate paper consumption. Our data on paper consumption is further disaggregated by paper category, including categories that are more likely to be affected by the use of the Internet (e.g., paper to produce newspapers or magazines) and a category that is less likely to be affected by the use of the Internet (i.e., paper used for domestic purposes). Our estimates show that Internet growth reduces consumption for the paper categories that are more likely to be affected by the diffusion of the Internet, whereas the growth of the Internet does not have a statistically significant impact on the paper category unlikely to be affected by the Internet.

The outline of the remainder of the paper is as follows. The next section summarizes some related literature. Section 3 presents some technological aspects concerning paper production, and also summarizes some health consequences arising from paper production. Section 4 provides some details concerning our data. Section 5 lays out the model and empirical strategy. Section 6 presents the estimation results. Section 7 quantifies the positive environmental effects arising from the reduction in paper consumption caused by growth in Internet use. Section 8 presents the results from further empirical examinations. The final section offers some conclusions.

2. Related Literature

While there are many studies examining the paper industry and also many studies examining how the diffusion of the Internet affected various markets (e.g., there exists a substantial amount of research regarding e-commerce, Internet piracy, and how Internet adoption affected media industries such as the television or the newspaper industries), only two studies examine how information and communication technologies affect paper consumption (Zhang and Buongiorno 1997 and Hujala 2011). This is surprising given the known environmental consequences of paper production.

Prior to the diffusion of the Internet, several studies estimated price and income elasticities of the demand for paper and paperboard products. For example, Buongiorno (1978) used a panel of data for the years 1963 through 1973 from 43 countries to estimate income and price elasticities for the demand for various paper categories: newsprint, printing and writing paper, and other paper and paperboard. Baudin and Lunderberg (1987) estimated price and income elasticities based on a panel of data from 56 countries for the period of 1961 through 1981. Zhang and Buongiorno (1998) examined the demand for paper by focusing on the substitution between paper and plastic in the US packaging market. Chas-Mail and Buongiorno (2000) used panel data to estimate demand equations for 14 European Union countries for the period of 1969 to 1995. McCarthy and Lei (2010) estimated a dynamic demand model for pulp and paper products in four major trading regions: Asia, Europe, the North American Free Trade Agreement Area (NAFTA), and South America, based on a panel of data available for the years 1961 through 2000 from the United Nations Food and Agricultural Organization. A common finding across all these studies has been the historically low price and income elasticities of the demand for paper and paperboard. Information on the elasticity of the demand for paper is crucial for policy design. For example, the price and income elasticities of the demand for paper are immediately linked to the effectiveness of taxes seeking to reduce the negative externalities arising from the production of paper.

Another strand of literature studies the determinants of Internet usage. Andres et al. (2010) analyze the process of Internet diffusion across the world using a panel of 214 countries during the period 1990–2004. Their estimated diffusion curves provide evidence of slow "catching up." The paper also explores the determinants of Internet diffusion and shows that network effects are crucial to explain this process. Furthermore, Chinn and Fairlie (2007) use panel data of 161 countries for the years 1999-2001 to identify the determinants in cross-country disparities in the usage of personal computers and Internet. Although income differences play a major role in explaining the digital divide, Chinn and Fairlie show that there are other important determinants such as regulatory quality and level of infrastructure. Estache et al.

(2002) also analyze the determinants of differences in Internet usage across countries and use their results to provide some policy recommendations for the Latin America region. Some other papers have focused on Internet diffusion. For example, Chong and Micco (2003) study the spread of Internet in Latin America and argue that in spite of being latecomers, Latin American countries have the advantage of lower costs of adoption and could easily catch up with technological leaders. They also find that a country's capacity to innovate helps explain the extent to which Internet is adopted. In a similar framework, Beilock and Dimitrova (2003) find that per capita income is one of the most important factors behind these differences. Their results also suggest that this effect is non-linear, with income differences having a larger effect in the use of Internet at lower income levels. Guillén and Suárez (2005) focus on the effect of economic, political and sociological factors on Internet usage.

The study of how the diffusion of the Internet has affected various markets has received substantial academic attention (a few examples include Goolsbee 2000 examining how taxes affect online versus offline channel selection, Goolsbee 2002 examining how the Internet can make markets more competitive, Brynjolfson and Smith 2003 examining how e-commerce can generate sales distributions with long tails, Zentner 2006 examining how piracy reduces the sales of recorded music, and Liebowitz and Zentner 2012 examining how Internet use affects the consumption of television). In this literature some studies have examined how digital content has affected the demand for printed content, which is more related to our study because printed content readership affects paper consumption. For example, Gentzkow (2007) estimated the substitution of print and online papers using micro data from Washington, DC. Similarly, Filistrucchi (2005) estimated the relationship between online newspapers and print papers using data from the main national daily newspapers in Italy, documenting that newspapers reduce the sales of print papers when they begin offering their content online. Simon and Kadiyali (2007) examined how offering digital content affects the demand for print magazines, finding that the provision of digital content cannibalizes the sales of print magazines.

Surprisingly, only two studies focus on estimating the effect of information and communication technologies (ICT) on the consumption of paper. Zhang and Buongiorno (1997) developed a model to estimate the effects of computers, televisions, and radios on the demand for printed materials in the USA. While this study did not find that ICT affected the demand for paper, it focused on a period of time when the Internet was in its infant stages of development. Hujala (2011) focused on how Internet adoption affected paper consumption using data at the country level and therefore her paper is more closely related to our study. She used a regression analysis model and a large global scale panel data from 1990–2007 to analyses the effect of ICT on paper demand for three paper grades: newsprint, office paper and magazine paper. Her results show that the Internet is a substitute for newsprint paper and possibly for magazine paper, and she also finds that both mobile telephones and a growing number of personal computers increase office paper consumption.

Our study uses a panel of data at the country level and complements the previous literature in several important dimensions. We created a data set combining several sources and therefore use different data than in previous studies. Our data on paper consumption come from the Food and Agriculture Organization of the United Nations and include 66 countries. Our data include information regarding a paper category that is unlikely to be affected by the rise in Internet use (Household and Sanitary paper), allowing us to conduct a falsification test. Our estimates are somewhat different than in Hujala (2011), which is the closest reference. While we find that the consumption of the paper categories that are more likely to be displaced by the Internet (newsprint) decreases substantially when Internet penetration increases, Hujala (2011) finds that the displacement for this paper category is negative but very small (nearly zero). These differences may arise from our use of different data or may also be due to our differing identification approach, which includes year effects to account for the possibility of correlated time trends in Internet adoption and paper consumption.

3. The Pulp and Paper Industry: Some Technical Aspects and Health Related Consequences

3a. Technical Paper Production Aspects

Paper production consists basically of removing lignin from wood pulp. There are two steps in the production of paper: paper pulp production (or pulping) and bleaching.

The pulping can be done either mechanically or chemically: a) Mechanical paper pulp production is more efficient in terms of the amount of wood used per ton of paper pulp (i.e., mechanical production employs less wood per ton of paper pulp). However, the final paper obtained using this method retains residual lignin and has a yellowish color. This paper is typically used for newspapers because of its low quality; and b) Chemical paper pulp production generates a paper of higher quality. This method separates the lignin from the wood pulp through hydrolysis at high temperature. In the process of production of paper pulp, wood is chipped and then a cooked with chemicals. In turn, the cooking can be carried out in three ways: Kraft or sulphate, sulphite, and chemical thermo-mechanical.

The second step for removing lignin from paper pulp is called 'bleaching.' When the pulping is done mechanically in the first stage, the bleaching usually takes place using hydrogen peroxide. While hydrogen peroxide attenuates the color by changing the lignin structure, it does not completely remove the lignin, which results in low quality paper.

When the pulping is done chemically in the first stage, the bleaching is done using the following three methods (sorted according to their polluting effects): a) Conventional: using highly polluting chlorine gas as it generates organochlorine compounds (especially dioxins). This is the most polluting production method; b)

Elemental Chlorine Free (ECF): using chlorine dioxide. Its effluents contain halogenated organic compounds and dioxins, but less than when using the conventional method; and c) Totally Chlorine Free (TCF): using ozone and hydrogen peroxide. This method generates fewer negative effects on health and the environment than the two previous methods. However, its use is limited because it has higher costs. Furthermore, this method cannot be used for the production of all types of paper.

Because clean paper production technologies have higher costs, a large part of the current production is done using highly polluting technologies: using Kraft pulping and Elemental Chlorine Free bleaching method currently takes the highest share of the total paper production.[5]

3b. Paper Production and Human Health

The dioxins generated in the production of paper are harmful to health according to the World Health Organization[6] The World Bank has some lending operations with the objective of reducing the amount of dioxins caused by the Pulp and Paper industry.[7] The most common toxicological effects that researchers attribute to dioxin are cancer, birth defects, immune system effects, effects on male and female reproductive system, impacts on child development, and hormonal effects. For example, the following studies link dioxins to serious health problems:

a) **Cancer:** In 1997 dioxin were categorized as a "known human carcinogen" by the International Agency for Research on Cancer (IARC) - a division of the World Health Organization (WHO). Also, a study by the U.S. National Institute

[5] http://www.greenpeace.org/argentina/Global/argentina/report/2006/4/el-futuro-de-la-producci-n-de.pdf
[6] http://www.who.int/mediacentre/factsheets/fs225/en/
[7] http://www.worldbank.org/projects/P125528/minimizing-formation-releases-upops-chinas-pulp-paper-sector?lang=en

for Occupational Safety and Health (NIOSH) found that workers with higher exposure to dioxins had, "more than 60% incidence of cancer mortality."[8]

b) **Cancer and Immunosuppression**: Onozuka, Yoshimura, Kaneko, and Furue (2008) examined a sample of 1,664 patients in Japan who suffer from a disease called "Yusho." This disease is caused by ingestion of rice oil contaminated with polychlorinated biphenyls or Dental follicle precursor cells (DFPCs). This study documents an increase in the number of patients with liver diseases and disorders of the immune system. The results show that the risk of mortality due to various cancers, but especially liver and lung cancer, significantly increased mortality compared with the mortality rates from these diseases in the general population.

c) **Cancer and Spina Bifida**: During the Vietnam War, an herbicide called "Agent Orange" was used to defoliate the jungles of Southeast Asia. Studies of Vietnam veterans exposed to Agent Orange suggests that children have an increased risk of spina bifida, a birth defect that occurs when the neural tube - which develops in the spinal cord - does not close during the first six weeks of gestation. Children born with spina bifida often lack control of bowel and bladder, and many are paralyzed or suffer from mental retardation. The evidence that dioxins cause the defect is strong enough that Vietnam veterans are compensated if their children are born with spina bifida.[9]

d) **Immunosuppression**: From studies on rats, mice, guinea pigs, rabbits, cattle, marmosets, monkeys, and humans, the Environmental Protection Agency (EPA) concluded that even low doses of dioxin can seriously harm the immune system. Dioxins directly reduce the number of B cells (immune cells developing in the bone marrow) and the number of T cells (immune cells developing in the thymus). EPA scientists believe that human embryos could

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[8] Williams, Rose Marie. Dioxina: Una toxina Universal. Revista de Medicina Medioambiental. Página 1

[9] American Cancer Society
http://www.cancer.org/cancer/cancercauses/othercarcinogens/intheworkplace/agent-orange-and-cancer

be very susceptible to a prolonged weakening of their immune function following in utero exposure to dioxins, even from low exposure levels. [10]

4. Data

In this paper we use panel data at the country-level in order to measure the causal effect of the increase in Internet use on paper consumption. We construct a panel data set that allows us to measure the relationship between the growth in Internet use and the evolution of paper consumption by combining information from various global organizations publishing country-level data and deriving variables from combining these data.

Our data set on paper consumption by country is disaggregated by paper category including the following categories: Newsprint, Printing and Writing, Household and Sanitary, as well as aggregate paper consumption. We derived data on paper consumption from country-level data on paper production, paper exports, and paper imports from the Food and Agriculture Organization of the United Nations (FAO). Specifically, our data on paper consumption were derived using the following equation:

$$Paper\ Consumption_{ijt} = Paper\ Production_{ijt} + Paper\ Imports_{ijt} - Paper\ Exports_{ijt}$$

where *i* represent the country, *j* represents the paper category , and *t* represents the year. Paper production can be disaggregated into various categories defined based both on the final use and on the technical characteristics concerning the production technology. Our data contain aggregate paper consumption and paper consumption for the following categories defined by the Food and Agriculture Organization of the

[10] http://www.ejnet.org/rachel/rehw414.htm#2

United Nations:[11] a) **Newsprint:** "Uncoated paper, unsized (or only slightly sized), containing at least 65 percent mechanical or thermo-mechanical wood pulp (percent of fibrous content), of the type used mainly for the printing of newspapers, usually weighing not less than 40 g/m2 and generally not more than 57 g/m2." b) **Printing and Writing:** "Paper, except newsprint, suitable for printing, writing or other graphic purposes, made from a variety of pulp blends and with various finishes. It may be uncoated and have been subjected to sizing, calendering, supercalendering, glazing, water-marking or similar simple processes, or it may be coated on one or both sides with coating material such as barium sulphate, clay (beneficiated kaolin), gypsum or zinc oxide, often supplemented with supercalendering, etc."; and c) **Household and Sanitary:** "Absorbent paper, creped or uncreped, sometimes embossed, made from bleached or unbleached pulps, recovered paper or combination of these. This type of paper should be sufficiently strong to avoid disintegration or tearing in use. Other important characteristics are high absorptive capacity, retention of absorbed fluids, softness, freedom from lint and unpleasant odours. It is made in white and a variety of colours and in single, double or more plies."

Our data set contains information for ten years from 1999 through 2008.[12] However, our panel is unbalanced and therefore the number of observations varies by paper category. In Table 1 we present summary statistics from the data on paper consumption. We computed the summary statistics presented in Table 1 using information from a balanced panel of countries due to the unbalanced nature of our data and in order to examine the yearly evolution of paper consumption. However, our regressions below will employ the entire unbalanced panel.

Column 1 in Table 1 shows that aggregate paper consumption has fluctuated during our study period, not showing a clear either positive or negative trend. However, the

[11] ftp://ftp.fao.org/docrep/fao/010/i0226t/i0226t.pdf
[12] The latest data available for employment is 2008. http://laborsta.ilo.org/STP/guest

absence of a clear trend in aggregate consumption masks heterogeneous patterns in paper consumption by paper category. While the consumption of Household and Sanitary paper (Column 4) has increased during our study period, and the consumption of Printing and Writing paper (Column 3) has fluctuated without a defined positive or negative trend, the consumption of Newsprint paper has decreased during the same period (Column 2).[13]

Table 1. Descriptive Statistics. Yearly Evolution of Paper consumption per capita (in kilograms)

	Column 1				Column 2				Column 3				Column 4			
	Aggregate Paper				Newsprint				Printing and Writing				Household and Sanitary			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
1999	138.2	91.9	14.2	395.1	23.8	18.8	1.9	59.6	42.9	39.7	1.9	187.2	9.1	7.4	0.0	24.0
2000	147.9	96.0	16.6	429.1	26.2	20.7	2.5	79.0	46.0	43.6	4.1	213.1	9.8	7.6	0.2	25.2
2001	146.0	90.5	17.7	375.0	25.4	19.6	2.4	72.2	45.4	41.6	4.4	201.3	10.0	7.5	0.3	23.7
2002	140.9	84.1	17.5	329.1	22.5	18.1	2.6	66.7	38.6	23.5	5.5	102.3	10.2	7.6	0.3	24.9
2003	143.1	80.2	22.3	326.5	22.9	17.8	3.0	69.9	39.8	23.1	6.3	88.4	10.4	7.6	0.3	25.0
2004	142.7	75.5	25.4	333.8	22.3	17.4	3.4	78.9	44.8	29.6	7.3	127.3	11.3	8.3	0.5	25.9
2005	144.1	77.1	27.4	324.6	22.4	19.2	3.2	87.7	45.9	28.5	7.1	108.6	11.0	7.7	0.4	24.2
2006	152.4	75.5	26.8	330.1	22.7	19.3	3.3	86.2	45.3	23.9	5.1	105.8	11.0	8.2	0.6	29.2
2007	149.8	71.8	33.7	324.5	22.0	19.2	3.5	88.8	44.9	24.2	6.6	112.1	11.3	8.7	0.6	31.4
2008	148.6	70.4	31.4	332.6	23.0	19.7	4.1	85.0	44.8	22.2	7.0	97.7	11.4	8.1	0.7	26.3

Source: Own calculations based on data from the Food and Agriculture Organization of the United Nations. Because our panel is unbalanced, and in order to facilitate the interpretation of the yearly evolution of paper consumption by category, Columns 1 and 2 include information from 24 countries, Column 3 includes information from 22 countries, and Column 4 includes information from 19 countries.

It is important to remember that paper consumption is driven by a variety of factors and Internet use is only one of its drivers. However, the statistics in Table 1 suggest that Internet use might have caused the negative trend for this paper category by showing that only the paper used in the production of newspaper exhibits a negative trend from all paper categories, and considering how fast the online reading of newspapers has diffused. Although suggestive of an Internet impact on the Newsprint paper category, the information in Table 1 only represents summary

[13] The Newsprint, Printing and Writing, Household and Sanitary paper categories represent around 50 percent of the total paper consumption. The remaining 50 percent includes the following categories: wrapping and packaging paper and paperboard, linerboard, kraft liner, unbleached, bleached, fluting medium, semi-chemical, other fluting medium, kraft wrapping and packaging paper, sack kraft,, other kraft wrapping and packaging paper, folding boxboard, pulp based, bleached chemical pulp based, other pulp based, recovered paper based, other paperboard), other wrapping and packaging paper and paperboard, and other wrapping paper.

statistics and thus these statistics do not explicitly account for the increase in Internet use. In contrast, our regressions below explicitly examine the relationship between Internet use and paper consumption by seeking to gauge the causal effect of the increase in Internet use on aggregate paper consumption and on paper consumption disaggregated by category.

Our database includes information on yearly trends in Internet penetration by country in addition to data on paper consumption. These data come from the International Communication Union (ITU), a specialized agency for information and communication technologies from the United Nations. Table 2 presents summary statistics from our data on Internet penetration showing that Internet penetration has grown rapidly during our study period. The large standard errors in Table 2 suggest that the growth rate has been heterogeneous across countries (i.e., Internet penetration grew substantially faster in some countries than in others). The large variation in the Internet penetration growth is helpful for our identification strategy, which will essentially derive from comparing changes in paper consumption for countries with slow versus fast Internet penetration growth.

Table 2. Yearly Evolution in the Internet Penetration Rate

Year	Mean	Std. Dev.	Min	Max
1999	18.56	14.03	1.86	41.49
2000	24.2	15.43	3.61	47.38
2001	28.34	17.20	4.54	56.6
2002	38.98	22.00	6.58	79.12
2003	44.6	22.06	8.9	83.14
2004	48.93	21.39	14.1	83.89
2005	52.77	21.18	17.8	87
2006	57.1	20.46	20	89.51
2007	61.2	18.62	22.2	90.6
2008	65.57	18.35	23.6	91.04

Source: International Communication Union (ITU). In order to facilitate the interpretation of the temporal evolution in the growth of Internet this table uses data from a balanced panel including data from 24 countries. However, our econometric analysis below uses all the data in the unbalanced panel.

Finally, our data set includes information on GDP per capita by country measured in constant US dollars (from the International Monetary Fund – IMF), information on the yearly evolution of education levels by country measured using the percentage of students in post-high school education over the whole population (from the United Nations Educational, Scientific, and Cultural Organization – UNESCO) and information on the share of each economic sector in labor employment (from the International Labor Organization – ILO). We present summary statistics of these data in the appendix.

5. Empirical Strategy

We seek to quantify the causal effect of the increase in Internet use on paper consumption. Internet use is likely to reduce the demand for some paper categories but is unlikely to affect others. For example, as aforementioned, the reading of online newspapers may induce some individuals to cancel their physical newspaper subscriptions. In turn, the decrease in newspaper circulation caused by the adoption of the Internet reduces the demand for the paper category used to produce newspapers.

We empirically examine the relationship between the growth of Internet penetration and the evolution of paper consumption by using a fixed effect model of the following form:

$$\ln\left(CP_{ijt}\right) = \alpha_{ij} + \beta_j \ln(GDP_{it}) + \mu_j EDU_{it} + \rho_j PROD_{it} + \tau_j INT_{it} + A_t + u_{ijt} \qquad (1)$$

where i represents the country, j represents the paper category (i.e., Newsprint, Printing and Writing, Household and Sanitary, and aggregate paper consumption), and t represents the year. The dependent variable ($\ln\left(CP_{ijt}\right)$) represents the

logarithm of paper consumption of category *j* in country *i* and in year *t*, measured in kilograms per capita. The variable (INT_{it}) represents Internet penetration (i.e., number of Internet users per 100 individuals) in country *i* and year *t*. Model (1) includes as control variables the logarithm of the GDP per capita, the percentage of students in post-high school education over the whole population, and a vector of variables ($PROD_{it}$) representing the share of each economic sector in the employment of labor. Model (1) includes country-level fixed effects (α_{ij}), and allows these fixed effects to be different for different paper categories (specifically we run separate regressions by paper category and the fixed effects in these regressions for each category *j* are not constrained as equal). Country-level fixed effects capture factors that are idiosyncratic to each country, such as the size of the country, language, and other cultural traits or demographic factors that are either time-invariant or can be considered to experience small changes during our study period. Model (1) also includes year fixed effects (A_t) these time effects seek to absorb temporal trends for the different paper categories. [14] Finally, (u_{ijt}) represents the error term.

Since Model (1) includes fixed effects by country and year, the empirical identification in our regressions arises from the change in Internet penetration and paper consumption within each country and across years. Our regressions thus evaluate whether or not paper consumption decreases faster in countries exhibiting faster increases in the rate of Internet penetration.

6. Fixed Effect Regression Results

In Table 3 we present estimates for our regression model presented in the previous section. We examine the effect of the Internet on aggregate paper consumption

[14] Levitt (2007) shows the need to include time effects in fixed effect regressions. However, Appendix E shows that the results excluding time fixed effects provide similar results with higher coefficients.

(Column 1), on the consumption of paper used to produce newspapers (Column 2), the consumption of Printing and Writing Paper (Column 3), and on the consumption of Household and Sanitary Paper (Column 4). Because our interest is in gauging the extent to which the increase in Internet use displaces paper consumption, Internet Penetration is our main independent variable of interest in Table 3. The regressions in Table 3 also include the logarithm of the GDP per capita in order to control for the evolution of wealth within each country, the percentage of post-high school students over the whole population to control for the evolution of the educational level within each country, and the share of each economic sector in the employment of labor to control for the labor force composition within each country. Although not reported, the regressions in Table 3 also include fixed effects by country and year in order to control for time invariant factors within each country and for aggregate time trends in paper consumption respectively.

The regression results in Column (1) of Table 3 show that the increase in Internet penetration reduces the aggregate paper consumption per capita. Since the dependent variable is measured in logarithms, the size of the estimated coefficient on the Internet penetration variable indicates that a one percent point increase in the Internet penetration rate is associated with a reduction in paper consumption by 0.40 percent. Interestingly, the regression estimates in Columns 2 and 3 show that Internet penetration reduces the consumption of both Newsprint Paper (Column 2) and Printing and Writing Paper (Column 3), but the effect on the consumption of Household and Sanitary Paper is not statistically significant (Column 4). The coefficient estimate on the Internet penetration variable in Column 2 suggests that a one percent point increase in the Internet penetration rate reduces paper consumption by 0.63 percent, and the coefficient estimate on the Internet penetration variable in Column (3) suggests that a one percent point increase in the Internet penetration rate reduces paper consumption by 0.65 percent.

An increase in Internet use is unlikely to reduce the consumption of Household and Sanitary Paper, so the regression in Column (4) of Table 3 can be used as a

falsification test. Our findings showing that the increase in Internet penetration reduced paper consumption for both Newspaper and Printing and Writing paper (Printing and Writing paper is used to produce magazines and books) therefore provide greater credibility for our empirical findings.

The results in Table 3 also show the estimates for the coefficients on the logarithms of the GDP per capita, the percentage of post-high school students over the whole population, and the share of each economic sector in the employment of labor. Only the GDP per capita appears to have a consistent sign in the regressions in Table 3, the effect is positive in all regressions. However, the effect is not statistically significant in Column 2 for the consumption of Newsprint Paper. Since the GDP per capita is measured in logarithms the coefficient estimates on this variable represent an elasticity. For example, the elasticity is 1.6 in Column 1 and it is high (3.3) in Column 4. The percentage of post-high school students over the whole population increases the consumption of both Newsprint paper and Printing and Writing paper as might be expected, but does not increase the aggregate consumption of paper or the consumption of Household and Sanitary paper. Finally, the variables capturing the change in the composition of the labor force do not show a consistent sign. It should be noted that because our regressions include fixed effects by country and year, these results might be expected assuming that the countries in our sample did not exhibit a substantial change in the composition of their labor forces during our study period (the source of identification in our regressions arises from within country and across time variation).

Table 3. Fixed Effect Regression Results

	Column 1	Column 2	Column 3	Column 4
	Aggregate Paper	Newsprint	Printing and Writing	Household and Sanitary
Internet Pentration (per 100 people)	-0.0040**	-0.0063***	-0.0065**	-0.0045
	(0.0017)	(0.0022)	(0.0027)	(0.0048)
GDP per capita (in logarithm)	1.6430***	0.3270	1.8510***	3.3440***
	(0.2170)	(0.2880)	(0.3260)	(0.5820)
Percentage Post High School Students (over whole population)	-0.9610	12.4383**	11.3895*	-15.2800
	(3.9590)	(5.1470)	(6.0860)	(11.0400)
Workers in Primary Sector (percentage)	-1.1640	-2.8450***	2.6310**	4.1030**
	(0.7470)	(0.9870)	(1.2600)	(2.0050)
Workers in Manufacturing Sector (percentage)	0.6450	-6.3890***	1.8520	5.2570*
	(1.2300)	(1.5610)	(1.8490)	(3.0540)
Workers in the Services (percentage)	2.012***	1.0320*	-0.2760	0.8360
	(0.4540)	(0.5790)	(0.6780)	(1.0660)
Observations	460	455	424	353
R-squared	0.97	0.96	0.95	0.91

Standard errors in parenthesis

*** p<0.01, ** p<0.05, * p<0.1

7. Quantifying the Decrease in Paper Consumption and its Effects on the Environment

We can use our estimates in the previous section to predict the extent to which the increase in Internet adoption has decreased paper consumption. We showed that a 1 percent increase in Internet penetration decreases aggregate paper consumption

by 0.4 percent. Because the Internet penetration rate amounted to 63.5 percent in 2008 (the final year in our sample) in the absence of the Internet the counterfactual paper consumption in 2008 would have been 25.5 percent (0.635 times 0.4) higher than observed.

Our estimates thus suggest that the increase in Internet adoption caused a large decrease in paper consumption. In order to evaluate the environmental consequences from this decrease in paper consumption it is useful to measure the decrease in paper consumption in kilograms. The most recent data on global paper consumption from 2011 (from the Food and Agriculture Organization of the United Nations) indicate that the global consumption of paper amounted to 400.335 million kilograms. In turn, according to the ITU Global Internet penetration amounted to 32.7 percent in 2011.[15] Combining these statistics and using our estimates from the previous section suggests that absent the Internet paper consumption in 2011 would have been 52.362 million kilograms greater than observed (multiplying 400.335 times 0.327 times 0.4).

The environmental effects from paper production vary by both the technology employed in its production and paper type. We can use as an approximation the production of 1000 kilograms of printing and writing paper using the Kraft pulping technology and EFC bleaching technology (see Section 3a).[16] According to the Environmental Paper Network (a network that brings together more than 100 NG0s and whose objective is to quantify the environmental impact of the paper industry) producing these 1000 kilograms of paper uses 3.47 tons of wood, 38.7 million BTUs of energy, 20,520 gallons of water, generates 2,283 pounds of solid waste, generates

[15] Note that our statistics regarding Internet penetration in Table 2 are higher than 32.7 percent. The explanation is that our statistics in Table 2 do not include data on Internet penetration from many countries with large population and very low penetration rates (See note Table 2).

[16] The Kraft pulping technology is employed in approximately 80 percent of the total paper production (Technical Association of the Pulp and Paper Industry "Fundamentals of the Kraft Recovery Process Technology"). The EFC bleaching technology is employed in approximately 75 percent of the Kraft total pulp production (Ensis/CSIRO (Australia) joint research "Frequently Asked Questions on Kraft Pulp Mills").

5,868 pounds of emissions, and generates 109.9 pounds of chemical waste water discharges. An annual decrease of 52.363 million kilograms of paper then would reduce annual wood consumption by 181.699 million kilograms (approximately 2.15 million trees), would reduce annual water consumption by approximately 1,000,000 million gallons (a 50 meter Olympic pool has a capacity of 660,253 gallons), annual energy consumption would decrease by 594 million megawatts (the annual consumption of Germany approximately). In addition, annual emissions to air would decrease by 307 million pounds, annual water discharges would decrease by 5754 pounds, and annual solid waste would decrease by 119 million pounds.

8. Further Empirical Analyses

We conducted several further empirical analyses and we present the results in the Appendix. First, we separated our sample of countries into two subsamples including OECD countries and non-OECD countries. Our regression results presented in Appendix B show that Internet penetration reduced paper consumption in the regressions using the subsample including non-OECD countries, but the estimated coefficient on the Internet penetration variable is not statistically different from zero in the subsample including OECD countries. These results are expected because there is more heterogeneity in the Internet penetration adoption rates among non-OECD countries than OECD countries - Internet penetration grows faster and more homogenously among OECD countries than among non-OECD countries.

Our regressions above do not account for the price of paper in each country. We can approximate the price of paper in each country by using synthetic prices created by dividing imports values and imports quantities (FAO). In Appendix C we show that the price of paper is not affected by the growth in Internet use. The results in

Appendix C thus suggest that our regressions estimates in Table 3 in the main text are not biased by not accounting for the price of paper.[17]

Finally, we present regression results using computer penetration as an additional covariate (Appendix D). The results on the computer penetration variable are surprising and do not suggest that computer use increase the consumption of paper as might be expected. However, we note that ITU discontinued the production of statistics on computer penetration because of the problems associated with measuring it adequately.[18]

9. Conclusion

Using a panel of country-level data we have found that Internet adoption decreases aggregate paper consumption. The effects appear to be driven by the paper categories that are more likely to be displaced by the Internet: the Internet reduces the consumption of the paper category used for newspapers and the Printing and Writing paper category that is used in the production of magazines and books. As expected, the Household and Sanitary paper category is not affected by the increase in Internet use. Our results also show that the reduction in paper consumption caused by the Internet is large in size and can thus have important positive environmental implications.

We believe our results have important policy implications. A large amount of attention and resources are currently directed to regulations trying to curb the

[17] We do not include the price of paper as a covariate in the regressions in Table 3 because prices and quantities are simultaneously determined.
[18] We also tried using other empirical strategies such as random trends models in order to account for idiosyncratic trends. Unfortunately, our study period is not long enough to account for idiosyncratic trends – the standard errors increase substantially.

negative externalities caused by production technologies, either in the way of environmental contamination or threats to human health (e.g., the Clean Air Act in the United States). While the traditional policies of inducing cleaner technologies are effective in reducing contamination, our results show that the Internet might be a complementary way to reduce these negative externalities. In this context, identifying and examining the main Internet adoption drivers becomes important (see Andres et al. 2010).

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Appendix A – Additional Summary Statistics

Table A1 shows that both the GDP per capita and the percentage of post-high school students over the whole population have grown during our study period; the growth in these variables is likely to increase paper consumption. The composition of employment by sector shows decay in participation for the primary and manufacturing sectors, and a growth in participation for services and construction sectors. This growth in the services sector may increase the consumption of Printing and Writing paper. However, growth in this sector's participation might increase Internet use, in turn inducing a decrease in the consumption of both Printing and Writing paper and Newsprint paper.

Table A1. Additional Descriptive Statistics

	GDP per capita (In US dollars)				Education (In percentage)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
1999	19,262	8,327	5,900	38,105	3.4	1.1	1.6	6.1
2000	20,079	8,557	6,100	39,100	3.6	1.1	1.5	6.4
2001	20,502	8,589	6,454	39,720	3.7	1.1	1.7	6.6
2002	20,916	8,555	6,972	40,068	3.9	1.1	2.0	6.7
2003	21,307	8,475	7,358	40,244	4.1	1.1	2.2	6.7
2004	22,045	8,599	8,005	41,563	4.3	1.1	2.2	6.7
2005	22,722	8,624	8,357	42,397	4.3	1.1	2.3	6.7
2006	23,499	8,556	9,031	42,993	4.4	1.1	2.3	6.6
2007	24,357	8,600	9,622	43,699	4.4	1.1	2.4	6.6
2008	24,366	8,421	10,346	43,430	4.5	1.0	2.5	6.6

	Primary (In percentage)				Manufacture (In percentage)				Services (In percentage)				Construction (In percentage)			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
1999	10.8	8.9	1.9	43.5	19.0	3.9	12.2	27.5	63.8	9.7	32.7	76.2	7.3	1.8	3.7	10.9
2000	10.3	8.9	1.9	44.3	18.8	4.0	12.4	27.1	64.3	9.6	32.9	76.5	7.4	1.9	3.7	11.8
2001	10.0	8.8	1.8	43.7	18.6	4.2	12.0	27.7	64.8	9.7	33.3	77.0	7.5	1.9	4.0	11.6
2002	9.6	7.9	1.8	38.0	18.3	4.4	12.0	27.7	65.3	9.4	36.2	77.5	7.6	1.9	4.5	12.0
2003	9.2	7.7	1.6	37.2	17.9	4.4	11.0	27.3	65.8	9.5	36.5	77.8	7.9	1.9	4.6	12.2
2004	8.6	7.0	1.6	33.1	17.7	4.6	11.1	27.1	66.3	9.0	39.3	77.6	8.1	1.9	5.2	12.5
2005	8.3	6.9	1.7	33.4	17.2	4.6	10.9	27.2	66.8	8.9	39.6	77.5	8.4	2.0	5.1	12.6
2006	8.0	6.6	1.7	31.8	16.9	4.7	10.4	28.2	67.1	8.7	41.0	77.8	8.7	2.0	5.2	13.1
2007	7.7	6.3	1.8	30.6	16.6	4.9	9.8	28.6	67.3	8.8	40.9	78.7	9.1	2.2	5.6	13.4
2008	7.3	6.1	1.9	29.9	16.4	5.0	9.8	28.6	68.0	8.7	41.5	79.7	9.0	2.0	5.4	12.2

Source: International Monetary Fund (IMF), United Nations Educational, Scientific, and Cultural Organization (UNESCO), and International Labor Organization (ILO).

Appendix B – Split Sample Regressions – OECD and Non-OECD Countries

OECD Countries

	Column 1	Column 2	Column 3	Column 4
	Aggregate Paper	Newsprint	Printing and Writing	Household and Sanitary
Internet Pentration (per 100 people)	0.00142	0.00327	0.000687	-0.00326
	(0.0011)	(0.0024)	(0.0028)	(0.0035)
GDP per capita (in logarithm)	0.627***	0.629	0.197	3.917***
	(0.2000)	(0.4200)	(0.4690)	(0.6710)
Percentage Post High School Students (over whole population)	2.97	20.25***	16.60**	-24.56***
	(2.6470)	(5.5680)	(6.8380)	(8.8640)
Workers in Primary Sector (percentage)	-3.621***	-1.798	-11.19***	0.815
	(1.3730)	(2.8870)	(3.1870)	(4.2450)
Workers in Manufacturing Sector (percentage)	3.353**	-2.928	-2.416	8.293**
	(1.2920)	(2.7180)	(3.0500)	(4.1980)
Workers in the Services (percentage)	-0.413	5.210*	-10.16***	0.268
	(1.3820)	(2.9060)	(3.1820)	(4.3280)
Constant	-1.417	-6.751	9.316	-37.77***
	(2.6720)	(5.6200)	(6.2230)	(8.8160)
Observations	257	257	241	221
R-squared	0.97	0.935	0.904	0.944

Non-OECD Countries

	Column 1	Column 2	Column 3	Column 4
	Aggregate Paper	Newsprint	Printing and Writing	Household and Sanitary
Internet Pentration (per 100 people)	-0.00994**	-0.0294***	-0.00863	-0.0187
	(0.0047)	(0.0047)	(0.0062)	(0.0142)
GDP per capita (in logarithm)	2.071***	1.121**	2.292***	4.114***
	(0.4530)	(0.4850)	(0.6040)	(1.3180)
Percentage Post High School Students (over whole population)	-5.102	18.38*	5.538	30.13
	(8.9410)	(9.3320)	(11.5900)	(28.1900)
Workers in Primary Sector (percentage)	-1.277	-2.031	4.207**	8.100**
	(1.2420)	(1.3120)	(1.9550)	(3.8060)
Workers in Manufacturing Sector (percentage)	-1.504	-8.944***	1.325	6.191
	(2.1570)	(2.1550)	(2.8630)	(5.6440)
Workers in the Services (percentage)	1.921***	0.759	-0.723	0.523
	(0.6710)	(0.6750)	(0.8870)	(1.6760)
Constant	-15.10***	-7.344*	-19.55***	-39.22***
	(3.8980)	(4.1920)	(5.3230)	(11.6600)
Observations	203	198	183	132
R-squared	0.941	0.944	0.931	0.862

Appendix C – Regressions on Paper Prices

	Column 1	Column 2	Column 3	Column 4
	Aggregate Paper	Newsprint	Printing and Writing	Household and Sanitary
Internet Pentration (per 100 people)	-0.000535	0.00107	0.00104	-0.00119
	(0.0022)	(0.0015)	(0.0013)	(0.0070)
GDP per capita (in logarithm)	0.373	0.593***	0.17	0.695
	(0.2630)	(0.1840)	(0.1550)	(0.5860)
Percentage Post High School Students (over whole population)	-2.46	1.628	0.607	-12.47
	(5.3270)	(3.7360)	(3.0840)	(14.2500)
Workers in Primary Sector (percentage)	-3.077***	1.117	0.759	-6.299
	(0.9880)	(0.7040)	(0.6000)	(5.1130)
Workers in Manufacturing Sector (percentage)	-4.095***	1.598	-0.133	0.634
	(1.5400)	(1.0850)	(0.9200)	(6.4500)
Workers in the Services (percentage)	-3.602***	-0.532	0.00426	-5.006
	(0.6160)	(0.3960)	(0.3370)	(4.9120)
Constant	6.153**	0.46	4.996***	4.205
	(2.4510)	(1.7110)	(1.4410)	(8.6500)
Observations	383	395	383	89
R-squared	0.57	0.572	0.729	0.533

Appendix D - Computer Penetration as an Additional Covariate[19]

	Column 1	Column 2	Column 3	Column 4
	Aggregate Paper	Newsprint	Printing and Writing	Household and Sanitary
Internet Pentration (per 100 people)	-0.00405**	-0.00536*	-0.00701**	-0.00471
	(0.0020)	(0.0028)	(0.0033)	(0.0047)
Computer Pentration (per 100 people)	-0.00474**	-0.00928***	-0.00539	0.00168
	(0.0022)	(0.0032)	(0.0037)	(0.0053)
GDP per capita (in logarithm)	1.238***	0.438	1.692***	2.845***
	(0.2790)	(0.4160)	(0.4680)	(0.6740)
Percentage Post High School Students (over whole population)	1.478	13.69**	9.52	-8.39
	(4.0900)	(6.0270)	(6.9800)	(10.1400)
Workers in Primary Sector (percentage)	-2.358	0.226	0.172	7.112
	(2.1630)	(3.1660)	(3.6490)	(5.0860)
Workers in Manufacturing Sector (percentage)	-0.422	-4.786	-0.916	6.708
	(2.1370)	(3.1280)	(3.5740)	(4.8870)
Workers in the Services (percentage)	-1.709	3.147	-4.943	2.445
	(2.1340)	(3.1850)	(3.6570)	(4.7760)
Constant	-5.877	-3.222	-10.15	-29.11***
	(3.8650)	(5.7770)	(6.5440)	(9.1870)
Observations	352	347	323	265
R-squared	0.98	0.967	0.957	0.947

[19] The collection of these indicators has been discontinued due to difficulties in measuring them adequately. Methodological criteria for the selection of ICT indicators for country and regional factsheets ITU

Appendix E – Fixed Effect Regressions without Time Fixed Effects

	Column 1	Column 2	Column 3	Column 4
	Aggregate Paper	Newsprint	Printing and Writing	Household and Sanitary
Internet Pentration (per 100 people)	-0.00501***	-0.00937***	-0.00519***	-0.00334
	(0.0013)	(0.0017)	(0.0020)	(0.0033)
GDP per capita (in logarithm)	1.581***	0.354	1.980***	2.952***
	(0.1940)	(0.2620)	(0.2980)	(0.5290)
Percentage Post High School Students (over whole population)	-1.471	10.40**	11.04*	-10.45
	(3.7390)	(4.8850)	(5.7510)	(9.9880)
Workers in Primary Sector (percentage)	-0.929	-2.285**	2.231*	4.285**
	(0.6950)	(0.9240)	(1.1590)	(1.8140)
Workers in Manufacturing Sector (percentage)	1.207	-5.274***	1.072	5.727**
	(1.0830)	(1.3800)	(1.6220)	(2.6630)
Workers in the Services (percentage)	1.935***	0.874	-0.141	0.693
	(0.4440)	(0.5660)	(0.6580)	(1.0280)
Constant	-11.72***	-0.545	-16.46***	-28.36***
	(1.8520)	(2.4950)	(2.8340)	(5.0020)
Observations	460	455	424	353
R-squared	0.972	0.962	0.952	0.911