PERSPECTIVES
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Broadband Expectations and the Convergence of Ranks

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Given the importance of broadband to economic development and competitiveness, there is little surprise that countries are interested in comparing the pace of broadband adoption with their peers. But how can we legitimately and usefully compare broadband penetration and adoption among countries? And how can we tell if we are "behind" if we do not have a clear indication as to what it means to be "ahead" or "on target"? Answering such questions is difficult at best, so it not surprising that the dirty work of doing so is often put off for another day.

> ***… Broadband adoption rankings, like telephone rankings, appear to be driven primarily by underlying economic and demographic forces, and not aggressive supply-side regulation and subsidies.***

In prior research, I have provided a few options for comparing broadband penetration among OECD countries. These options use econometric models that decipher the role played by certain demographic and economic conditions in determining broadband adoption. I found that such factors explain almost all the difference among OECD countries in broadband adoption, such as income, income inequality, education and age.[1] Still, questions remain about whether public policy can effectively and efficiently boost penetration, and a key talking point in many of these debates in the U.S. consist of concerns about the United States' 15th position among OECD countries. Other alternative broadband comparisons paint a generally favorable picture for the U.S., such as the recent study by broadband technology company Akamai.[2]

In this PERSPECTIVE, I do not intend to resolve the question of how broadband ranks can or should be used for policymakers. Rather, I intend to make a few observations about where I believe broadband adoption across the OECD is heading and what we might expect to see happen to the OECD's broadband rankings over the next several years.

In particular, there is strong evidence that the relative broadband adoption ranks across the OECD are converging to the wireline telephone adoption ranks in the mid 1990's. This is the time when wireline telephone service reached maturity and before consumers began to abandon traditional telephone services for VoIP or mobile services. In 2007, the U.S. ranked 15th in broadband adoption, while ranking 16th in wireline telephone adoption in 1996, suggesting the U.S. is not an outlier in this regard. This is an important insight because it suggests that broadband adoption rankings, like telephone rankings, appear to be driven primarily by underlying economic and demographic forces, and not aggressive supply-side regulation and subsidies.

Rank Scrambling or Sorting?

Broadband, presumably like most high-technology goods and services and in each country, follows over time an adoption curve of some sort. Adoption curves of items such as telephone service, color televisions, personal computers, and mobile phones follow familiar patterns: there is period of fast growth in the early phases of adoption that eventually slows as the service approaches maturity. A country that is an early mover will be "ahead" at first, but will not necessary achieve the highest level of penetration in the end. Indeed, in most cases, the first mover will fall back as others expand their interest in broadband. While the "race" is continuing, position changes among countries should be expected until the race is over, because some countries may reach maturity before others. But the race is more of a marathon, not a sprint: as the race progresses, the relative positions among countries should start to look more and more similar to the final outcome, when all countries are at maturity.

There currently is a fair amount of volatility in OECD broadband rankings. On average, every six months the broadband subscription rank of twenty OECD members changes.[3] Sometimes these leaps or drops can be large. For example, from June to December 2007, Luxembourg moved from 15th to 9th, while Australia fell from 12th to 16th. Over longer intervals, the changes can be larger still. From 2001 through 2007, Luxembourg, the United Kingdom, and Norway have all climbed the charts by nine spots or more. Over the same period, Austria, Belgium, and the United States slid down the rankings by nine spots or more.

But if the rankings are headed somewhere, there should be a discernable pattern to these shifts in rankings. And, indeed, the data suggest one possibility: that rank of OECD members for broadband subscription is converging to their respective rankings for mature wireline telephone service in the mid 1990's.

Why would broadband subscriptions converge to *wireline* telephone rankings? The analogy is appropriate for many reasons. By the mid-1990s, in most (but not necessarily all) OECD countries, wireline telephone service was available nearly universally and penetration was very high. For example, in the United States, service was available ubiquitously with roughly 94% of all households subscribing to the service.[4] So, telephone rankings (at maturity) provide a suitable measure of the potential market for broadband, where that potential market is largely deemed acceptable both in terms of availability and adoption.

In addition, like broadband, most households only need one telephone line, so the data are similarly scaled (resolving, to some extent, the household versus per-capita debate).[5] Similarly, the type of business using a broadband circuit counted by the OECD is likely to be the same type of business that has a telephone service counted by the OECD.[6] So, based on "what's counted," the analogy is a good one.

Further, wireline subscriptions reflect the underlying economic and demographic endowments of a country. Research has shown the potent influence of endowments on both telephone and broadband subscriptions, and there is reason to suspect that such endowments would have similar influence on the adoption of the two services. Both services are sensitive to income, prices, and so forth. There are some exceptions, however. The age and education of a population is likely to have a more influential effect on broadband than telephone service.

The Convergence of Wireline and Broadband Rankings

A review of the data indicates that the wireline telephone market matured in about 1996, and since that time has been in decline due to VoIP, wireless, and even broadband substitution. So in comparing landline telephone to broadband penetration, I will use 1996 wireline telephone subscriptions and their corresponding OECD rankings.[7]

Today, of the top 10 ranked countries in broadband subscriptions, nine are also top 10 ranked countries in wireline telephone subscriptions. Of the bottom 10 ranked countries, eight are also in the bottom 10 of telephone subscriptions per capita. These are coincidence rates of 90% and 80%, respectively. It is difficult to describe such correspondence as accidental or the outcome of a random process.

In 2001, only five of the top 10 in broadband were also top 10 in telephone rankings; seven of the bottom 10 in broadband were also bottom 10 in telephone rankings. This change is the first piece of evidence that, over time, the two rankings are becoming more alike. The coincidence rates in 2001 further indicate the economic and demographic endowments seem to exert a potent influence on outcomes, their influence increasing over time.

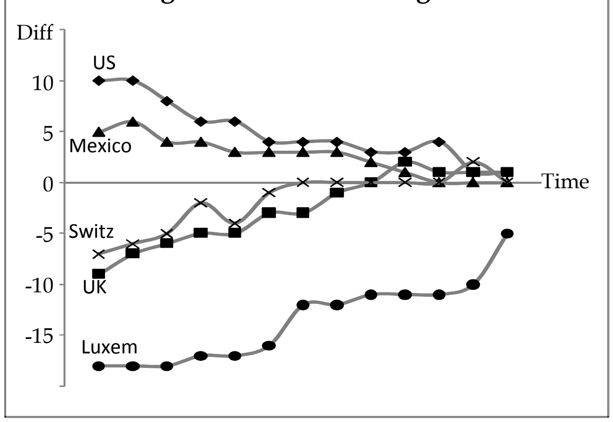
Continuing with this line of reasoning, in 2007, the U.S. ranked 15th in broadband subscriptions per capita and in 1996 it ranked 16th in telephone subscriptions per capita. Of the fourteen countries ranking higher than the U.S. in broadband, twelve rank higher in telephone (a coincidence rate of 86%). Of the fifteen below in broadband rankings, twelve also rank lower than the U.S. in telephone subscriptions (again, a coincidence rate of 80%). Again, there is very high coincidence between telephone and broadband rankings, both generally and with respect to the United States.

Is there any other evidence that the two ranks becoming more alike? Plenty. In 2001, the average (absolute) difference between the broadband and telephone rank was 6.1 places. Today, the difference is 3.2 places, so that nearly half of the difference between the rankings has disappeared in six years.

Also, in 2001, the difference between broadband and telephone ranking was less than three spots for 13 of the OECD countries (fewer than half the countries). Today, that three spot difference is satisfied by 21 countries (two-thirds of OECD countries). Only 5 countries have differences of 5 spots or more today, whereas 14 countries had differences of that size in 2001. The data also reveal that 70% of OECD countries have moved closer to their telephone ranking over the seven year period. Obviously, the differences in rankings are shrinking, indicating that the two rankings are becoming more alike.

Figure 1 illustrates the convergence paths of a few OECD members. On the vertical axis, I measure the difference between broadband and telephone rank at time *t*, and time is measured on the horizontal axis. The illustration clearly shows the convergence of the two ranks over time. Luxembourg, a broadband laggard according to my earlier research, is quickly recovering and approaching its telephone rank. The other countries in the graph are all within one position of their telephone rank at the end of 2007.

Figure 1. Rank Convergence



There are exceptions. The largest differences are for Greece and Korea. Broadband in Greece is currently 12 spots behind where its mature landline telephone ranking, while broadband in Korea is 14 spots higher than its telephone ranking. Notably, both countries are moving closer to their telephone ranking over time. Three countries—Canada, the Netherlands, and Sweden—also have fairly large differences in the two rankings today. Unlike Korea and Greece, however, these three show no signs of movement in the "right" direction. Of course, these larger deviations may have more to do with peculiarities in telephone subscriptions than in broadband subscriptions, and my earlier research suggests that of these only Greece is particularly exceptional with respect to broadband adoption.[8] These exceptions, nevertheless, may provide some guidance for further study.

A more statistically robust procedure provides further evidence of convergence. In Table 2, we see that the correlation of broadband and telephone ranks is rising quickly over time.[9] If the two rankings were identical, the correlation coefficient would be 1.0. By 2007, the correlation is up to the very high value of 0.855, up from 0.589 just six years ago.[10] There is less than a 2% chance this sequence of rising correlation coefficients is random.[11]

Table 1. Correlation Coefficients and Average Differences

Year	*Spearman Correlation Coefficient*	Average Difference (Abs. Value)
2001	0.589	6.1
2002	0.609	5.9
2003	0.650	5.5
2004	0.683	5.0
2005	0.751	4.2
2006	0.782	3.8
2007	0.855	3.2

The final column of Table 2 shows the difference in ranks is shrinking by about one-half spot per year. Clearly, telephone rank has something to say about the present and future of broadband rank, and the similarities of the two ranks is increasing over time.

Looking at Subscription Rates

Thus far, I have focused on the relationships among rankings. While sometimes informative, the use of ranks is generally undesirable since it tosses information away—a difference of one spot may be associated with a very small or very large difference in subscription rates. Small differences obviously say something different about relative performance than do large ones.

To avoid this problem, I turn now to the relationship of broadband and telephone subscription *rates* rather than *ranks*. In the end, a proportionality to telephone subscription rates of broadband implies a convergence of ranks, but we can measure that convergence with better data by using the subscription rate.

A simple econometric expression helps form expectations regarding the relationship between the subscription rates. Let B and TEL be the broadband and telephone subscription rates in the linear regression model (absent the error term):

$$\ln B = \alpha + \beta \ln TEL \qquad (1)$$

where "ln" indicates the natural log transformation. Given this specification, if the two subscription rates are proportional, then $\beta = 1.0$. The coefficient α measures what that proportionality is, so if the two subscription rates are identical then $\alpha = 0$; if the broadband rate is proportional to the telephone rate but equal to one-half the telephone rate, then $\alpha = -0.7$ (where $\exp(-0.7) = 0.5$).[12] As α moves closer to zero, the broadband subscription rate moves closer to the telephone subscription rate.

Using Equation (1) as the basis for the regression, I estimate the α and β coefficients for each period.[13] The results are summarized in Table 3. The negative values for the α coefficients show that broadband subscription is less than telephone subscription rate, but we know that from the sample means. More importantly, this difference is shrinking over time, as revealed in the movement of the coefficients toward zero.

Table 2. Proportionality of Rates

Year	Constants α (t-stat)	Coefficients β (t-stat)
2001	-2.6 (-3.3)	2.82 (3.4)
2002	-1.6 (-2.4)	2.84 (3.4)
2003	-1.4 (-3.6)	2.18 (5.4)
2004	-1.1 (-3.9)	1.78 (6.0)
2005	-0.9 (-4.2)	1.50 (6.7)
2006	-0.8 (-6.0)	1.19 (8.3)
2007	-0.7 (-7.8)	1.09 (11.6)

The β coefficients are also informative. Historically, the broadband and telephone subscription rates have not been tightly related—the β coefficients are large are the t-statistics smaller (though still significant). In a few short years, however, the two subscription rates are now roughly proportional ($\beta \approx 1.0$). For year-end 2006 and 2007, we cannot reject the null hypothesis that $\beta = 1.0$; we can for the other periods.

The observed proportionality implies that the broadband and telephone rankings will be similar, and the declining constant term indicates that the difference in average subscription rates between broadband and telephone is declining over time.[14] We cannot say for certain that the broadband rate will one day equal the telephone adoption rate, but the trend suggests they will get closer. A back-of-the-envelope forecast of the 2001-2007 trend suggests that the broadband subscription rates will be about 75% of the telephone rate in 4.4 years, and broadband will equal the telephone subscription rate in 9.6 years.[15] But, these are very distance forecasts based on seven years of data (13 observations).

Conclusions and Policy Implications

Over time, the rankings of broadband subscriptions across the OECD are becoming increasingly similar to the rankings of wireline telephone subscriptions when the wireline service was at maturity in the mid 1990's.

There is good reason for this convergence of broadband and wireline telephone penetration.

The central issue in this debate should not center upon lamenting or focusing on the rankings between OECD member states. Effective demand-side programs make sense not because some international bureaucracy indicates that we are somehow "behind" by some opaque ranking scheme. These programs make sense because they produce tangible results.

Telephone subscriptions are a plausible proxy of the potential market for broadband subscriptions, and the two services are counted in similar ways by the OECD. As broadband diffusion reaches maturity, we should expect the subscription rates, and their rankings, to look somewhat like that for wireline telephone service. Broadband is the new telephone, so to speak; an increasingly essential tool of communication.

Are there any policy ramifications that result from these empirical regularities? The type of preferred policy prescriptions may differ by the reader, but the most obvious is that a country's mature, wireline telephone rank is a useful method of approximating where a country's ultimate broadband penetration rate is likely to end up. Having such an educated guess available should reduce the amount of anxiety over rankings. Observing similar rankings across the two services implies suitable broadband performance since few argue that the telephone networks in most OECD countries were either under-deployed or under-subscribed. But if a country's broadband rank is lagging its mature, wireline telephone position (like Greece), that is a situation that should be analyzed and addressed, first via a fact-finding mission and then possibly through public policy.

Public policy does play a role in driving broadband deployment and subscriptions, as we have discussed in POLICY PAPERS NOS. 29 and 33. Even though demographic and economic conditions drive a large part of the pace of broadband adoption, demographics is not destiny and, in fact, understanding these demographic factors can be utilized to maximize a country's rate of broadband adoption. For example, our research has shown that income inequality has a significant negative impact on broadband adoption. As a result, in countries with relative large levels of income inequality, programs specifically designed to counterbalance that condition, such as computer ownership and training programs for low-income households, may have an appreciable effect. Indeed, similar policies, like Lifeline and LinkUp universal service programs, were used for landline voice telephone service.

The central issue in this debate should not center upon lamenting or focusing on the rankings between OECD member states. Effective demand-side programs make sense not because some international bureaucracy indicates that we are somehow "behind" by some opaque ranking scheme. These programs make sense because they produce tangible results.

Changes to Previous Version:

"A back-of-the-envelope forecast of the 2001-2007 trend suggests that the broadband subscription rates will be about 75% of the telephone rate in 10 years, and broadband will equal the telephone subscription rate in 20 years" changed to "A back-of-the-envelope forecast of the 2001-2007 trend suggests that the broadband subscription rates will be about 75% of the telephone rate in 4.4 years, and broadband will equal the telephone subscription rate in 9.6 years." The change was due to the forecast periods in the earlier version being computed from the first time period in the sample rather than the last.

NOTES:

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[1] G. S. Ford, T. M. Koutsky and L. J. Spiwak, *The Broadband Performance Index: A Policy-Relevant Method of Comparing Broadband Adoption Among Countries*, PHOENIX CENTER POLICY PAPER NO. 29 (July 2007); G. S. Ford, T. M. Koutsky and L. J. Spiwak, *The Broadband Efficiency Index: What Really Drives Broadband Adoption Across the OECD?*, PHOENIX CENTER POLICY PAPER NO. 33 (May 2008). Both papers are available at: www.phoenix-center.org.

[2] Akamai Corporation, THE STATE OF THE INTERNET, 2ND QUARTER 2008, White Paper (Sept. 2008)(available at: http://www.akamai.com/stateoftheinternet).

[3] A change in one country may lead to changes in others. At the extreme, if the 30th rank were to move to 1st, then there must be 30 changes in ranks (every country changes rank). This is true even though only one country has really changed (the 30th).

[4] TRENDS IN TELEPHONE SERVICE (Feb. 19, 1999), Tbl. 17.1.

[5] Measuring subscriptions in per-capita terms distorts the rankings because household size varies considerably across the OECD. The United States, for example, would need 30% more broadband subscriptions than Sweden just to make up for the difference in household size (2.7 versus 2.0).

[6] The OECD counts primarily DSL and cable modem services (and some fiber). The large, high capacity circuits used by larger businesses are not counted, but such businesses are unlikely to purchase standard telephone services either. *See* http://www.oecd.org/sti/ict/broadband (Broadband Criteria page).

[7] I use 1996 telephone data to avoid the impact of VoIP and wireless services on the count of telephone subscriptions. The goal is to find an analogy of a mature network, not a declining one. Other years do not produce remarkably different results, but it is clear that more recent subscription data is heavily influenced by line loss from wireless, VoIP, and broadband. The results are robust to alternative years, though noticeably weaker in more recent periods. For this period, the rankings are: Sweden (1), Denmark (2), Canada (3), Luxembourg (4), Switzerland (5), Iceland (6), Norway (7), Finland (8), France (9), Netherlands (10), Australia (11), United Kingdom (12), Germany (13), Greece (14), Japan (15), United States (16), Belgium (17), New Zealand (18), Austria (19), Italy (20), Korea (21), Spain (22), Ireland (23), Portugal (24), Czech Republic (25), Hungary (26), Slovak Republic (27), Turkey (28), Poland (29), and Mexico (30).

[8] PHOENIX CENTER POLICY PAPER NO. 33, *supra* n. 1 (all four countries had efficiency scores, BEI, over 0.95). Greece was found to be the worst performer in both POLICY PAPERS 29 and 33. In addition, the OECD members are not yet in the maturity phase of broadband diffusion. Unfortunately, we are stuck making decisions with short-run data.

[9] The calculations are made using semester data (390 observations), but I report only the end-of-year correlations for expositional purposes.

[10] By design, a correlation coefficient has values between -1.0 and 1.0. If the correlation coefficient is 0.0, then the two rankings are unrelated. If the correlation coefficient is 1.0, then they are identical, and if -1.0, then they are exact opposites. The closer the correlation coefficient gets to either 1.0 or -1.0, the more intense is the relationship between the two series.. Here, correlation is measured using the Spearman Rank Correlation, a widely used statistical calculation designed specifically for rank data. All of these correlation coefficients are statistically significant at standard levels. R. Steel and J. Torrie, PRINCIPLES AND PROCEDURES OF STATISTICS: A BIOMETRIC APPROACH (1980). For the small sample test and critical values, *see, e.g.*, G. Kanji, 100 STATISTICAL TESTS (2006) at 109.

[11] The distribution of the correlation coefficient is symmetric, so there's a 50-50 chance of an increase or decrease in correlation from one period to the next. Over 13 periods, the probability of observing 12 positive changes is about 0.02%. So, we can easily reject the hypothesis (at standard levels) that this run of increasing correlation coefficients arises from a random process. We could also apply a statistical procedure called the Run Test. For 13 observations, a string of only positive values easily allows the rejection of the null hypothesis (the values are chosen randomly) at the 1% level. Kanji, *id*.

[12] If $B < TEL$, then the α will be negative. If $B > TEL$, then α will be positive.

NOTES CONTINUED:

13 Semester data is used so there are 390 observations in the regression with dummy variables used to generate the year-specific coefficients. For expositional reasons, only the year-end coefficients are reported. All coefficients are statistically significant at the 5% level or better.

14 In 2005, the conditional broadband subscription rate was 0.40 of the telephone rate (exp(-0.91)), but has risen to 0.50 (exp(-0.7) = 0.50) in 2007.

15 The forecast equation is $\alpha_t = a + b \cdot \ln(t)$.

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