PERSPECTIVES
PHOENIX CENTER FOR ADVANCED LEGAL & ECONOMIC PUBLIC POLICY STUDIES

Normalizing Broadband Connections

George S. Ford, PhD*

May 12, 2009

As governments around the world, including the United States, place increased emphasis on the deployment and adoption of broadband technology, it becomes increasingly important that countries have appropriate and correct benchmarks by which to measure progress. In the United States, the Broadband Data Improvement Act of 2008 and the American Recovery and Reinvestment Act of 2009 both seek to improve broadband data collection and invest millions of dollars into mapping and measuring broadband availability.

The most-cited international statistics comparing broadband adoption are the broadband subscriptions per capita "rankings" published twice a year by the Organisation of Economic Co-operation and Development (OECD). Unfortunately, while the OECD figures draw significant attention from policy makers around the world, they suffer from a significant flaw that distorts the level of broadband adoption both within and across countries.

In this PERSPECTIVE, I explain the fundamental flaws in the OECD's approach—namely that measuring fixed broadband subscriptions per-capita is not a "penetration" measurement because fixed broadband is purchased on a per-location, not per-person basis.[1] Much better measures are required if countries want to assess and compare broadband adoption in their societies compared to others. In particular, I outline one possible method of comparing broadband adoption among industrialized economies—the number of broadband connections per telephone lines.

The Flaw in the OECD Rankings

Despite its frequent use of the term, the OECD measurement of fixed broadband subscriptions per capita is not a "penetration rate." Fixed broadband services are purchased to provide broadband connectivity to a particular location—a home or a business establishment—not to a particular individual. Indeed, with WiFi and corporate networks, the sharing of a fixed broadband connection is routine and should be expected. The number of fixed broadband connections per person is a flawed measure because it will vary based on the average size of a household or business establishment.

This change in normalization can have a significant impact because the size of households and business establishments varies significantly among OECD nations. Even if every business and household had a broadband connection, broadband subscriptions per capita would still be well below 1.0.[2]

The reason for this is simple—people do not buy broadband subscriptions, households and businesses do. Thus, the per capita index depends on household size, the business portfolio of each country, and how connections actually get counted. Without accounting for such differences, it is impossible to draw meaningful conclusions from comparisons the subscription rates among countries.

As governments around the world, including the United States, place increased emphasis on the deployment and adoption of broadband technology, it becomes increasingly important that countries have appropriate and correct benchmarks by which to measure progress.

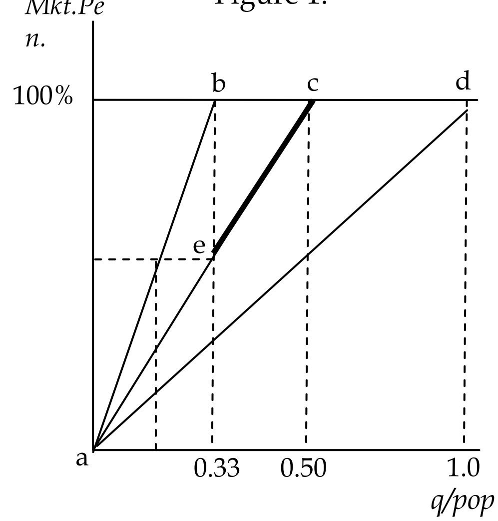
The problem of applying a per capita normalization to broadband subscriptions is readily apparent. Consider Portugal, in which there are approximately 3 persons per household. If every household had a broadband connection, then the per capita subscription rate in Portugal would be 0.33. In Sweden, alternately, there are approximately 2 persons per household. So, if every home had a connection, then the per-capita subscription rate is 0.50.

Plainly, Portugal can have better broadband adoption than Sweden despite the fact that per-capita connection rate is higher in Sweden. If, for example, all homes had connections in Portugal (0.33 per capita) and a little more than two thirds had connections in Sweden (0.34 per capita), Sweden still would outrank Portugal by the OECD's per-capita standards. Yet, Sweden obviously would be lagging behind Portugal in this hypothetical scenario.

The defect in the per capita normalization of connections from this example is illustrated in Figure 1. For the figure, assume we are counting only fixed connections for households (no business lines). Connections per capita are measured along the horizontal axis, whereas actual penetration of the potential market—households by assumption—is measured along the vertical axis. As before, assume Portugal averages of about 3 persons per home and Sweden averages 2 persons per home. If all homes in both countries had broadband access—a "Broadband Nirvana"—then the per capita subscription rate for Portugal is 0.33 and for Sweden is 0.50.[3]

In the figure, the line labeled a-b represents the penetration relationship for Portugal whereas the line labeled a-c represents Sweden. Note first that the lines a-b and a-c are very different from the line a-d, the latter being the penetration relationship envisioned by the per capita normalization. Even at maximum subscription for each country, the penetration rates are well below 1.0 in per capita terms.[4] Further, even though both countries are at maximum subscription, they have different per capita subscription rates.

Figure 1.



There is, then, a substantial range of per capita subscription rates for which we are deceived about the relative performance of these two countries. The scope of the error is marked in the figure as the dark line labeled e-c, assuming a maximum subscription rate for Portugal. The potential for incorrect ranking exists across the entire range of adoption rates.[5]

Quite simply, a per capita index of broadband adoption gives false signals about relative broadband adoption across geo-political units.[6]

In the U.S., nearly every business and household had a fixed line telephone when the 1996 Telecom Act was passed. Yet, telephone subscriptions per capita were only 0.49 at the time. In Sweden, which also had near ubiquitous telephone adoption, the telephone per-capita subscription rate was 0.69. This difference is large but obviously should be taken to mean that Sweden was significantly "better" at telephone access and adoption than the U.S. Both countries had near fully deployed and subscribed telephone services, so what we have observed here is a difference without a difference, and the difference is due mostly to the per capita normalization.

So, if the OECD's method of measuring broadband penetration is flawed, with what should we replace it? In the following sections, I outline an alternative approach for industrialized societies—the number of broadband subscriptions per telephone subscription.

Telephone penetration in modern, industrial economies generally achieved the goal of universal service by the mid-1990's, and many policymakers have stated that their goal is to make broadband as available and used as dialtone telephone technology. By the mid-1990's, in most OECD countries, pretty much every business and household that wanted a telephone could obtain one. Moreover, because landline telephones generally served households and business premises, one would expect that they would be purchased in a similar manner as fixed broadband lines. As a result, I believe that when comparing broadband adoption rates, it is appropriate to compare a country's current number of broadband subscriptions to universal telephone subscriptions, at least until better normalization criteria are created.

Universal Telephone as a Proxy for Measuring Broadband Subscriptions

In response to my earlier criticisms of the per-capita normalization, others have suggested that households may be a better standard.[7] Household normalization, while perhaps better than population, is also defective. OECD connection counts include some business connections, which, in the U.S., are about one-third of total connections, so the denominator is improperly scaled.[8] Still, with households in the denominator, the household size problem is largely resolved, which should make households a better normalization standard than per capita used by the OECD.

However, I believe that an even better method of normalizing exists that would suit the policy goals of governments that want to maximize broadband access and adoption. Dividing the number of fixed broadband lines per capita in the country by the number of fixed-line telephones per capita *circa* 1996 in the country would provide policymakers with a more reliable and consistent benchmark for measuring whether broadband access and adoption is proceeding appropriately.[9]

This method of normalization would be, I believe, appropriate for modern, industrial to compare themselves to their peers. It is my assumption that by the mid-1990's, the goal of "universal access" to telephone subscription was achieved in most industrialized economies—as a result, the telephone subscription rate at that time generally took into account the factors such as household and business size that vex the current OECD's approach.

In general, wireline telephony is consumed in a similar fashion to the types of broadband connections counted by the OECD. Typically, households and businesses buy such connections, so it resolves the population problem inherent to the population normalization issue. It also includes business lines, which is an improvement over households.

For broadband, the market potential is households plus businesses (of the type using connections that are counted). Say, for example, that we have a count of households H and businesses F. Of these, some share s_H and s_F adopt telephones. The number of telephones, then, is $T = s_H \cdot H + s_F \cdot F$. As the shares of adoption rise to near universal adoption ($s_i \rightarrow 1.0$), as was the case for most developed countries in the mid-1990's, then $T \approx H + F$, which is a sensible measure of market potential.

In industrialized economies, the adoption rate of wireline telephone service is a function of demand-side factors, supply-side factors, and governmental intervention. Given decades of sustained public policy effort in many OECD countries for universal telephone service, one could regard that wireline telephone adoption rate *circa* 1996 as a plausible proxy for the optimal, social-welfare maximizing level of penetration. As a result, measuring broadband adoption against this presumably welfare-maximizing adoption rate would seem to be the most consistent and most revelatory method of comparing whether that society is adopting broadband in an optimal fashion.

Unlike population or households, the telephone subscription number provides a meaningful proxy for communications infrastructure required for the economy. Broadband is a kind of capital input and has a positive cost, and its marginal product depends on the stock of other capital (i.e. roads, education stock) and also labor. So, one cannot speak of an optimal level of telecom infrastructure without considering these other input levels. As these other inputs vary, the returns to communications infrastructure vary, so the optimal amount of such infrastructure varies. If communications infrastructure is a complement to other forms of capital (e.g., transportation networks) that are not widely deployed, then communications infrastructure will have lower marginal product than in another country with greater capital stocks. What good is increasing sales via the Internet if there are no roads to deliver them on?

Finally, the relative economic development of countries changes over time. Some less developed countries may, in the end, skip the widespread deployment of telephone services and deploy broadband services instead. These countries will have a relatively high broadband to telephone infrastructure. As a result, if one is interested in comparing countries to one another, I expect that my proposed normalization method would be the better suited for comparing the industrialized economies of the OECD than developing economies. However, the normalization method I propose is not without value for less-developed countries, because it will highlight countries that these countries may, in fact, be poised for more significant communications-driven economic growth, even if their per capita adoption rates are lower than others. Economic growth is driven by improvements in technology, not merely the scale of technological deployment.

Of course, I do recognize that using universal telephone penetration as a normalizing standard is imperfect as well. One obvious flaw is that it is unlikely that households and businesses will have multiple broadband connections, yet second lines and multiple business telephone lines are common. However, the issue is not perfection, since perfection is not possible with simple normalizations. The question is which variable—population, households, or telephones—is least flawed.

In an effort to decide which normalization criteria is least imperfect, I propose a few statistical tests to see which normalization criterion—per capita, per household, or per telephone—is best.

Statistical Tests

The idea behind normalization of broadband connections is that if a country's population is twice as large, then its broadband connection count "should be" twice as large. In other words, broadband connections are assumed to be proportional to population when using a per-capita normalization. Fortunately, it is easy to test for proportionality, and by doing so, we can evaluate the legitimacy of this implicit assumption embodied in the per-capita normalization.

The proportionality test is simply

$$\ln B = \alpha + \beta \ln X + \varepsilon, \quad (1)$$

where B is broadband connections, X is the normalization criteria, "ln" is the natural log transformation, and ε is the econometric disturbance. A test for proportionality is simply β = 1, which can be evaluated using the Wald test.[10] If β = 1, then a 10% increase in population leads to a 10% increase in broadband connections, on average. We perform this test for each of the alternative normalization criteria.

Also, since the dependent variable, ln$B$, is the same for each regression, we can compare the goodness of fit across the alternative models using R^2 ("r-squared"). The R^2 of the regression provides an index of the percent of variability in broadband subscriptions explained by the normalization criteria.[11] A larger R^2 implies a larger proportion of the variation in broadband connections is explained by the variation in the normalizing variable.

Perhaps the most direct test is simply to evaluate the hypothesis that one model (or one normalization) is better than the other. Since each normalization variable is an alternative model of the number of broadband connections, we can determine which is "best" using the Davidson-MacKinnon *J*-Test, which I describe later.[12]

I turn now to the tests. We have three normalization variables: population (P), households (H), and telephones (T). Equation (1) is estimated for each, using data from December-07 and June-08. We get the following:

$$\ln B_i = -0.07 + 0.91 \cdot \ln P_i + \varepsilon_i\,; \quad (2)$$

with a t-statistic on β of 20.76 and an R^2 of 0.88;

$$\ln B_i = -0.02 + 0.96 \cdot \ln H_i + \varepsilon_i\,; \quad (3)$$

with a t-statistic on β of 25.90 and an R^2 of 0.92; and

$$\ln B_i = -0.52 + 0.99 \cdot \ln T_i + \varepsilon_i\,. \quad (4)$$

with a t-statistic on β of 46.32 and an R^2 of 0.97.

The results strongly suggest a preference for fixed telephones as the best normalization variable. The β coefficient is nearly 1.0 for Equation (4), and much closer to 1.0 than the other alternatives. Further, the R^2 and the t-statistic on β is largest for the T normalization. *Fixed telephones at maturity explain a whopping 97% of the variation in broadband subscriptions across the OECD*.

For the population variable, the most commonly used normalization, we can reject the null hypothesis (at the 5% level) that β = 1.[13] Thus, we can reject proportionality between population and broadband connections, which is an implicit assumption of the population normalization methodology.

An additional test, the Davidson-MacKinnon *J*-Test, proceeds as follows, using Equations (2) and (3) to demonstrate. First, estimate Equation (2), and from that generate the predicted values of the regression ($\hat{y}$). Then, augment Equation (3) with the fitted value $\hat{y}$ as an additional regressor. If the coefficient on the additional regressor ($\hat{y}$) is not (statistically) different from zero, then accept Equation (3) as the true model. If the zero null hypothesis on $\hat{y}$ is rejected, then Equation (3) is not the preferred model. We can then reverse the test and augment Equation (2) with the fitted value from Equation (3) and perform the test.

Table 1. Summary of J-Test (t-statistics)

	Model		
Add'l Variable	*B(P)*	*B(H)*	*B(T)*
P	…	-2.59*	-1.00
H	6.06*	…	-0.09
T	13.89*	10.49*	…

* Significant at the 5% level or better.

Table 1 summarizes the results of the *J*-test across the three models. The values in the table are the t-statistics on the additional regressor. If (the absolute value of) the t-statistic is larger than about 2.00, then we reject the null hypothesis that the model evaluated is preferred to its alternative.

From the table, we can see that is not possible to state a preference for either P or H, since all the reported t-statistics indicate statistical significance.[14] Thus, P is providing some additional information not captured by H (t = -2.59), and H is providing information not provided by P (t = 6.06).

In contrast, the table shows that the telephone normalization T is preferred to both population (P) and households (H). Neither of the coefficients on the additional regressors is close to statistical significance in the telephone-normalization equation (t = -1.00, -0.09), implying that population and households provide no additional information to that in telephone variable (T). Yet, T provides additional information to both the P and H models (t = 13.89, 10.49).

As with the other statistical results, it appears that telephones is the best normalization criterion for broadband connections, at least from a statistical perspective. The above discussion also suggests it has better conceptual properties as well.

Broadband Connections Per Telephone

Inevitably, if telephones are a better normalization than the others, then someone will want to rank countries based on the per-telephone normalization. Keep in mind that telephones may be a better normalizing variable, but it is still imperfect. First, we have not adjusted for the value of broadband connectivity, which may differ substantially across countries.[15] Second, we are limited to an analysis of fixed connections, whereas mobile broadband is the fasting growing connection modality.

Nevertheless, I will succumb to the peer pressure. In Table 2, I summarize broadband connections per telephone for the 30 OECD countries along with connections per capita and their ranks (using June 2008 data, the latest available).

The statistical tests are unambiguous—telephones are preferred to either the population or household normalizations of broadband connections.

There are a number of interesting insights. First, observe that the broadband per-telephone (B/T) index has less variability than the per-capita (B/P) normalization. The coefficient of variation (standard deviation divided by the mean) is 0.19 for B/T, but 0.39 for B/P. This arises because the T normalization eliminates many of the defects of the per-capita normalization. In fact, half of the variability in the adoption index has been eliminated through better normalization.

Second, the rank of a number of countries radically changes. Big increases in rank are observed for the Czech Republic (23 to 10), Hungary (24 to 8), Ireland (21 to 6), Mexico (30 to 13), and Poland (27 to 15). Moderate positive changes are observed for Korea, now 1st rather than 6th, and Spain, rising six places from 20th to 14th.

Table 2. Normalized Broadband Connections

Country	B/T	Rank	B/P	Rank
Australia	0.527	19	0.235	16
Austria	0.461	25	0.206	18
Belgium	0.583	9	0.264	12
Canada	0.510	21	0.279	10
Czech Rep.	0.578	10	0.158	23
Denmark	0.613	5	0.367	1
Finland	0.563	12	0.307	8
France	0.522	20	0.264	13
Germany	0.527	18	0.262	14
Greece	0.234	30	0.112	26
Hungary	0.590	8	0.157	24
Iceland	0.637	3	0.323	5
Ireland	0.599	6	0.191	21
Italy	0.428	26	0.182	22
Japan	0.469	24	0.230	17
Korea	0.755	1	0.312	7
Luxem.	0.536	17	0.283	9
Mexico	0.563	13	0.047	30
Nether	0.712	2	0.355	2
New Zeal.	0.496	22	0.204	19
Norway	0.627	4	0.334	3
Poland	0.560	15	0.096	27
Portugal	0.418	27	0.148	25
Slovak Rep	0.385	28	0.089	28
Spain	0.563	14	0.198	20
Sweden	0.484	23	0.323	6
Switz.	0.593	7	0.327	4
Turkey	0.352	29	0.068	29
UK	0.560	16	0.276	11
US	0.564	11	0.250	15
Mean	0.534		0.228	
St. Dev.	0.103		0.089	

These changes should be of little surprise. The population normalization fails to account for the economic realities of a country, other than its population. Telephones, however, provide a useful proxy for the demand- and supply-side conditions in communications markets as well as government intervention. Thus, poorer countries with less telephone infrastructure move up in the rankings. This rise in the rankings is explained by economic conditions, but is also sensible from a performance perspective, since a few broadband connections in a poorer, less developed country is a big deal, whereas the same number of connections in a richer, more advanced country may be trivial.

The B/T normalization is also useful in that accounts, to some degree, for growth in communications infrastructure, and it is the improvements that will eventually drive economic growth. Growth is change.

The largest reductions in rank are for Canada (10 to 21), Luxembourg (9 to 17), and Sweden (6 to 23). The remaining countries change rank by relatively small amounts. The U.S. rises from 15 to 11, while the U.K. falls from 11 to 16.

Importantly, the differences in the B/T index across countries are mostly small. The U.S. ranks 11th and the UK ranks 16th, but their index values are essentially indistinguishable (0.560 and 0.564). This is true for other country comparisons as well. Denmark ranks 5th, for example, but its index value is only slightly larger than that of the U.S. (0.613 versus 0.564) and could be attributed to sampling variability. In fact, fifteen of the thirty countries are within 10% of the mean value.

The similarity across countries in the B/T index is consistent with POLICY PAPER NOS. 29 and 31, where we show that most countries are performing in line with expectations. Greece is again an outlier, having a very low adoption for broadband. Korea moves to 1st position in this alternative, and this may make sense given the high demand for broadband in that country. However, as our earlier work shows, Korea has endowments highly favorable to broadband, so a high subscription rate is expected.

Conclusion

There is no magic bullet or easy way to compare the rate of broadband deployment and adoption between countries. Different countries have different histories, demographic, and economic conditions, all of which affect the pace of broadband adoption. Countries have different goals as well, and may prefer different technologies.

However, given the importance of broadband infrastructure to modern economies, it should be expected that policymakers will want to compare themselves to their peers. Unfortunately, the most frequently used statistic for these comparisons—the OECD's "broadband subscriptions per capita" rankings—are flawed because the per capita normalization method used is inappropriate. As a result, policymakers that use the OECD figures as a method of comparison will routinely be pointed in the wrong direction.

In this PERSPECTIVE, I outline a different approach that I believe best serves the needs of policymakers as a first approximation, particularly in industrialized countries. Fixed broadband penetration should be measured by reference to universal wireline telephone penetration achieved in the mid-1990's. By most accounts, in most OECD countries, wireline telephone penetration in the mid-1990's was near-universal—virtually every home and business that wanted dialtone service could obtain it. Unlike per capita and per household measurements, telephone connections holds a direct nexus to the consumption of communications services, and accounts for many of the economic and demographic variations across countries.

As a result, the penetration rate for wireline telephone service then could be seen as a rough proxy for some of the demographic (e.g., household and business size) conditions that undermine the per capita (and per household) methods of normalization. Moreover, given that policymakers today want to make broadband service as ubiquitous and affordable as wireline dialtone service is, this method of normalization provides those policymakers with a legitimate benchmark for measuring their progress against that goal.

NOTES:

[*] **Dr. George S. Ford** is the Chief Economist of the Phoenix Center for Advanced Legal and Economic Public Policy Studies. The views expressed in this PERSPECTIVE do not represent the views of the Phoenix Center, its staff, its Adjunct Follows, or any if its individual Editorial Advisory Board Members.

1 The point is recognized in a recent study by the International Telecommunication Union ("ITU"), MEASURING THE INFORMATION SOCIETY: THE ICT DEVELOPMENT INDEX (2009), at 18 (assuming reference value of 0.60).

2 *See* 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), at Tbl. 2 (available at: http://www.phoenix-center.org/pcpp/PCPP29Final.pdf).

3 *See* PHOENIX CENTER POLICY PAPER NO. 29, *id.*; Testimony of George S. Ford, PhD, Chief Economist Phoenix Center for Advanced Legal & Economic Public Policy Studies, Before the House Committee on Commerce and Energy - Subcommittee on Telecommunications and the Internet Hearing on "Digital Future of the United States: Part IV: Broadband Lessons from Abroad" (April 24, 2007)(available at: http://www.phoenix-center.org/FordRankingTestimony24April2007.pdf).

4 In its recent analysis of these statistics, the ITU makes a similar observation. *See* ITU, MEASURING THE INFORMATION ECONOMY: THE ICT DEVELOPMENT INDEX (2009) at 17 (arbitrarily setting the "ideal" value of connections per-capita at 60).

5 Since we are only measuring household subscriptions in this example, the errors would be eliminated if normalizing by households. In reality, the connection counts include business lines, so household normalizations are also defective.

6 For a graphical exposition, see Presentation of Phoenix Center Chief Economist George S. Ford before the OECD Expert Workshop on Measuring Mobile/Wireless Service Data: Evaluating Broadband Adoption, Lisbon, Portugal (February 2009)(available at: http://www.phoenix-center.org/FordOECDLisbon.pdf); Presentation of Phoenix Center Chief Economist George S. Ford before the 36th Annual Public Utility Research Center (PURC) Conference: *Broadband Rankings, Broadband Policy*, February 4, 2009 – University of Florida http://www.phoenix-center.org/UofFPresentationFeb2009.pdf.

7 Ford Testimony, *supra* n. 2; POLICY PAPER NO. 29, *supra* n. 2; R. D. Atkinson, D. K. Correa, J. A. Hedlund, *Explaining International Broadband Leadership*, Information Technology and Innovation Foundation (May 2008) (available at: http://www.itif.org/files/ExplainingBBLeadership.pdf).

8 Trends in Telephone Service, Federal Communications Commission (August 2008), Tbls. 2.1, 2.3: http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

9 G. S. Ford, *Broadband Expectations and the Convergence of Ranks*, POLICY PERSPECTIVE 08-03 (October 1, 2008)(available at: http://www.phoenix-center.org/pcper.html).

10 D. Gujarati, BASIC ECONOMETRICS (1995), p. 268-9.

11 *Id.* at 201-2. The R^2 is on the unit interval (0 to 1.0), and can be interpreted as the percent of variation in ln$B$ explained by variations in ln$X$.

12 *Id.* at 490-3.

13 The conclusion is unchanged when excluding the U.S. from the sample (the largest population by far).

14 A downside of the *J*-Test is that it is not always possible to reject one model as inferior to the other.

15 OECD Workshop, *supra* n. 6, and POLICY PAPER NO. 36, THE BROADBAND ADOPTION INDEX: IMPROVING MEASUREMENTS AND COMPARISONS OF BROADBAND DEPLOYMENT AND ADOPTION (forthcoming).