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The Broadband Performance Index:

A Policy-Relevant Method of Comparing Broadband Adoption Among Countries

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The Broadband Performance Index: A Policy-Relevant Method of Assessing Broadband Adoption Among Countries

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Abstract: In this PAPER, we present a new and policy-relevant means of comparing the broadband adoption rates among countries—the Broadband Performance Index ("BPI"). Unlike the OECD, which ranks countries' broadband performance using raw, per capita subscription data alone, the BPI is a policy-relevant means of comparing broadband adoption among countries because it measures whether actual broadband penetration in a country meets, exceeds, or fails to meet its expected performance. We generate the BPI for each OECD country with econometric techniques that take into account a number of factors, such as income, income inequality, education, population age, and population density. The BPI shows that among OECD countries, broadband adoption in the U.S. generally meets expectations. Interestingly, countries often cited as broadband "miracles," like Korea and Japan, are average performers like U.S., and several countries ranked higher than the U.S. by the OECD (such as Denmark and Norway) are significantly underperforming. Countries like Portugal and Turkey, each of which rank behind the United States in the OECD rankings, are actually surpassing their demographic and economic endowments substantially.

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I. Introduction

A host of research papers have shown that a number of factors play a sizable and statistically significant role in broadband demand, including price, income, and population density. Nevertheless, debates often rage about where countries "rank" among their peers for broadband services with little regard for these demographic and economic factors. In this PAPER, we present an alternative, economically-legitimate and policy-relevant means of comparing the broadband adoption rates among countries that takes these factors into effect—the Broadband Performance Index, or BPI.

There is a clear need for this alternative approach to comparing broadband adoption among countries. The Organisation for Economic Co-operation and Development (OECD) and International Telecommunications Union (ITU) report the raw number of broadband subscriptions among their members. Despite the inherent defects in such numbers, policymakers around the globe pay

considerable attention to these "broadband rankings." However, while nationalistic debates rage about where countries "rank" among their peers for broadband services based upon the raw data in the OECD and ITU reports, policymakers often fail to consider whether countries are over-performing or underperforming in broadband penetration given their economic and demographic endowments. These demographic and economic endowments include the human and financial resources present in a country or society that impact its broadband subscription rate, such as income, levels of higher education, income inequality, population density, and other factors.

To provide policymakers a tool to compare broadband subscription rates between countries, this PAPER develops and presents the Broadband Performance Index (BPI). This index quantifies the relationship between a country's broadband subscriptions per capita and that country's economic and demographic endowments. This approach is policy-relevant because it strips away many factors over which telecom policymakers have very little influence or control. As a result, we believe that the BPI provides telecom policymakers with a method of comparing broadband subscription rates among countries that is superior to existing measurements, all of which depend upon raw data that do not take these factors into account.

We compute the Broadband Performance Index for each OECD country by first estimating the relationship between these endowments and broadband subscriptions, and we use that information to compare how that country performs relative to expectations. The index for each country indicates whether a country's broadband subscription rate meets, exceeds, or falls below what would be reasonably expected for that country, given its demographic and economic endowments.

Some of our findings will be of significant interest to policymakers. For example, we find that the United States generally meets expectations in its conversion of its national endowments into broadband subscriptions. This finding conflicts with claims that the United States is in a "broadband ditch" and is failing to perform up to expectations, at least with respect to subscriptions.[1]

[1] *See, e.g.,* Commissioner Michael J. Copps, Disruptive Technology … Disruptive Regulation, 2005 MICHIGAN STATE LAW REVIEW 1-8 (2005); Federal Communications Commission, Availability of Advanced Telecommunications Capability in the United States, Fourth Report to Congress, Statement of Commissioner Michael J. Copps (Sep. 9, 2004) (available at: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-208A1.pdf), 5.

Also, we find that many relatively poor countries, like Turkey and Portugal, which actually rank behind the United States according to the OECD, are doing a better job of converting their national endowments into broadband penetration than many highly ranked countries. Indeed, many countries that rank higher than the United States according to the OECD, like Denmark and Norway, are in fact underperforming the United States when one considers demographic and economic factors.

The Broadband Performance Index also provides a number of related insights for policymakers, since our analysis suggests that there are a number of ways to improve broadband adoption and a number of limitations on doing so. First, a country's demographic and economic endowments explain the vast majority of the variation in broadband subscription across the OECD. Thus, other government programs-like education policy-can directly affect those factors and increase the rate of broadband adoption. Education policy, then, is broadband policy. Second, public policy may be able to attenuate the effect of endowments that reduce subscription. Examples may include low-income assistance programs for computer purchases and training centers. Finally, successful programs designed to consolidate demand in order to facilitate the deployment of broadband service in sparsely populated areas, such as Connect Kentucky, could also be examined.

The rest of the PAPER proceeds as follows. In Section II, we discuss the importance of respecting the limitations of broadband rankings, with particular attention to the OECD broadband rankings and the problems that emanate from use of this raw data in policy debates. In Section III we outline our empirical approach which we use to determine the extent to which certain demographic and economic endowments, like GDP per capita, education level, and income inequality, affect a country's broadband subscription rate. This calculation provides the basis for Section IV, in which we describe and calculate the Broadband Performance Index for each of the 30 OECD countries.

II. The Need for a Policy-Relevant Means of Comparing Broadband Subscription Rates Among Countries

As the global economy grows and becomes more competitive, national leaders are increasingly and appropriately focusing on broadband subscriptions in their countries as a way to benchmark themselves against other countries and

identify areas of concern. Every six months, the OECD releases a ranking of broadband subscription rates for each of its thirty country members, including the United States and most other major industrialized countries of the world.[2] Unfortunately, almost by definition, a list in which countries are "ranked" from 1 to 30 will have every country (save one) "looking up" at their peers with envy and oftentimes for policy direction. And there is no shortage of advocates who utilize the raw results of these rankings and country-to-country comparisons to argue for policy changes.[3] In some cases, comparisons across countries have led to a direct policy response. Japan has explicitly adopted a "2010 U-Japan Strategy" policy framework that was developed with the intention of following (and surpassing) Korea's "u-Korea Promotion Strategy."[4] The Slovak Republic, disappointed with their broadband penetration, in 2006 began to pay certain consumers directly 160 Euro per year to subscribe to broadband.[5]

Table 1 summarizes the OECD broadband subscription and rankings data for December 2006, which is the most recent release that ranks the United States 15th among the 30 OECD countries. This middling rank continues a consistent downward trend for the United States: starting from 5th place in 2001, the United States fell to 8th in 2002, to 10th in 2003, to 12th in 2004, to 13th in 2005, and now 15th in 2006. As measured by the OECD, the broadband subscription rate in the United States has increased 436% from 2001 through 2006, but obviously penetration in other OECD countries has increased at an even faster rate. The

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[2] For the latest release of the broadband subscription statistics, *see* OECD Broadband Statistics, June 2006 (available at: http://www.oecd.org/document/9/0,2340,en_2649_201185_37529673_1_1_1_1,00.html#TimeSeries).

[3] *See, e.g.,* Communications Workers of America, *Speed Matters: Affordable High Speed Internet for All* (June 2007) (available at: http://files.cwa-union.org/speedmatters/SpeedMattersCWAPositionPaper.pdf).

[4] T. Murakami, Nomura Research Institute, *Japan's National IT Strategy and the Ubiquitous Network* (2005) (available at: http://www.nri.co.jp/english/opinion/papers/2005/pdf/np200597.pdf), 5, 19 ("Signs of the global evolution of the ubiquitous network were first seen in Korea. . . By adopting and promoting a typical government-led industrial policy, Korea has steadily pursued the fulfillment of such a strategy.").

[5] European Commission, IADC, *E-Government Fact Sheet – Slovakia – History* (available at: http://ec.europa.eu/idabc/en/document/6129/411).

ITU presents similar list for a larger collection of countries, and the United States performs similarly in these rankings as well.[6]

Table 1. Broadband Subscriptions per 100 Inhabitants and Rank

(OECD Countries, December 2006)

Country	Subscription	Rank	Country	Subscription	Rank
Denmark	31.9	1	Australia	19.2	16
Netherlands	31.8	2	Austria	17.3	17
Iceland	29.7	3	Germany	17.1	18
Korea	29.1	4	Spain	15.3	19
Switzerland	28.5	5	Italy	14.8	20
Norway	27.7	6	New Zealand	14.0	21
Finland	27.2	7	Portugal	13.8	22
Sweden	26.0	8	Ireland	12.5	23
Canada	23.8	9	Hungary	11.9	24
Belgium	22.5	10	Czech Republic	10.6	25
United Kingdom	21.6	11	Poland	6.9	26
Luxembourg	20.4	12	Slovak Republic	5.1	27
France	20.3	13	Greece	4.6	28
Japan	20.2	14	Turkey	3.8	29
United States	**19.6**	**15**	Mexico	3.5	30

Source: www.oecd.org.

The release of the broadband rankings data always sparks collective hand-wringing of leaders around the globe.[7] It appears the natural first response of

[6] *See* International Telecommunications Union, "Broadband Goes Mobile" (Dec. 6, 2006) (ranking the United States 21st in broadband connections per capita among a larger grouping of countries) (available at: http://www.itu.int/osg/spu/newslog/CategoryView,category,Mobile.aspx). The OECD data is more recent and, therefore, our analysis focuses on the OECD figures.

[7] For example, in 2004, when the United States ranked tenth, President George W. Bush is quoted as saying, "Tenth is ten spots too low as far as I'm concerned." *See* Ashlee Vance, *Bush Demands Net Access Tax Ban*, THE REGISTER (Apr. 26, 2004) (available at: http://www.theregister.co.uk/2004/04/26/bush_says_nonettax). A flurry of press releases from around the world follows the semi-annual release of the broadband rankings by the OECD. Even a statistics curiosity—like Ireland dropping one place to the Czech Republic "passing" Ireland in the June 2006 rankings, despite the fact that the two countries have been in a virtual dead heat—is taken seriously and sparks a policy debate. *See* Emmet Ryan, "Czech mate for Irish broadband," ELECTRICNEWS.NET (Oct. 14, 2006) (available at: http://www.enn.ie/news.html?code=9830016); IrelandOffline, "IrelandOffline Slams Ineffective Government Broadband Policies, Ireland falls a place in OECD Broadband Rankings, 14 countries gain more than Ireland" (Oct. 14, 2006) (available at: http://www.irelandoffline.org/2006/10/13/irelandoffline-slams-ineffective-government-broadband-policies/#more-285) (quoting chairman of an Irish advocacy group in response that

(Footnote Continued. . . .)

policymakers (and those attempting to influence them) is to assume that the subscription rates and rankings are solely the consequence of broadband policy, that highly-ranked countries must be doing something "right," and that low-ranked countries are somehow doing something "wrong." But this reflexive response assumes that broadband policy is the only determinant of broadband subscription. But broadband adoption is not a race—broadband is instead a service purchased by households and businesses, and it is reasonable to expect that households and businesses in different societies with different conditions will make different purchasing decisions. Countries have different economic and demographic endowments that play a vital role in determining broadband subscription. Since things like income, education, and age are all important determinants of broadband subscription, countries with endowments that favor broadband adoption (e.g., high income and education, young population, and household size) naturally will have higher rates of broadband subscription than others. One certainly cannot assume that such countries have superior broadband policies simply because they have younger, more highly-educated workforces.

Further, the OECD ranks countries by residential and business "broadband subscriptions per capita." This method of presenting the raw data of broadband subscriptions does not account for differences in average household and business size. While some normalization is necessary when attempting to compare countries that differ substantially in size, this method of "ranking" countries will bring a demographic bias to the result, particularly because broadband circuits are consumed not on a per capita basis but by households and businesses. Indeed, two countries may have the same subscription rate of broadband for its businesses and households yet be ranked differently by the OECD simply because of differences in household or business size.

A thought experiment can highlight the problems with the OECD's approach. In Table 2, we use OECD data (and some other sources) to show what the OECD broadband rankings would look like in a "Broadband Nirvana"—a situation in which *every* household and business establishment across the OECD has a broadband connection.[8] One would initially think that in a Broadband

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"[n]othing short of a complete slash and burn of current telecoms policy will make a dent on our international position for broadband.").

[8] Business establishment data is reported by the OECD. Organisation of Economic Co-operation and Development, STRUCTURAL AND DEMOGRAPHIC BUSINESS STATISTICS: 1996-2003 (2006).

(Footnote Continued. . . .)

Nirvana, every OECD country would be tied for first place, but the per capita method of ranking that the OECD utilizes does not show that result. In fact, in the scenario in which every home in business in the United States and every other OECD country had a broadband connection, the OECD would rank the United States 20th—five spots lower than the United States ranked in December 2006. Moreover, the United States would be further from the top position than it is today (16 percentage points back rather than 11 points back in 2006).

Table 2. The Broadband Nirvana

(Every home and business has broadband)

Country	Subscription	Rank	Country	Subscription	Rank
Sweden	54.1	1	New Zealand	39.8	16
Iceland	48.9	2	Portugal	39.2	17
Czech Republic	47.8	3	Japan	39.0	18
Denmark	47.8	4	United Kingdom	38.9	19
Finland	47.7	5	**United States**	**38.0**	**20**
Germany	44.9	6	Luxembourg	37.8	21
Netherlands	43.7	7	Greece	36.2	22
Switzerland	42.9	8	Slovak Republic	35.1	23
France	42.4	9	Ireland	34.7	24
Canada	41.9	10	Poland	34.1	25
Hungary	41.1	11	Spain	33.8	26
Belgium	41.0	12	Australia	31.5	27
Austria	40.6	13	Korea	25.4	28
Italy	40.4	14	Mexico	24.7	29
Norway	40.3	15	Turkey	21.2	30

Source: April 24, 2007 Testimony of George S. Ford before the House Energy & Commerce Committee on Digital Future of the United States: Part IV, Broadband Lessons from Abroad (available at: http://energycommerce.house.gov/cmte_mtgs/110-ti-hrg.042407.Ford-Testimony.pdf).

Table 2 shows that there will be large differences in the per capita subscription rates across countries even if every household and business in the OECD had a broadband subscription. As a result, we would still be able to rank the countries (and cause policymakers to wring their hands enviously) even if all OECD countries were identical in terms of broadband availability and subscription. Household and business size vary considerably, with the United States having a larger average household size than countries like Sweden and

In a few cases, statistical procedures are used to estimate missing observations. Since the definition of establishment may vary across countries, the exact numbers in the tables should be considered as illustrative.

Iceland that rank above it in the broadband subscription rankings. OECD countries are simply not uniform demographically, so that ranking subscription rates on a per capita basis provides an incomplete and inaccurate picture.

Policymakers that want to use rankings as a component of their search for broadband policies to emulate should study Table 2. In the Broadband Nirvana that we posit, there is nothing left for policymakers to do because every household and every business has a broadband connection. Yet, by today's rhetorical standards, United States policymakers would continue to lament the fact that the country has sunk to 20th among the OECD and, no doubt, commission studies about what policies Sweden and the Czech Republic have utilized to achieve such a high rank. In reality, in this scenario of complete broadband adoption by each household and business, the only means of moving up in the rankings would be to, say, kick teenagers out of their parents' basement, which would lower the relative household size in the United States and, consequently, increase subscriptions on a per capita basis.

Thinking about rankings in this Broadband Nirvana shows that countries will obviously have different subscription rates for a number of other reasons. Other factors, like income have similar impacts. For example, the very poor are less likely to own computers, much less purchase broadband. As a result, in poorer countries, the broadband subscription should be expected to be lower relative to richer countries. As a result, policymakers need to consider income, education, and other factors just as much as household size when they consider where their country ranks among its peers. To do so, policymakers need a method of separating demographic and economic factors that impact broadband adoption from the effects of broadband policy. Such a tool would measure the effectiveness to which a country converts its demographic and economic conditions into broadband subscriptions. The resulting measurement will inform telecom policymakers as to which countries may be over-performing or underperforming as a result of broadband policy. In the following two Sections, we describe and calculate such an approach: the Broadband Performance Index.

III. An Empirical Approach to Analyzing Broadband Penetration

There have been a number of attempts to quantify the impact of income, education, and so forth on broadband subscription at the household and national

level.[9] Consumers purchase broadband not out of national pride but based on a standard set of factors that are involved in purchasing any product or service, including availability, price, consumer income, and other demographics and market conditions. Consequently, as discussed above, it makes little sense to compare broadband subscription rates across countries without considering the role of relevant economic and demographic factors.

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[9] W. Distaso, P. Lupi, F. M. Manenti, *Platform Competition and Broadband Uptake: Theory and Empirical Evidence from the European Union*, 18 INFORMATION ECONOMICS AND POLICY 87-106 (2006); W. Gong, Z. G. Li, R. L. Stump, *Global Internet Use and Access: Cultural Considerations*, 19 ASIA PACIFIC JOURNAL OF MARKETING AND LOGISTICS 57–74 (2007); S. E. Polykalas and K. G. Vlachos, *Broadband Penetration and Broadband Competition: Evidence and Analysis in the EU Market* , 8 JOURNAL OF POLICY, REGULATION AND STRATEGY FOR TELECOMMUNICATIONS, INFORMATION AND MEDIA 15-30 (2006); J. Choudrie, Y. K Dwivedi, *Investigating Factors Influencing Adoption if Broadband in the Household*, 46 THE JOURNAL OF COMPUTER INFORMATION SYSTEMS 25-34 (2006); I. Cava-Ferreruela, and A. Alabau-Muñoz, *Broadband Policy Assessment: A Cross-National Empirical Analysis*, 30 TELECOMMUNICATIONS POLICY 445-63 (2006); I. Takanori Ida and T. Kuroda, *Discrete Choice Analysis of Demand for Broadband in Japan*, 29 JOURNAL OF REGULATORY ECONOMICS 5-22 (2006); S. J. Savage and D. Waldman, *Broadband Internet Access, Awareness, and Use: Analysis of United States Household Data*, 29 TELECOMMUNICATIONS POLICY 615-633 (2005); J. Choudrie, Y. K Dwivedi, *The Demographics of Broadband Residential Consumers in a British Local Community: The London Borough of Hillingdon*, 45 THE JOURNAL OF COMPUTER INFORMATION SYSTEMS 93-101 (2005); S. Oh, J. Ahn, and B. Kim, *Adoption of Broadband Internet in Korea: The Role of Experience in Building Attitudes*, 18 JOURNAL OF INFORMATION TECHNOLOGY 267-280 (2003); K. T. Duffy-Deno, *Business Demand for Broadband Access Capacity*, 24 JOURNAL OF REGULATORY ECONOMICS 359-72 (2003); G. Madden and M. Simpson, *Residential Broadband Subscription Demand: An Econometric Analysis of Australian Choice Experiment Data*, 29 APPLIED ECONOMICS 1073–1078 (1997); D. J. Kridel, P. N. Rappoport, and L. D. Taylor, *An Econometric Model of the Demand for Access to the Internet by Cable Modem* in FORECASTING THE INTERNET: UNDERSTANDING THE EXPLOSIVE GROWTH OF DATA COMMUNICATIONS (edited by D.G. Loomis and L.D. Taylor (Kluwer Academic Publishers (2001)); P. Rappoport, D. Kridel, L. Taylor, K. Duffy-Deno, J. Alleman, *Residential demand for access to the Internet*, in G. Madden (Ed.), THE INTERNATIONAL HANDBOOK OF TELECOMMUNICATIONS ECONOMICS: VOL. II (2002); Savage, S., & Waldman, D. *Estimating Consumer Preferences for Internet Access. in Broadband Demand Study Final Report*, Telecommunications Research Group, University of Colorado, Boulder (2002); CHARACTERISTICS AND CHOICES OF INTERNET USERS, United States General Accounting Office (2001); Z. Papacharissi and A. Zaks, *Is Broadband the Future? An Analysis of Broadband Technology Potential and Diffusion*, 30 TELECOMMUNICATIONS POLICY 64-75 (2006); A. Tookey, J. Whalley, S. Howick, *Broadband Diffusion in Remote and Rural Scotland*, 30 TELECOMMUNICATIONS POLICY 481-495 (2006); E. Ferro, *Broadband Diffusion Dynamics: A Systemic Analysis*, 4 INTERNATIONAL JOURNAL OF ELECTRONIC BUSINESS 146-161 (2006); V. Spurge and C. Roberts, *Broadband Technology: An Appraisal of Government Policy and Use by Small- and Medium-sized Enterprises,* 23 JOURNAL OF PROPERTY INVESTMENT & FINANCE 516-524 (2005); J. Choudrie and H. Lee, *Broadband Development in South Korea: Institutional and Cultural Factors*, 13 EUROPEAN JOURNAL OF INFORMATION SYSTEMS 103-114 (2004); S. Locke, *Farmer Adoption of ICT in New Zealand*, 3 THE BUSINESS REVIEW 197 (2005).

Our purpose in this analysis is to provide a more refined analysis that takes into account the demand and supply-side conditions that drive broadband penetration in a country. Only after such factors (like population density, GDP, population age, etc.) are considered would comparisons between countries be valid. These factors create an expected (or "natural") level of subscribership. With that information in hand, we can calculate the extent to which a country is over- or underperforming its expected level of subscribership. This method provides a policy-relevant tool for those interested in comparing broadband policy regimes between countries.

A. *The Broadband Performance Index*

Of interest to us is to compare the actual broadband subscription rate of a country to the rate reasonably expected based on the country's economic and demographic endowments. The difference forms the basis of the Broadband Performance Index (or BPI), and the value of this index is determined by a wide range of idiosyncratic factors in a country, including but by no means limited to broadband policies, that contribute to broadband subscription. A ranking of the performance index may be very different from a ranking of subscription rates. We might find, for example, that a country with a high subscription rate may actually be a poor performer relative to its endowments, suggesting that the country is not a particularly good example of a successful broadband policy. Or, countries with low subscriptions rates may, in fact, have very good broadband policies if their actual rate of subscriptions exceeds what our model would expect. In our view, the success of a country's broadband policy is not simply the achievement of high broadband subscription rate, but whether a country's actual subscription rate surpasses what would be reasonably expected based on endowments.

The idea behind calculating the Broadband Performance Index can be stated simply. Say there is a single factor X that systematically determines broadband subscription B. Across a large number of countries it is determined that each unit of X translates into 0.10 units of broadband subscription, on average. So, a country i's expected broadband subscription rate is simply $\hat{B}_i = 0.1 \cdot X$. Now, say we have two countries, Country A and Z with X endowments of 3 and 5, respectively. The expected broadband subscription rate in Country A is 0.3 and in Country Z is 0.50. But, say actual subscriptions rates in Countries A and Z are 0.35 and 0.45. Country A is performing better than expected, with an additional 0.05 in subscription above expectation ($B = 0.35$, $\hat{B} = 0.30$). Country Z, however, is 0.05 units below expectations ($B = 0.45$, $\hat{B} = 0.50$). These differences are the consequences of idiosyncratic determinants (i.e., not X) of broadband

subscription which may include a wide range of country-specific influences on broadband subscription. In this example, even though Country Z has a higher subscription rate, Country A is the better performer, because it is doing more with its endowments than Country Z, which fails to perform as well as the average country would if it had Country Z's endowments.

More specifically, the performance index is computed using multivariate regression. Say there are multiple *X* factors that systematically determine broadband subscription. To determine the relationship between broadband subscription *B* and the *X*'s, we estimate using data for a group of countries

$$B_i = \sum_{j=1}^{k} \alpha_k X_{k,i} + \varepsilon_i \tag{1}$$

where α_k are the coefficients for *k* systematic determinants of broadband subscription and ε is the econometric disturbance term that measures the idiosyncratic influences on broadband subscription. The expected subscription rate is

$$\hat{B}_i = \sum_{j=1}^{k} \hat{\alpha}_k X_{k,i} \ , \tag{2}$$

where the $\hat{\alpha}$ are estimates of the α in Equation (1). The difference between the actual and expected subscription rate is

$$B_i - \hat{B}_i = \hat{\varepsilon}_i \, . \tag{3}$$

where $\hat{\varepsilon}$ is an estimate of ε in Equation (1). The Broadband Performance Index, then, is

$$BPI = \hat{\varepsilon}_i \, / \max(|\, \hat{\varepsilon}_i \,|) \, . \tag{4}$$

From Equation (4) we see that the performance index lies between -1 and 1. Values closer to 1 indicate good performance, whereas values closer to -1 indicate poor performance. A value close to 0 indicates the country meets expectations or is an average performer. We can certainly rank the BPI to create an ordinal scale of performance, but comparing the BPI itself across countries is more revealing since it measures the degree of performance differences. Ordinal scales, like rankings, provide information only on which of two things is bigger

or smaller, not how much bigger or smaller. The "how much" is very important for policy making.

B. *Empirical Approach*

From this previous section, we see that the starting point of the analysis is to quantify the relationships between country endowments and broadband subscription rate across the OECD. That is, we need to calculate good estimates of α in Equation (1). Once this is accomplished, computing the Broadband Performance Index is relatively straightforward.

We have selected a number of economic and demographic factors for this analysis, based upon the research that has been conducted to date and data availability. Using the last three semesters of data on broadband subscription for OECD countries, we estimate an econometric model of the general form:

$$\begin{aligned} B_i = f(&PRICE_i, GDPCAP_i, GINI_i, EDUC_i, AGE65_i, DENSITY_i, BIGCITY_i,\\ &PHONE_i, PHONE_i^2, HHSIZE_i, BUSSIZE_i, DEC05, JUNE06) + \varepsilon_i \end{aligned} \quad (6)$$

where B_i is broadband subscriptions per capita in OECD country *i*, *PRICE* is an index of broadband price in country *i*, *GDPCAP* is gross domestic product per capita in country *i*, *GINI* is the nation's Gini Coefficient (a measure of income inequality) in country *i*, *EDUC* is the percent of persons with post-secondary or tertiary education in country *i*, *AGE65* is the percent of the labor force age sixty-five or older as a percentage of the labor force in country *i*, *DENSITY* is the number of households per square kilometer in country *i*, *BIGCITY* is the percent of the population living in the country's largest city in country *i*, *PHONE* is the number of telephones (landline and mobile) per 100 persons in country *i* and $PHONE^2$ is its square,[10] *HHSIZE* measures persons per household in country *i*, *BUSSIZE* measures persons per business establishment in country *i*, and *DEC05* and *JUNE06* are dummy variables that equals 1 for the relevant period of the data (0 otherwise), and ε is the econometric disturbance term for country *i* (the idiosyncratic component of subscription).[11] The dummy variable for December

[10] Specification tests indicated a non-linear relationship with respect to *PHONE*, so we include the square of the regressor.

[11] We intentionally exclude country-specific dummy variables (fixed effects estimation), since that approach would account for most departures from average performance in such a limited dataset. We also exclude variables for unbundling regimes and do so intentionally. The

(Footnote Continued. . . .)

2006 data is left out to avoid the dummy trap. We use data for periods December 2005, June 2006, and December 2006, for a total of 90 observations, and limit our sample (for much of the analysis) to the last three semesters of data to get a reasonably large sample size of the latest subscription rates. We also consider and report the results from alternative samples (both larger and smaller).

Notably, we take the OECD subscription rate data and the value of the endowments as given. Defects in the data create problems in econometric estimation, and numerous parties have criticized the OECD's subscription data. But, this criticism is valid for any and all uses of the OECD's data, so our approach is not more or less flawed than others in this respect. We used the best data we could find and note its potential shortcomings.

Further, we include price in the regressions, and doing so allows public policy to enter into the calculation of the *BPI*, at least to some extent. Thus, it could be argued that only non-price policy effects are captured in the performance indicia. Nevertheless, we leave price in the regressions since excluding it could render biased estimates of the coefficients. Thus, we note this limitation of the analysis. We provide, for illustrative purposes, the computed BPI based on a regression model that excludes price.

C. *Expectations*

We have the following expectations regarding the regressors. Based on earlier research, we expect the coefficient on *PRICE* will be negative, though we cannot claim that Equation (3) is a demand curve.[12] We also expect a negative sign on *AGE65*, since earlier research has shown that Internet use is lower for older persons. Alternately, we expect higher levels of broadband subscription in

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experience in the U.S. and abroad indicates that unbundling regimes are far too idiosyncratic for simple specifications. An unbundled loop dummy variable, for example, completely ignores the conditions and terms upon which loops are available (including prices). The unbundling regime in the U.S., for example, is exceedingly complex with numerous peculiarities that cannot be captured with simple specifications. The unbundling regimes, therefore, are treated as idiosyncratic and are relegated to the disturbance term of the regression. Earlier research is unable to find a statistically-significant relationship between unbundling and broadband subscription. *See, e.g.,* S. Wallsten, *Broadband and Unbundling Regulations in OECD Countries,* AEI-Brookings Joint Center Working Paper No. 06-16 (June 2006) (available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=906865).

[12] Rather than specify a demand curve, Equation (1) represents an equilibrium relationship.

countries that are richer (*GDPCAP*), have more educated citizens (*EDUC*), and are more densely populated (*DENSITY*). We do not have an a priori expectation for the *BIGCITY* regressor but include it as another measure of population density. While one might expect a positive sign, with *DENSITY* already in the regression, the effect of *BIGCITY* is not so clear. If one holds density constant, as *BIGCITY* gets larger it may imply that the population is more geographically spread out or that the rural areas are very sparsely populated, suggesting a negative sign. Furthermore, a large urban population is not simply a measure of population density but may reflect other factors.

Income inequality is expected to reduce broadband subscription (*GINI*). We expect the historically high consumption of communications services indicates both high demand for communications ad adequate supply of communications network, so the coefficient on *PHONE* is expected to be positive. We expect a negative sign on $PHONE^2$, indicating that we expect broadband subscription to rise with the number of telephones per capita, but at a decreasing rate. The variable *BUSSIZE* is expected to be negatively signed since the subscription data is in per capita terms. In other words, larger values of *BUSSIZE* indicate fewer businesses thereby indicating fewer business subscriptions on a per capita basis. For the same reasons, larger households (*HHSIZE*) also should reduce subscriptions per capita, since presumably only one broadband connection is needed per household. We make no a priori predictions on the sign of *HHSIZE*, however, since larger households may have larger demands for broadband services. Since broadband subscription grows over time, we suspect the coefficients on *DEC05* and *JULY06* will be negative since both are measured relative to the December 2006 period.

D. *Data*

The bulk of the data is provided by the OECD FACTBOOK 2006 and the World Bank's WORLD DEVELOPMENT INDICATORS 2006.[13] Most regressors are at least three-year lags (with the exception of *PRICE*), due to data availability. Using lagged values has some advantages, since it commonly asserted that broadband impacts economic development and other economic and demographic factors.

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13 Organisation of Economic Co-operation and Development, OECD FACTBOOK—ECONOMIC, ENVIRONMENTAL AND SOCIAL STATISTICS 2006 (available at: http://miranda.sourceoecd.org/vl=632386/cl=39/nw=1/rpsv/fact2006/).

Thus, the lagged data helps attenuate the potential for simultaneity bias.[14] We use the last year of data available for all periods.

Price data is from an OECD report that provides detailed price data for broadband services.[15] The variable *PRICE* is the introductory rate for broadband service assuming the customer generates 1GB of traffic per month (since some prices are metered). Of all the variables, price is the most difficult to measure since quality data on prices is scant. Also, there are many prices paid for broadband services in a population, so any single measure of price will suffer from a variety of defects. Nevertheless, we expect price to be an important determinant of subscription, so we include the variable as a regressor. Notably, we also employed many other measures of price, but found none to be statistically significant in the regression.[16] While the price variable we choose appears to perform well in the regressions, we nevertheless caveat our findings by observing that a single index of price for broadband service suffers from numerous shortcomings, and the price data is not of great quality. Others have done the same.[17]

Data on *GDPCAP*, *EDUC*, *AGE65*, *DENSITY*, *TAXES*, and *PHONE* are all provided by the OECD FACTBOOK 2006. The DEVELOPMENT INDICATORS FACTBOOK also provided data for *BIGCITY*. Missing observations on some

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14 D. Gujarati, BASIC ECONOMETRICS (1995), 654. This choice of lag was also motivated by the available data.

15 Organisation of Economic Co-operation and Development, Working Party on Telecommunication and Information Services Policies, BENCHMARKING BROADBAND PRICES IN THE OECD (June 2004) (available at: http://www.oecd.org/dataoecd/58/17/32143101.pdf).

16 For example, an alternative measure of price is constructed by dividing the *PRICE* variable by the downstream speed of the broadband connection. We also calculated the price for the 1.5Mbit downstream service, or as close to that downstream speed is available. Again, we calculate based on 1GB traffic per month. We also divided this variable by download speed. None of these prices were statistically significant in the regression (though all negatively signed). The World Bank also prices a measure of price, but this price measure was also insignificant in the regression. We also considered a recent price index reported by Correa and the Information Technology and Innovation Foundation. *See* Daniel K. Correa, *Assessing Broadband in America: OECD and ITIF Rankings* (Apr. 2007) (available at: http://www.itif.org/files/BroadbandRankings.pdf), 4. This price index also was statistically insignificant (though it did have a negative sign). Stepwise regression was also performed on all the price variables (the other regressors always included), and our chosen measure of price was the only additional regressor selected.

17 Wallsten, *supra* n. 11.

variables were filled using other data sources. Notably, the *BUSSIZE* variable is computed using population and business establishment data, the latter of which was unavailable for four countries. We employ two standard resolutions to this problem: (a) estimate business establishments for the four countries from the data available using least squares regression (*BUSSIZE_1*) and (b) replace *BUSSIZE* for these four countries with the mean of *BUSSIZE* for the others (*BUSSIZE_2*).[18] The results were very similar across the alternatives. All values of the regressors are constant over the sample. Finally, data on broadband subscription, ranking, and population is provided by the OECD.

E. *Estimation Details*

We consider both the log-log and lin-lin functional forms in our analysis. Heteroscedasticity is often a problem with subscription rate data, and White's test confirms its presence in this data.[19] As prescribed by Maddala, we estimate both specifications using weighted least squares and use White's robust standard errors to compute the *t*-statistics.[20] White's test indicates that the weighting scheme resolved the heteroscedasticity problem for both specifications.[21] The null hypothesis of RESET ("no specification error") cannot be rejected at standard significance levels for the log-log specification, but is easily rejected for the lin-lin functional form.[22] Further, the log-log specification predicted out-of-sample observations better than the lin-lin functional form.[23] Based on this

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[18] *See* W. Greene, ECONOMETRIC ANALYSIS (2000), 259-63; R. Pindyck and D. Rubinfeld, ECONOMETRIC MODELS & ECONOMIC FORECASTS (1991), 219-23. Another alternative would be to set *BUSSIZE* equal to zero for missing values and include a dummy variable equal to one for these four countries. This approach, however, is identical to *BUSSIZE_2*. Greene, *supra* at 262.

[19] The χ^2 statistics for the White test on the unweighted data are 27.66 (Prob < 0.01) for the log-log and 21.02 (Prob < 0.07) for the lin-lin specifications. The absence of heteroscedasticity is important given the role of the disturbance term in computing the BPI.

[20] G. S. Maddala, LIMITED DEPENDENT AND QUALITATIVE VARIABLES IN ECONOMETRICS (1983), 29. This specification is the minimum chi-square method for the linear and log-linear model.

[21] The null hypothesis of the White test for the weighted data is rejected at the 35% for the log-log and 70% for the lin-lin specification.

[22] The F-statistic for the lin-lin model is 7.27 with a probability level less than 0.01.

[23] We excluded the December 2006 data from the sample, estimated the model, and then used that model to predict the excluded observations. The Mean Absolute Percent Error and Theil Inequality Coefficient for the log-log model are about two-thirds of those of the lin-lin model across specifications.

analysis of the specifications, we rely on the log-log functional form to compute the BPI.

F. *Results*

Our total sample contains 90 observations (30 OECD countries, 3 semi-annual reports). The regression results are summarized in Table 3. We provide the estimates using *BUSSIZE_1* and *BUSSIZE_2*, to demonstrate the small effect of the alternate remedies for missing data. Most of the discussion is based on the *BUSSIZE_1* variable. The marginal effects for a 10% increase in each variable are summarized in Table 3. The models fit the data well, with about 86% of the variation in subscription rates explained. In other words, the economic and demographic conditions we study account for 86% of the differences that we observe in broadband adoption among the OECD—only 14% of the differences come from other factors like telecommunications policy (not affecting price, which is included as a regressor). Both specifications exhibit strong statistical significance of the regressors, with nearly all variables statistically significant at the 5% level or better. As previously noted, we cannot reject the null hypothesis of "no specification error" for either of the log-log equations, and testing also indicates homoscedastic disturbances. By many accounts, then, the models appear to be good ones.

All the estimated coefficients have the expected sign. A 10% increase in the price index (*PRICE*) reduces the subscription rate by about 2.4%.[24] The effect of income (*GDPCAP*) is large, with a 10% increase in per capita GDP increasing the subscription rate by about 8.1%. Importantly, the distribution of income matters, and the elasticity is larger than income (*GDPCAP*) itself. A 10% increase in income inequality (*GINI*) reduces broadband subscriptions by about 9% (8.5% or 10.6%), the largest effect of any of the regressors in the model. Education has a positive and significant effect, with a 10% rise in the percentage of persons with post-secondary education increasing subscription by 1.9%. Consistent with earlier research, the older is the population the lower is broadband subscription. A 10% rise in the percent of population age 65 or older reduces subscription by about 7%. This is a significant difference and in and of itself accounts for much

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24 This elasticity is not a measure of the own-price elasticity of demand, since we have not estimated a demand curve.

of the difference between the broadband subscription rate in Korea, which has a relatively young population, and Japan, which has a relatively old population.[25]

The role of population density on broadband subscription is frequently contested.[26] Our regression results indicate a positive relationship between population density and broadband subscription, ceteris paribus, but that the impact is small. A 10% rise in density, ceteris paribus, increases subscription by just less than 1%. The larger the population in the capital city, other things constant, the lower the subscription rate, though this result is just statistically significant at the 10% level and the marginal effects is very small (0.6% or less). This negative sign was somewhat expected, since a larger population in the largest city, density constant, suggests the city covers a wider geographic area.[27] So, again, the interpretation is that higher population density increases subscription but only slightly. Density is bound to influence availability, which in turn influences subscription. The failure to detect such an effect in other studies is perhaps due to poor model specification or poor measures of density (or both).[28]

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25 The difference in values for *AGE65* between Japan and Korea is very large (26.9% to 12.4%).

26 *See, e.g.*, Correa, *supra* n. 16 at 5-6 ("[p]opulation density is not a sufficient explanation for America's lagging broadband penetration.").

27 If *DENSITY* is excluded, then the sign on the coefficient for *BIGCITY* is positive, supporting this interpretation.

28 Some of the arguments against *DENSITY* as a relevant factor are based on univariate regressions of subscription on density. This approach is clearly inappropriate for determining the relationship between the two since there are so many other factors driving subscription.

Table 3. Regression Results

	Coef. (t-stat)	Approximate Marginal Effect (10% increase)	Coef. (t-stat)	Approximate Marginal Effect (10% increase)
Constant	-21.065	…	-21.685	…
	(-6.55)*		(-6.36)*	
lnPRICE	-0.242	-2.4%	-0.216	-2.2%
	(-4.09)*		(-3.23)*	
lnGDPCAP	0.810	8.1%	0.781	7.8%
	(7.42)*		(7.53)*	
lnGINI	-0.848	-8.5%	-0.992	-10.6%
	(-5.72)*		(-6.37)*	
lnEDUC	0.186	1.9%	0.187	1.5%
	(3.33)*		(2.97)*	
lnAGE65	-0.717	-7.2%	-0.675	-6.9%
	(-8.64)*		(-7.12)*	
lnDENSITY	0.080	0.8%	0.041	0.4%
	(5.86)*		(3.42)*	
lnBIGCITY	-0.060	-0.6%	-0.041	-0.2%
	(-1.66)		(-0.99)	
lnPHONE	6.855	2.8%	7.390	2.7%
	(4.38)*		(4.39)*	
lnPHONE^2	-0.681	…	-0.733	…
	(-4.05)*		(-4.01)*	
lnHHSIZE	0.067	0.7%	0.168	1.8%
	(0.38)		(0.89)	
lnBUSSIZE_1	-0.350	-3.5%	…	…
	(-7.27)*			
lnBUSSIZE_2	…	…	-0.330	-3.1%
			(-6.12)*	
DEC05	-0.083	…	-0.083	…
	(-3.25)*		(-2.97)*	
JULY06	-0.210	…	-0.209	…
	(-8.18)*		(-7.29)*	
Unw. R^2	0.86		0.86	
RESET F	0.46		0.61	
White χ^2	16.59		19.63	

* Statistically significant at the 5% level or better.

We also find a positive effect on broadband subscription from the consumption of traditional telephone services. A 10% increase in the number of telephones per capita increases broadband subscription rate by nearly 3% (at the sample mean of *PHONE*).[29] Thus, past communications demand is a relevant

[29] The marginal effect is the coefficient on *PHONE* plus the two times the coefficient on *PHONE*^{2} multiplied by the mean of *PHONE*.

factor in determining broadband subscriptions per capita, which is not surprising.[30] The positive sign on *PHONE* and the negative sign on $PHONE^2$ indicate that broadband subscription rises with telephone consumption but does so at a decreasing rate. Recent OECD data indicates that the United States ranks 24th in telephone subscription per capita, so the fact the country is not ranked very high in broadband subscription is not necessarily surprising. The negative coefficients on the time dummies indicate broadband subscription rates are growing at about 8.5% per semester.[31]

Table 4 presents the results of the first regression shown in Table 3 in a different format. In Table 4, we rank the endowments by their relative impacts on broadband subscription, and do so based on two measures of "impact." To show which demographic and economic condition have the most impact on broadband subscriptions, the left side of Table 4 simply sorts the factors we study based on their marginal effects as summarized in Table 3. The largest marginal effect (in absolute value) is the income inequality measure, *GINI*: on average, a 10% increase in *GINI* reduces a country's broadband subscription rate by 8.5%. In contrast, a 10% increase in GDP per capita (*GDPCAP*) increases a country's broadband subscription rate by 8.1%.

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30 Since *PHONE* is expressed on a per capita basis, the variable may explain a part of the variation in subscription based on the per capita definition of the subscription rate.

31 The coefficients in the log-log model are interpreted as $\exp(\beta)$-1.

Table 4. Broadband Subscription and Endowments

Variable Ranked by Size Effect	Magnitude of Effect (for 10% increase)	Variable Ranked by Size Effect	Magnitude of Variation Explained (Partial R^2)
GINI	-8.5%	AGE65	0.50
GDPCAP	+8.1%	GDPCAP	0.42
AGE65	-7.2%	BUSSIZE	0.41
BUSSIZE	-3.5%	DENSITY	0.30
PHONE	+2.8%	GINI	0.31
PRICE	-2.4%	PHONE	0.20
EDUC	+1.9%	PRICE	0.18
DENSITY	+0.8%	$PHONE^2$	0.18
HHSIZE	+0.7%	EDUC	0.13
BIGCITY	-0.6%	BIGCITY	0.04
		HHSIZE	0.00

The right side of Table 4 sorts the endowments by their Partial R^2 values, where the Partial R^2 measures the proportion of the variation in broadband subscription explained by the regressor having already accounted for the variation in subscription explained by the other regressors.[32] In other words, the regressors are ranked by their relative "additional" power to explain the variation in broadband subscription across the OECD countries. Age and income (*GDPCAP*) are the most potent determinants of broadband subscription. Business size, income inequality and density are also significant contributors to explaining variations across the OECD in broadband subscription. The large effect of *BUSSIZE* suggests that the per capita presentation of the data that the OECD reports twice a year may be inappropriate.

32 The Partial R^2 is $t^2/(t^2 + n - k)$, where t is the t-statistic, n is sample size and k is the number of regressors. A. Darnell, A DICTIONARY OF ECONOMETRICS (1994), 301-02.

G. *Alternative Specifications*

The estimates in Table 3 are based on the chosen specification of the model; a specification which appears to perform well based on a variety of criteria. If our findings are to be useful to policymakers, then an evaluation of the robustness of the results reported in Table 3 (and the calculation of the BPI, infra) is worthwhile. As a result, in this Section III.G we consider a variety of alternative specifications. While these adjustments to sample and specification are sometimes significant, the results of our regression are not materially altered.

1. *Endogeneity of Price*

A common criticism of models such as Equation (6) is that price and subscription are jointly determined. To account for this possibility, we specify an equation for price and estimate the subscription and price equation jointly using Two-stage Least Squares ("TSLS").[33] Additional instruments for the price equation include (the natural log of) an index of the price of telephone services, the share of the dominant technology (DSL or cable) in the country, the ratio of government tax revenue to Gross Domestic Product, and average temperature in the capital city.[34] TSLS is also beneficial since it is often employed in the presence of mis-measured variables (and price is crudely measured here).[35] The results are summarized in Table 5, Column A. Price remains statistically significant and the coefficient is slightly larger (more negative). In all, there are no significant changes to report.

2. *Excluding Price*

We also recognize that the price variable is crudely measured. As a result, we estimate the model excluding the price variable. We would argue this model is mis-specified, but the null of RESET is not rejected. The results are summarized in Table 5, Column B.

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33 Gujarati, *supra* n. 14 at 686.

34 Phone price data is from OECD COMMUNICATIONS OUTLOOK (2005), Table 6.5.

35 Gujarati, *supra* n. 14 at 469-70. In the price equation, three of the four additional regressors are statistically significant at the 5% level or better. The R^2 of the regression is 0.75, and the null hypothesis of RESET ("no specification error") is not rejected. *See* J. Wooldridge, ECONOMETRIC ANALYSIS OF CROSS SECTION AND PANEL DATA (2002), 90-94.

Table 5. Regression Results

(Log-Log Models Only)

	From Table 3	A	B	C	D	E
	Coef. (t-stat)					
Constant	-21.065 (-6.55)*	-20.412 (-5.83)*	-25.911 (-8.68)*	-20.201 (-5.64)*	-26.010 (-6.59)*	-25.334 (-5.10)*
lnPRICE	-0.242 (-4.09)*	-0.275 (-3.49)*	…	-0.201 (-2.98)*	-0.288 (-5.12)*	-0.371 (-3.13)*
lnGDPCAP	0.810 (7.42)*	0.799 (7.19)*	0.889 (7.24)*	0.766 (6.42)*	0.868 (7.32)*	0.856 (3.56)*
lnGINI	-0.848 (-5.72)*	-0.849 (-5.66)*	-0.837 (-5.27)*	-0.883 (-4.68)*	-0.794 (-6.02)*	-0.580 (-2.19)*
lnEDUC	0.186 (3.33)*	0.183 (3.18)*	0.208 (3.63)*	0.178 (2.68)*	0.221 (4.17)*	0.287 (2.21)*
lnAGE65	-0.717 (-8.64)*	-0.702 (-8.04)*	-0.831 (-9.95)*	-0.682 (-6.60)*	-0.809 (-10.30)*	-1.027 (-4.78)*
lnDENSITY	0.080 (5.86)*	0.078 (5.15)*	0.099 (7.35)*	0.077 (5.22)*	0.099 (6.77)*	0.102 (4.05)*
lnBIGCITY	-0.060 (-1.66)	-0.058 (-1.55)	-0.073 (-2.09)*	-0.066 (-1.62)	-0.059 (-1.69)	-0.204 (-2.16)*
lnPHONE	6.855 (4.38)*	6.640 (4.03)*	8.450 (5.30)*	6.615 (3.87)*	8.828 (4.73)*	9.303 (4.35)*
$lnPHONE^2$	-0.681 (-4.05)*	-0.658 (-3.69)*	-0.857 (-5.02)*	-0.656 (-3.55)*	-0.894 (-4.59)*	-0.964 (-3.86)*
lnHHSIZE	0.067 (0.38)	0.104 (0.55)	-0.207 (-1.27)	0.064 (0.30)	0.069 (0.42)	-0.262 (-1.14)
lnBUSSIZE_1	-0.350 (-7.27)*	-0.347 (-7.10)*	-0.367 (-6.73)*	-0.323 (-6.07)*	-0.414 (-8.33)*	-0.521 (-5.05)*
JULY06	-0.083 (-3.25)*	-0.083 (-3.23)*	-0.083 (-3.18)*	-0.082 (-3.31)*	-0.084 (-2.56)*	-0.161 (-2.38)*
DEC05	-0.210 (-8.18)*	-0.210 (-8.17)*	-0.208 (-7.57)*	…	-0.213 (-7.30)*	-0.364 (-4.43)*
JULY05	…	…	…	…	-0.348 (-10.18)*	…
DEC04	…	…	…	…	-0.471 (-10.60)*	…
Unw. R^2	0.86	0.87[a]	0.84	0.88	0.82	0.86
RESET F	0.46	…	0.1.20	0.72	7.57*	4.77*
White χ^2	16.59	17.02	11.32	9.76	32.54*	27.66*
Obs	90	90	90	60	150	90

* Statistically significant at the 5% level or better.
[a] Square of the correlation of the actual and predicted dependent variable.

3. *Exclude Year 2005*

Eliminating all data from the Year 2005 reduces our sample size from 90 to 60 observations. But, it also shortens the time period over which we assume the coefficients are the same. The results are not materially different as summarized in Table 5, Column C.

4. *Adding Additional Data*

Because the variables we have included, like *GDPCAP* and *GINI*, are calculated on an annual basis and are published with substantial lags, our initial specification only utilizes the last year of data available. We also wanted to estimate the relationship between endowments and the most current broadband subscription rates, so we limited our sample to the last three available semesters of data on subscriptions. Using the last three semesters in order to produce 90 separate observations seemed like a sensible balance. For illustrative purposes, however, we expand the dataset to include data back to December 2004, which adds 60 data points for a total of 150 observations. The results are summarized in Table 5, Column D.

The additional data has surprisingly little effect, though the model fails to pass RESET indicating model mis-specification. Despite the defects in the specification, the estimated coefficients are not much affected and the statistical significance of the variables is unchanged.

5. *Unweighted Least Squares*

In Table 5, Column E, we present the results of the main log-log specification estimated by least squares rather than weighted least squares. We do so because the weights used in the other regressions are proportional to population, thereby making large countries more influential in determining the values of the coefficients. In this alternative, ordinary least squares approach there are some changes in the coefficients and significance levels, but the general findings of our primary specifications are not much altered. For this specification, the null hypothesis of both White's test and RESET is rejected, indicating specification errors.

H. *Summary*

In summary, in light of the results from these alternative specifications, the results of our initial regression analysis are remarkably robust to specification and sample choice. It would appear that the factors that we have identified—the

economic and demographic "endowments" of a country—have a consistent and robust impact on the broadband subscription rate of the OECD countries. As we discuss above, the economic and demographic conditions we identify explain 86% of the difference that we observe in broadband adoption among the 30 OECD countries. Only 14% of the differences between the OECD countries in broadband subscriptions can be attributed to other factors like telecom policy.[36] As a result, any assessment of a country's performance or consideration as to whether a country's telecom policy is hurting or harming its rate of broadband adoption needs to take these endowments into account. As we discuss in the next Section, we believe that it may be sensible to compare OECD countries not simply by the subscription rate and "rank" but instead by reference to the relative efficiency in which they convert their endowments into broadband penetration. Our Broadband Performance Index is such a measurement.

IV. Broadband Subscriptions, Demographic and Economic Endowments, and Performance

The statistical analysis above shows clearly that economic and demographic endowments are important determinants of broadband subscription. The regression model explains 86% of the variation in broadband subscription across the OECD countries. Factors reasonably considered outside the realm of broadband policy explain the vast majority of variations in broadband subscription rate across the OECD. Clearly, a tool better than ranking countries by raw broadband subscription data is needed if telecom policymakers wish to understand better their progress in stimulating the adoption of broadband.

In this Section, we present and discuss the Broadband Performance Index (BPI), which is calculated from the regression analysis described above. The BPI is a new method of ranking OECD countries by reference to the *relative efficiency* of converting economic and demographic endowments into broadband subscriptions. The BPI identifies which countries are essentially making the most out of the cards that they are dealt and reveals those that, despite having

[36] Even if one does not consider price, the other demographic and economic factors we consider explains 84% of the variation in subscription rates. *See* Table 5, Column B. As a result, while some might assert that the price of broadband service may be related to a country's telecom policy (particularly its competition policy), most of the variation in broadband subscription rate among the OECD is still explainable by the other demographic and economic conditions that we study.

robust broadband subscription levels, are not living up to expectations given their highly favorable economic and demographic endowments.

A. *The Broadband Performance Index*

In Figure 1, we rank the countries by the BPI computed using Equation (4).[37] Recall that the BPI has values ranging from -1 to 1. A positive BPI score (up to 1.000) indicates that the country is over-performing or is "above expectations"—its broadband subscription rate is outpacing its endowments. A negative BPI score (down to -1.000) indicates that the country is underperforming or is "below expectations"--its broadband subscription rate trails what should be expected. A BPI score of 0.000 means that the country is converting its endowments into broadband subscriptions as one would expect, or that the country is generally "meeting expectations." For expositional purposes, the December 2006 OECD rank of broadband subscription is also provided in the figure (in parenthesis next to the country name).

Figure 1 presents a somewhat different picture than the standard OECD rankings. As is discernable from the figure, the performance index and the OECD broadband rank are only somewhat positively correlated; the correlation coefficient of the rankings is 0.47. For those countries with positive BPIs, the average OECD rank is 11.6, whereas those countries with negative BPIs have an average OECD rank of 18.9. Countries with higher OECD ranks tend to have higher BPIs as well. Yet, there are a number of countries with high OECD rank that are underperformers, and many low OECD rank countries that are over-performers.

The Broadband Performance Index shows that Finland, Iceland and Portugal are the best at transforming their nation's endowments into broadband subscriptions, while New Zealand, the Czech Republic, the Slovak Republic, Luxembourg, Ireland and Greece are the worst.[38] Greece is, by far, the most significant underperformer in the OECD. The United States ranks 14th, with a BPI score of -0.006. This means that the broadband subscription rate in the

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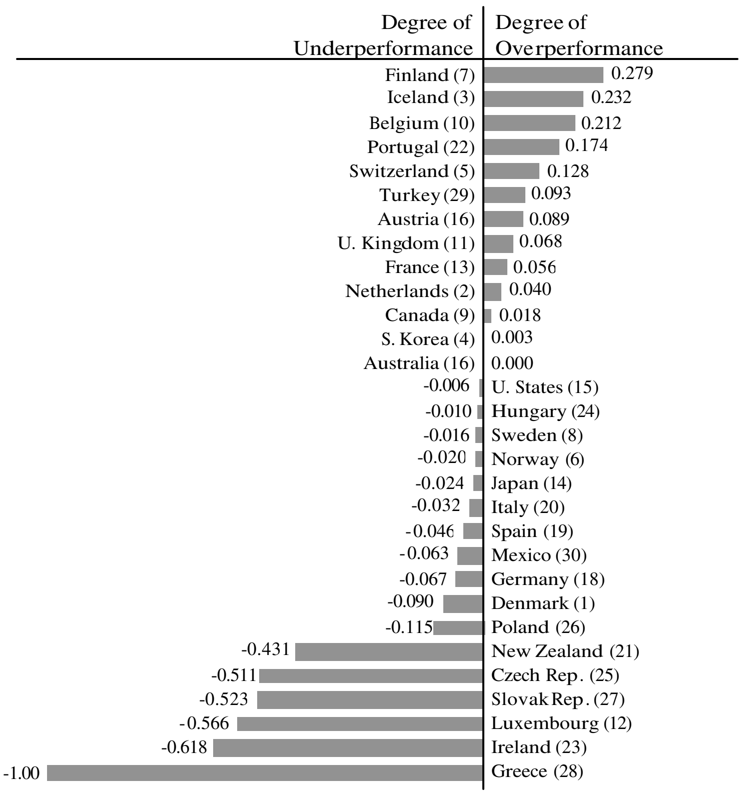
37 The disturbances are averaged over the sample (3 observations for each country).

38 Dividing the BPI by its standard deviation, we find that the underperformance of the Czech Republic, the Slovak Republic, Luxembourg, Ireland and Greece are all statistically significant (at the 10% level or better).

United States is commensurate with its demographic and economic endowments, no better but no worse.

Figure 1. Broadband Performance Index
(December 2006 OECD Rank from Table 1 in Parenthesis)



There are some surprises in Figure 1, particularly for those that believe countries should emulate the policies of countries that are ranked "higher" in the OECD rankings. For example, many compare the United States to Korea and Japan by reference to their higher relative stature in the OECD rankings.[39] However, Figure 1 shows that neither Korea (OECD 4, BPI 0.003) nor Japan

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[39] *Speed Matters, supra* n. 3 at 10, 15-17, 28 (recommending that U.S. create an "Office of Telecommunications" because Korea and Japan "have created secretarial level departments or ministries").

(OECD 14, BPI -0.024) are particularly interesting models to emulate, as both appear to be grouped along with the United States as converting their endowments into broadband subscriptions with roughly average efficiency. Despite claims of a "Japanese Broadband Miracle,"[40] Japan is roughly only living up to expectations, as is Korea, which has a far-reaching broadband industrial policy that involves substantial network subsidies. Moreover, Denmark, which the OECD ranked 1st in December 2006, is underperforming relative to its endowments (OECD 1, BPI -0.090). Finland, Iceland and Switzerland, in contrast, are over-performers that also rank high in the OECD rankings.

Interestingly, many countries that have subscription rates that are relatively low among the OECD rankings nonetheless rank high in our assessment. Portugal, while ranked 22nd by the OECD, has a subscription rate well above expectations and is one of the more significant over-performers (OECD 22, BPI 0.174). Turkey, second-to-last in the OECD for broadband subscriptions, is actually faring quite well according to the BPI (OECD 29, BPI 0.093), given that it is the poorest, least-educated, and least-developed countries in the OECD. If one were going to look to broadband policies to emulate, then policymakers should examine the policies of those countries with larger BPI scores to learn how each has overcome significant hurdles to broadband deployment and subscription. This approach would appear to be far superior that to than blindly follow the policies of Korea, Japan and Scandinavia, in which broadband subscriptions barely meet expectations despite very favorable endowments and, in some cases, concerted efforts to improve broadband subscription.[41]

B. *Sensitivity Analysis*

As we discussed above, the estimated coefficients are robust to range of specifications and sample sizes. Yet, in terms of ranking countries by their performance, different specifications of the models may render different predictions. In Table 6, we present the results of the performance rankings based on a range of model specifications.

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40 *See, e.g.*, Information Technology and Innovation Foundation, "ITIF Policy Forum: Understanding the Japanese Broadband Miracle" (Apr. 4, 2007).

41 We do, however, recognize that what policies may work in a country like Turkey may certainly be different than what might work in the United States. That said, a focus purely upon the OECD raw data would cause U.S. policymakers to ignore Turkey entirely, as the OECD ranks Turkey 29th.

Table 6. The Broadband Performance Index Across Specifications

A		B		C		D	
Finland	0.28	Finland	0.29	Iceland	0.20	Finland	0.32
Iceland	0.23	Iceland	0.24	Finland	0.20	Iceland	0.31
Belgium	0.21	Belgium	0.22	Switzerland	0.17	Belgium	0.24
Portugal	0.17	Portugal	0.18	Belgium	0.16	Portugal	0.19
Switzerland	0.13	Switzerland	0.12	Turkey	0.16	Switzerland	0.16
Turkey	0.09	Austria	0.11	Portugal	0.13	Turkey	0.14
Austria	0.09	Turkey	0.08	France	0.09	UK	0.11
UK	0.07	UK	0.07	Canada	0.07	Austria	0.08
France	0.06	France	0.05	Denmark	0.06	France	0.08
Netherlands	0.04	Netherlands	0.05	UK	0.04	Poland	0.08
Canada	0.02	Australia	0.02	Italy	0.03	Netherlands	0.05
S. Korea	0.00	Canada	0.01	S. Korea	0.02	Hungary	0.02
Australia	0.00	Hungary	0.01	Sweden	0.01	Australia	0.02
US	-0.01	S. Korea	0.00	Norway	0.01	Canada	0.01
Hungary	-0.01	US	-0.01	US	-0.01	S. Korea	0.00
Sweden	-0.02	Sweden	-0.02	Japan	-0.03	US	-0.01
Norway	-0.02	Norway	-0.02	Netherlands	-0.03	Sweden	-0.01
Japan	-0.02	Japan	-0.02	Austria	-0.05	Norway	-0.01
Italy	-0.03	Italy	-0.04	Spain	-0.05	Japan	-0.04
Spain	-0.05	Spain	-0.04	Germany	-0.05	Italy	-0.05
Mexico	-0.06	Mexico	-0.06	Mexico	-0.08	Denmark	-0.06
Germany	-0.07	Germany	-0.07	Australia	-0.12	Spain	-0.07
Denmark	-0.09	Poland	-0.10	Hungary	-0.14	Mexico	-0.08
Poland	-0.12	Denmark	-0.11	Poland	-0.20	Germany	-0.09
New Zeal.	-0.43	New Zeal.	-0.43	New Zeal.	-0.44	New Zeal.	-0.40
Czech Rep.	-0.51	Czech Rep.	-0.48	Luxembourg	-0.47	Czech Rep.	-0.58
Slovak Rep.	-0.52	Slovak Rep.	-0.52	Slovak Rep.	-0.53	Luxembourg	-0.65
Luxembourg	-0.57	Luxembourg	-0.58	Ireland	-0.67	Slovak Rep.	-0.66
Ireland	-0.62	Ireland	-0.61	Czech Rep.	-0.72	Ireland	-0.66
Greece	-1.00	Greece	-1.00	Greece	-1.00	Greece	-1.00

In Column A, we repeat the information provided in Figure 1. In Column B, we provide the performance index from the log-log specification estimated by two-stage least squares where price is jointly determined with subscription (From Table 5, Column A). In Column C, we provide the BPI for each country with the *PRICE* variable (which may be influence by broadband policy) excluded from the regression (From Table 5, Column B). In Column D, the performance index is computed using only the July 2006 and December 2006 data (From Table 5, Column C). We choose these four alternatives since all of the specifications are satisfactory from a statistical standpoint.

The calculated BPIs across models are very stable across specifications. While there is some movement "in the middle," the over- and under-performers are consistently indicated. The United States remains in a similar position, along with Japan and South Korea, in the group of countries in which broadband subscriptions are generally tracking what their demographic and economic

conditions would predict. The more extreme performers (under and over) are consistent across the alternative computations of the BPI.

V. Conclusion

Ensuring the diffusion of broadband technology—and its consequential impact on the economy such as expanding the workforce, improving efficiency, and developing new goods and services—is perhaps the most significant telecom policy challenge in the last thirty years. Policymakers need to have useful tools that help them determine whether their policies are having an impact on broadband subscription. Unfortunately, a frenzy of rhetoric surrounds the "ranking" of broadband subscription among countries. This rhetoric ignores the simple fact that demography, geography, and economic conditions affect the rate of broadband adoption and those conditions cannot necessarily be affected directly or indirectly by telecommunications policy. Therefore, to develop and employ an effective broadband policy, policymakers must understand the impact that these factors have on broadband adoption.

In this PAPER we have devised and calculated a Broadband Performance Index that takes these natural endowments into account and provides an alternative method of ranking countries among their OECD peers. Our results are interesting, as they show that broadband adoption in the United States is largely in line with what would expect from its economic and demographic conditions. This stands counter to allegations of some that U.S. policy has failed and pushed the country into a "broadband ditch."

However, several countries are performing much better than their demographic and economic endowments would suggest. Our analysis shows that broadband adoption in Finland, Iceland, Portugal and even Turkey outpace their expected levels substantially. And while countries like Japan and Korea (which the OECD ranks above the United States in its raw data) have been cited as policy regimes that the United States should emulate, our Broadband Performance Index shows that both Korea and Japan are average performers like the United States. Clearly, broadband policy regimes in those countries are not generating more broadband subscriptions than demographic, geographic and economic conditions would predict.

Our analysis certainly does not mean and is not intended to suggest that policymakers in the United States should be content with its present performance. In particular, our analysis addresses only the broadband subscription rate and not the speed or quality of the broadband connections that are available. In our opinion, improving the bandwidth and diversity of

broadband connections is an important goal, and some recent decisions by the Federal Communications Commission and state governments have nudged the country in the right direction.[42]

The results of this analysis do suggest that the typical rhetoric surrounding broadband rankings can be misleading and misguided. To better compare the role that policy plays in increasing broadband adoption among countries, we encourage further research along these lines. This POLICY PAPER is the first to approach this issue in this manner, and there may be some obvious and not-so-obvious refinements to our efforts. As always, policymakers should consider the findings reported here as one element in a portfolio of evidence. That said, we believe that the Broadband Performance Index is a new and important means of comparing broadband adoption rates among countries that can assist the development of an analytically sound broadband policy.

[42] *See* L. Spiwak, *Wiring America*, THE HILL (April 24, 2007) (available at: http://www.phoenix-center.org/oped/TheHill24April2007.pdf); Ford Testimony, *supra* Table 2.