DIGITAL ECONOMY – MACROECONOMIC ANALYSIS

Fixed and Mobile broadband adoption rates across the world: Present and Future

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The adoption of new technologies tends to follow a well-known pattern of diffusion (S-curve)

The historical evolution of the **fixed broadband adoption rate has fitted well this S-curve pattern so far**. This is more evident in Developed Economies (DMs) than in Emerging Economies (EMs). **The mobile-broadband adoption process has been much faster and deeper than the fixed-broadband one**. While fixed broadband penetration seem to be reaching a saturation level around 40-50% of the population, the mobile adoption rate has surpassed the 100% level in some countries and it has increased three fold in the last five year (2009-2014).

We present an empirical model to explain & forecast fixed and mobile broadband adoption

We estimate non-linear models for fixed & mobile adoption rates, which follow a Gompertz curve (S-curve), with the parameters determining the shape of the curve as a function of several economic, social and demographic factors. Our modeling strategy has important advantages. First, the goodness of fit is clearly superior to other alternative models. Second, the use of other linear and non-linear alternative methodologies for forecasting lead in some cases to highly unrealistic features (flat, explosive or decreasing trends).

We find different determinants for the saturation level and speed of convergence

The saturation level of both the fixed and mobile broadband rates depends positively on GDP per capita and population density and negatively on income inequality and the size of households. The speed of convergence of fixed and mobile-broadband rates depends positively on education and the age of the population. The fixed-broadband speed of convergence also depends positively on the level of income and the urbanization rate.

The future of the fixed broadband adoption will be driven by the Emerging Markets (EMs)

The most advanced countries are near their saturation rates in fixed-broadband technology and they will not experience higher increases in the next decade.The largest increase in this technology will be in EMs from Asia and Latam. The gap between DMs and EMs will remain.

The level of mobile broadband adoption will change rapidly in both DMs and EMs

The levels of mobile adoption rates will indeed change sharply in the next decade given the earlier phase in which the technology is. The change in adoption rates will be much larger relative to the fixed one. The world's rank will not change too much as growth will be generalized.

Figure 1
Changes in Fixed-Broadband penetration 2014-25

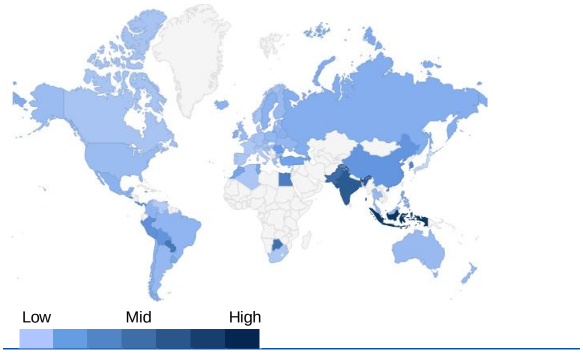
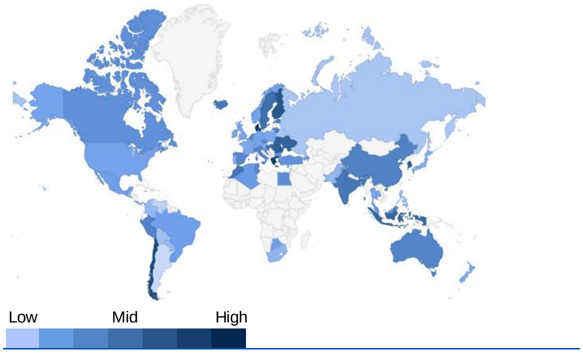


Figure 2
Changes in Mobile-Broadband penetration 2014-25



The recent evolution of fixed and mobile broadband adoption rates

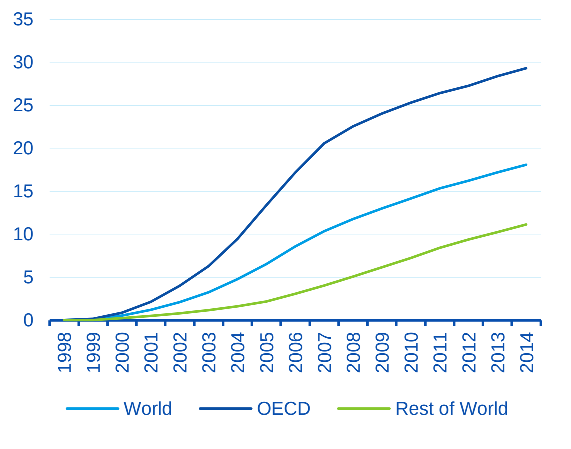
The process of adoption of any technological innovation is inherently challenging to understand and forecast given that it is indeed something ***new* and *disruptive*** and therefore we do not have previous information to rely on. However, **the adoption rates of most innovative technologies tend to follow a well-known pattern of diffusion**, usually **described as an S-Curve which can be divided in three major stages**:

- In the first stage, **early innovators and pioneering adopters are the first to embrace an innovation and thus, penetration is usually low**. In the case of the fixed broadband, this stage took place in the second half of the nineties in OECD countries, while it lasted a little longer in Emerging Markets.
- **The adoption rates reaches later a critical point when the mass market perceives the new technology attractive, feasible and profitable, and thus leading the penetration rate to grow almost exponentially**. As can be seen in Figure 3 fixed-broadband penetration rates increased very rapidly between 2003 and 2007 in OECD countries. In the case of EMs the inflexion point is less clear and they still seem to be in a fast-growing stage.
- **Finally, the number of new adopters slows down until it reaches a saturation point in which almost all possible adopters have already embraced the new technology or it loses attractiveness due to the appearance of the next generation of technology.** As observed in Figure 3, the fixed-broadband penetration rate has gradually moderated its growth in OECD countries in the last 6-7 years.

In summary, **the evolution of the fixed broadband adoption rate has so far followed the S-curve pattern**, **although this is more evident in the OECD than in the rest of the countries (EMs) as they are more advanced in the curve** (Figure 3).

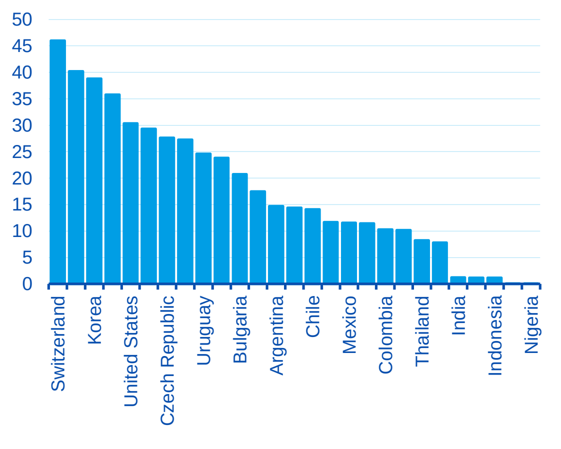
The actual average level of fixed-broadband penetration in Advanced Economies is around 30% or nearly 75% in terms of penetration rate per household, taking into account that the average household size is 2.5 in OECD. Importantly, **the current level differs widely across countries and regions**, for instance in Switzerland the fixed broadband rate has reached 45%, whereas in some African countries penetration rates reach barely a 1% per person (around 5% of households).

Figure 3
Fixed broadband penetration rate in the World



Source: BBVA Research, ITU and World Bank

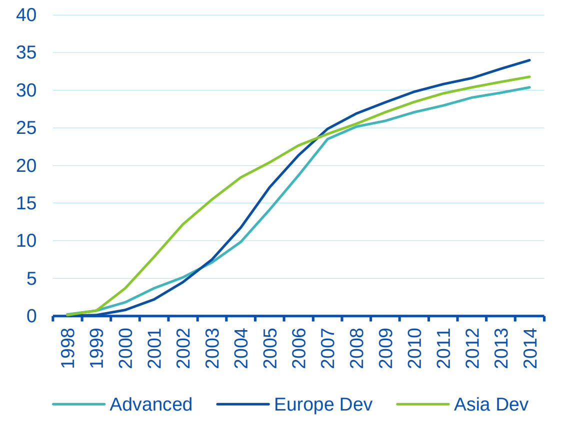
Figure 4
Fixed broadband penetration rate in selected countries (2014)



Source: BBVA Research, ITU and World Bank

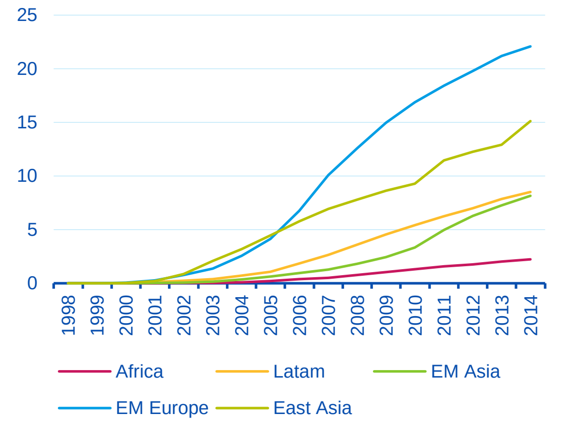
The evolution has been clearly different across different regions (figure 5 and 6). **The most advanced regions and countries have had a quite similar behavior**. **The emerging economies have experienced lower levels of penetration and the divergence among them is also higher**. Among the latter, **Emerging Europe is the region with the strongest penetration, not far from the one observed in the most advanced economies**. On the opposite side, **Africa is clearly lagging behind.**

Figure 5
Fixed Broadband Penetration Rate in Advanced Economies



Source: BBVA Research, ITU and World Bank

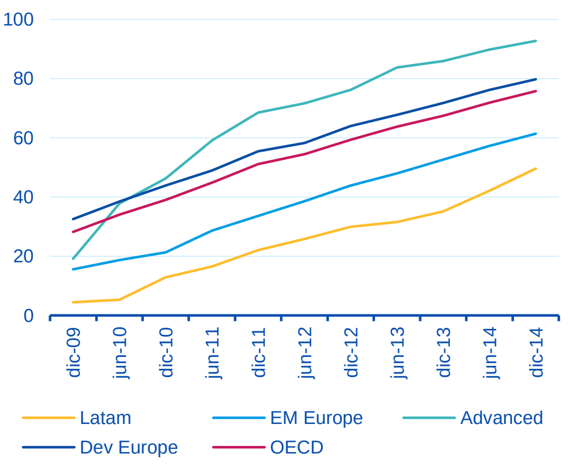
Figure 6
Fixed Broadband Penetration Rate in Emerging Economies



Source: BBVA Research, ITU and World Bank

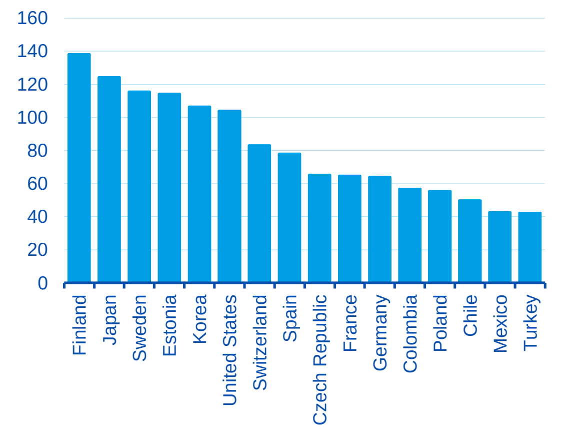
In the case of the mobile (wireless) technology we can only rely on information from OECD countries (Developing and Emerging economies). This reduces our sample to only 36 countries and only from to 2009 on. **The mobile adoption process has been much faster and deeper than the fixed broadband one (Figure 7)**. **While fixed penetration rates seem to be reaching a saturation level around 40% of the population, the mobile adoption rate has surpassed the 100% level in some countries and it has increased three fold in only five years, from 2009 to 2014**.

Figure 7
Mobile (wireless) broadband penetration rate in OECD



Source: BBVA Research, OECD

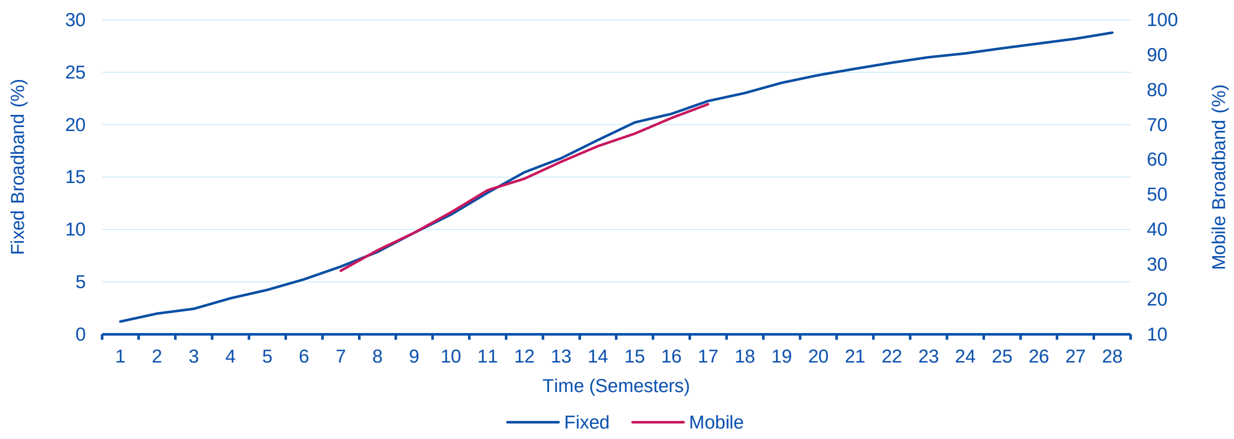
Figure 8
Mobile (wireless) broadband penetration rate in selected OECD countries (2014)



Source: BBVA Research, OECD

Besides, it looks as if **the mobile adoption process follows a more "linear" process** than the fixed broadband (Figure 7). However, **this could be the result of the fact that in Figure 7 we are only looking at the first stages of the process**. As an exercise, **if we put together both fixed and mobile adoption processes in the same scale of time (Figure 9), we can see that they are indeed following a very similar pattern** but with far larger adoption rates in the mobile case.

Figure 9
Fixed vs. Mobile Broadband Penetration Rates in OECD Countries



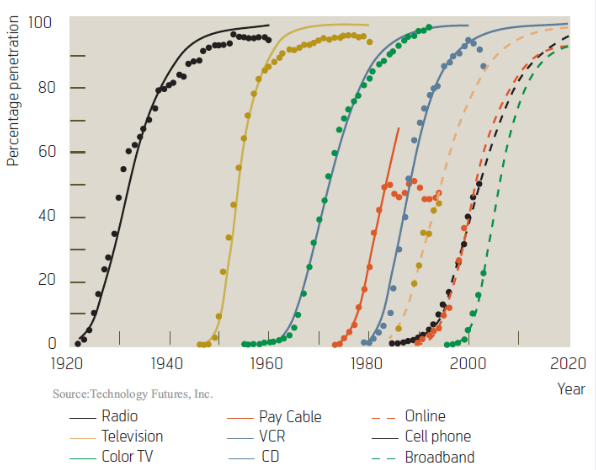
Source: BBVA Research, ITU and World Bank

Box 1. Modeling fixed and mobile penetration rates

The general pattern of technology adoption is an S-shaped curve that is quite common to a wide range of technologies as it can be seen in figure 10, where we have depicted different examples of estimated technological diffusion curves in the past[1]. However, when we look at the actual shape of such S-curves across different countries it is clear that they differ widely due to idiosyncratic differences in infrastructure, regulation, competition and demographic and socioeconomic factors.

Thus, we have developed our own models to forecast the future evolution in fixed and mobile broadband penetration, assuming a Gompertz curve as the specific logistic function behind these diffusion processes. We allow the parameters governing the shape of the Gompertz curves to vary across countries and time depending on socioeconomic and demographic determinants. The complete methodological approach used throughout this document will be described in a forthcoming Working Paper.

Figure 10
Other examples of Technology Diffusion



Source: Technology Futures, Inc.

The fixed broadband model

The estimated specification for the penetration rate for fixed broadband is the following: [2]

$$PEN_{it} = exp\left(\alpha_{it} * exp(\gamma_{it} * \exp(\beta_{it} * time))\right) \quad (1)$$

Where *i* stands for the country and *t* represents time. ***The key parameters in the Gompertz curve are α which determines the saturation level and β which determines the speed of diffusion of the new technology.***

We estimate this model in a sample of 78 countries between 1998 and 2014, using data from ITU and World Bank.

In our model, the ***saturation level*** depends on a set of variables (Zs) such as the level of development or GDP per capita (+), on income inequality (-), average size of households (-) and on population density (+). We estimate that the global saturation rate is currently around 16% of the population. We should notice that given the average household size in the world this would be equivalent to a penetration per household near 53%.

$$\alpha_{it} = \alpha_0 + \alpha_1 Z_{it}^1 + \cdots + \alpha_s Z_{it}^S + \theta_i \quad (2)$$

Furthermore, ***the speed of diffusion*** also depends on a different set of variables (Xs). In particular, countries with higher per capita GDP (+), higher skills or secondary education (+), median age (+) and urbanization rates (+) will show a higher speed of diffusion of the new technology:

$$\beta_{it} = \beta_0 + \beta_1 X_{it}^1 + \ldots + \beta_k X_{it}^k + \varphi_i \quad (3)$$

The parameter γ is assumed constant across time and countries. θ_i and φ_i are some country dummies that are included ad-hoc for specific countries.

1: In these curves a 100% saturation rate is assumed.
2: In this specification we also take into account the fact that the dependent variable is always non-negative, and thus, we use a Poisson-like distribution.

The mobile broadband model

Besides the fixed broadband model we have also developed a model for the mobile broadband adoption rate. The structure of the model is very similar although the parameters, variables and saturation levels can change somehow. It is important to remind that the results in the mobile case are limited to a sample of high and medium income countries (36 countries) due to data constraints.

In this case, the ***saturation level*** of the curve finally depends on the level of development or GDP per capita (+), median age (-), income inequality (-), the average size of households (-), and the urbanization rate (+) (although its final effect also depends on the population density). In the Mobile case, the OECD saturation level is estimated at around 100%.

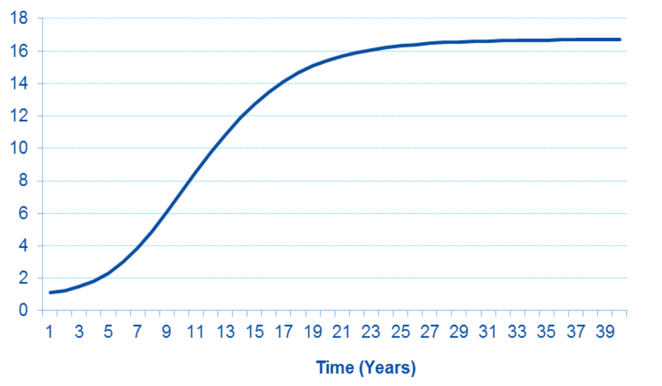
Moreover, in the broadband model ***the speed of adoption and convergence*** of each country to its saturation level depends on the proportion of workers/population with post-secondary education (+) and the median age of the population (+).

Behind Penetration Rates

In Box 1 we briefly described the models for the S-curve penetration rates. The average estimated penetration curves for the fixed and mobile cases can be observed in Figures 11 and 12 respectively. As can be observed, there are important differences between the two technologies in both the saturation levels and the speed of convergence. As explained in the methodological box, we allow each country to have a different saturation rate level and a different speed of convergence depending on the values of their determinants. Therefore, the S-curves displayed in Figure 11 and 12 are just sample averages and not necessarily reflect a "natural" saturation level in each technology.

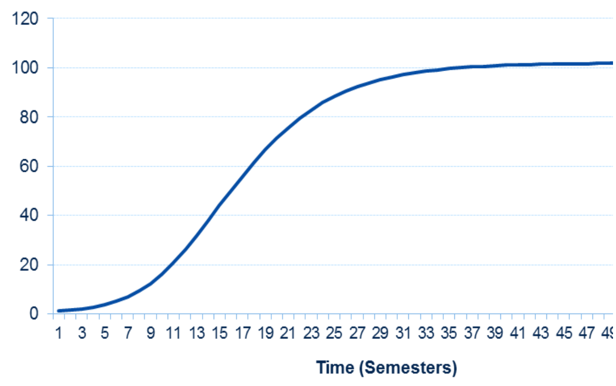
The variables that affect the saturation level and the speed of convergence in each case are not exactly the same, neither is their impact. In this section we describe how the explanatory variables affect the S-curve in the case of the fixed broadband penetration rate and provide some graphs showing the estimated impact of each variable. For the mobile case, we provide a shorter description of the effects of its determinants. The complete results for the mobile case are described in a forthcoming Working Paper.

Figure 11
Global fixed-broadband estimated penetration curve



Source: BBVA Research, ITU and World Bank

Figure 12
OECD mobile-broadband estimated penetration curve



Source: BBVA Research and OECD

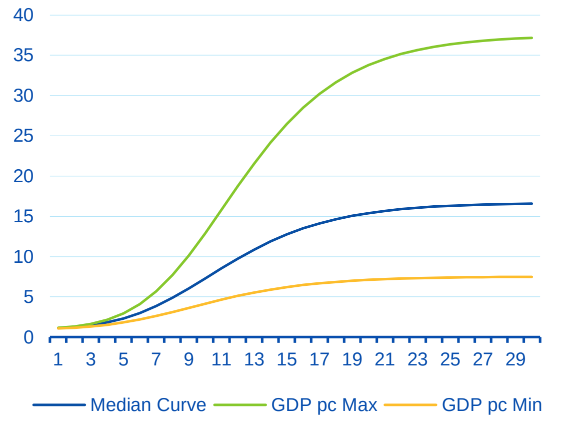
The determinants of fixed broadband penetration rate

The importance and impact of the explanatory variable behind the fixed-broadband adoption rate differ widely. **The factor that has the highest impact on both the saturation level and on the speed of convergence is clearly the income per capita**, as it can be seen in Figures 11 to 18. As in many other technologies, advanced countries have higher saturation points and are also closer to such saturation points because they are richer and face lower constraints to demand and exploit a new technology.

In the following figures we can observe the different ranges of saturation levels and speeds of convergence for a given country, according to the median, the minimum and the maximum values of the other determinants. For instance, a country with the minimum income per capita in the sample, 400 USD PPP, would only reach a saturation level of 7.5% of the population (keeping all other variables at the global median level). However, this saturation level raises to 37.5% (a difference of 30 pp) in a country with the maximum income per capita (near 110,000 USD PPP).

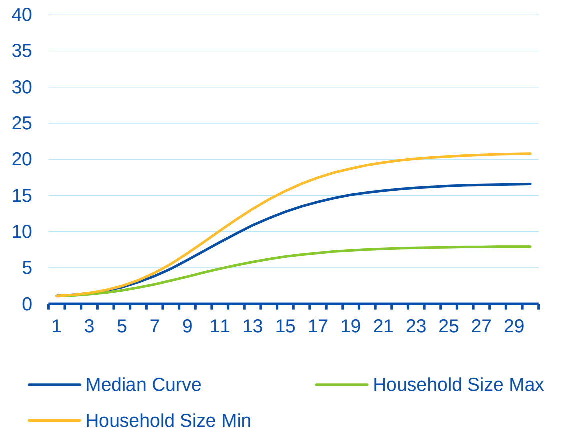
The size of the household is also an important determinant. A country with 6.5 household members (maximum) would only have a saturation level of 5% of the population, whereas a country with only 2 household members would reach a 21% saturation level. This factor is quite important in explaining the difference between Developed and Emerging Markets as the difference between household sizes is significant, with very low household sizes in the richer countries. Income inequality is also an important determinant, although far from the level of income. The difference in the saturation level between a country with the highest and lowest income inequality is about 9 pp. Finally, we estimate that the maximum effect of population density is about 7.5 pp.

Figure 13
Income per capita effect on saturation level (Positive, Significant)



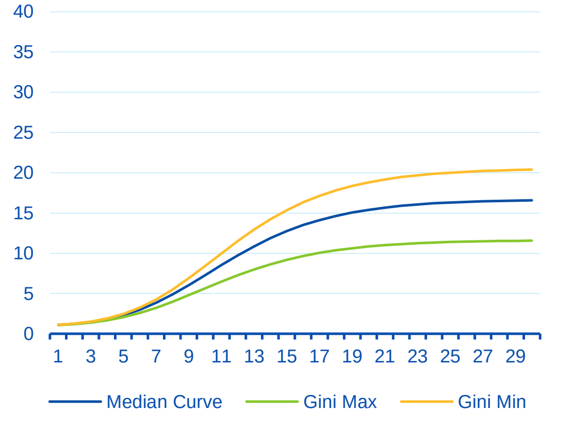
Source: BBVA Research, ITU and World Bank

Figure 14
Household Size effect on saturation level (Positive, Significant)



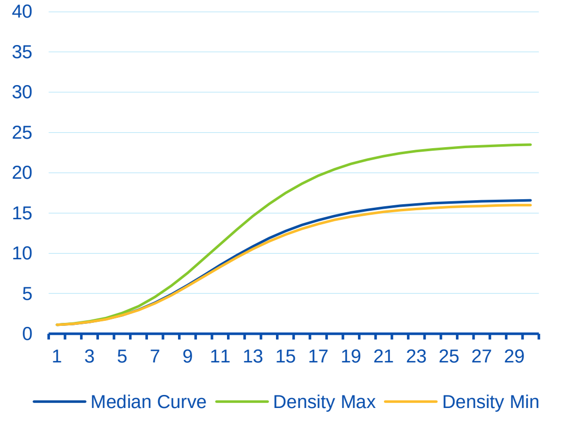
Source: BBVA Research, ITU and World Bank

Figure 15
Income inequality effect on saturation level (Negative, Significant)



Source: BBVA Research, ITU and World Bank

Figure 16
Population density effect on saturation level (Positive, Quad., Significant)



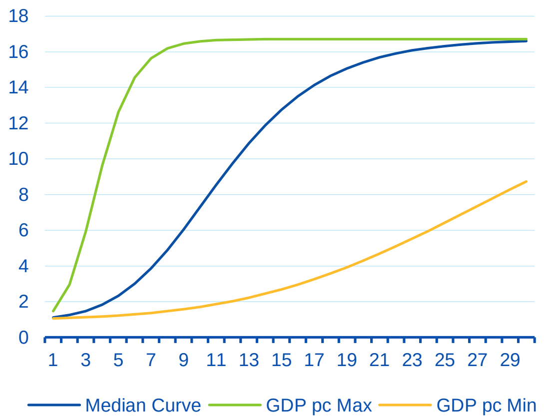
Source: BBVA Research, ITU and World Bank

The speed of convergence will also be affected by different variables. Income per capita is not only a determinant of the saturation level but also of the speed of convergence. For example, a country with only 400 USD PPP of income per capita would need more than 100 years to converge to its saturation level, while a country with the maximum level of income only needs near 15 years to reach its saturation point.

This is also the case of **higher education (proxied by the percentage of people with post-secondary education or higher), the variable that has the highest impact on the speed of convergence**. For example, a country with 54% of tertiary education only needs about 16 years to converge to its saturation level, whereas a country with only 3% of tertiary education would need 51 years to converge.

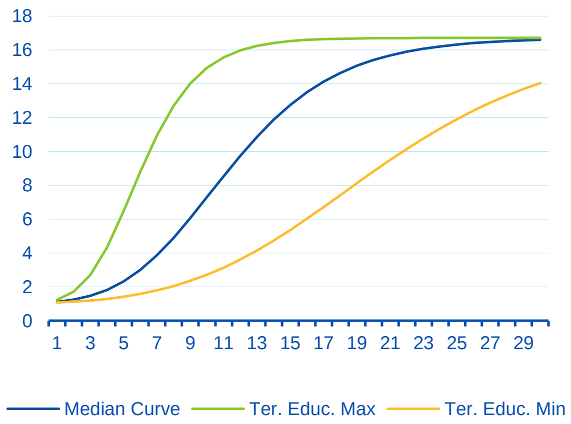
Aging also plays an important role in the catch-up process. The difference in years needed to converge to the saturation level between a country with a median age of 16 years and a country with a median age of 50 years is about 30 years. Finally, the difference in years needed to converge between a country with a 44% urbanization rate and a country with a 90% urbanization rate is nearly 13 years.

Figure 17
Income per capita PPP effect on speed of convergence (Positive, Significant)



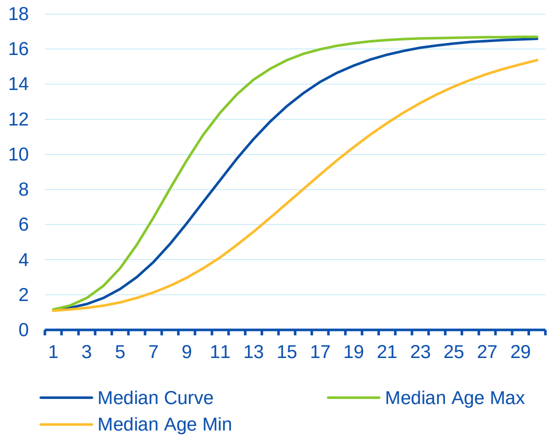
Source: BBVA Research, ITU and World Bank

Figure 18
Tertiary education effect on speed of convergence (Positive, Significant)



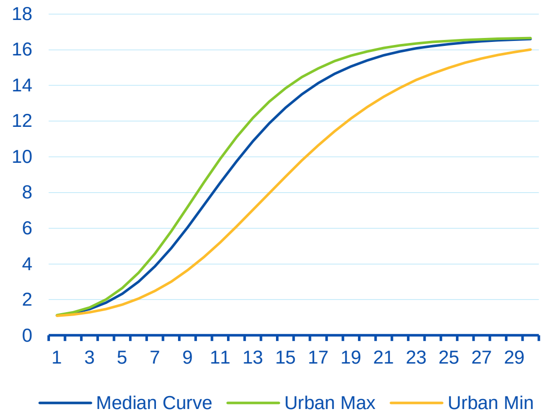
Source: BBVA Research, ITU and World Bank

Figure 19
Median age effect on speed of convergence (Positive, Significant)



Source: BBVA Research, ITU and World Bank

Figure 20
Urbanization rate effect on speed of convergence (Negative, Significant)



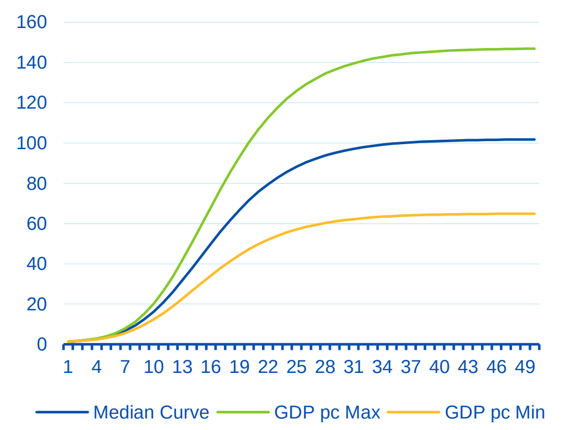
Source: BBVA Research, ITU and World Bank

The determinants of mobile (wireless) broadband penetration rate

As explained before, we have also modeled the S-curve for the mobile adoption rate. In this case the number of countries is restricted to the 36 OECD countries and the number of years is lower (2009-2014), although in this case we use quarterly data. As in the fixed technology case, we can estimate the importance of the different determinants in both the saturation level and the speed of convergence. Here we describe the most salient features but the complete analysis can be found in the forthcoming working paper.

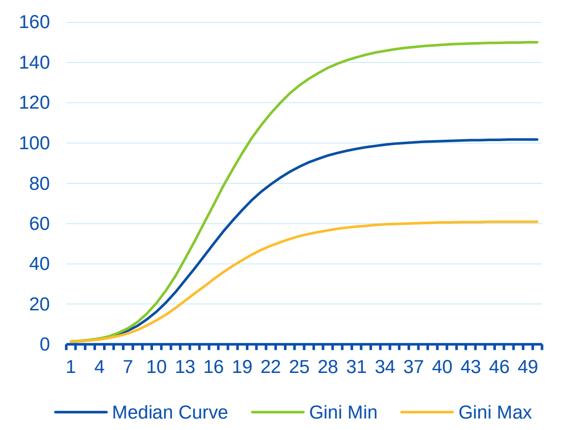
In the case of the saturation level of the mobile adoption, the most influential variable is income inequality. According to our model and ceteris paribus (keeping the rest of the variables at the median model) the difference between a country with the maximum income inequality in the sample (a Gini Index of 56), and the minimum (a Gini of 25) is substantial. The most unequal country would only reach a saturation level of 61% of the population, while the country with the minimum Gini index of 25 would reach a saturation level of 150%. **This is an important difference (near 90 pp) and it should warn us about the technology exclusion in some countries.**

Figure 21
Income inequality effect on saturation level (Negative, Significant)



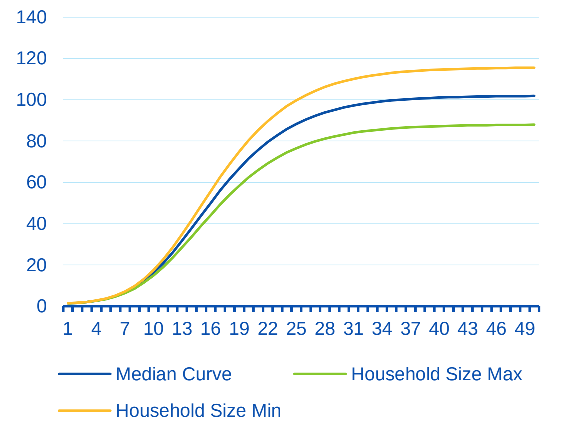
Source: BBVA Research, ITU and World Bank

Figure 22
Income per capita effect on saturation level (Positive, Significant)



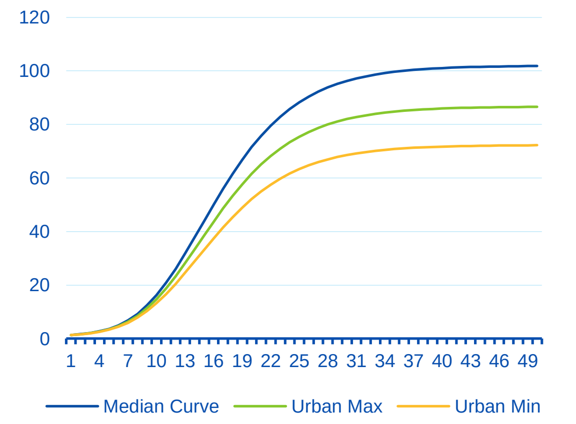
Source: BBVA Research, ITU and World Bank

Figure 23
Income inequality effect on saturation level (Negative, Significant)



Source: BBVA Research, ITU and World Bank

Figure 24
Urbanization rate effect on saturation level (Positive, Significant)



Source: BBVA Research, ITU and World Bank

The second most important factor is income per capita. Our estimations indicates that a country with the minimum income per capita in the sample, that in this case is 6,500 USD PPP, would reach a saturation level of 65% of the population (keeping all other variables at the global median level). A country with the maximum income per capita of 90,000 USD PPP would reach a saturation level of 147%, a difference of 82 pp.

Household size and urbanization are also important. A country with 4.2 household members (maximum) would have a saturation level of 88% of the population, whereas a country with only 2 household members would reach a 115% saturation level. We have also estimated that the difference in the saturation level between a country with the highest and lowest urbanization rate is about 26 pp. However we have to clarify that this is the effect for a country with a high level of population density. Different effects of urbanization rate have been estimated for different ranges of population density. The lowest effect of urbanization rate corresponds to countries with the highest density and its maximum difference in such case is about 14 pp.

On the other hand, in the mobile case, the variable that has the highest impact on the speed of convergence is the percentage of population with post-secondary education. A country with 47% of tertiary education only needs about 15 years to converge to its saturation level, whereas a country with only 9.5% of tertiary education would need 35 years to converge.

The difference in years needed to converge to the saturation level between a country with a median age of 22 years and a country with a median age of 46 years is about 6 years.

How the world looks like in 2014 and how it will look ten years from now?

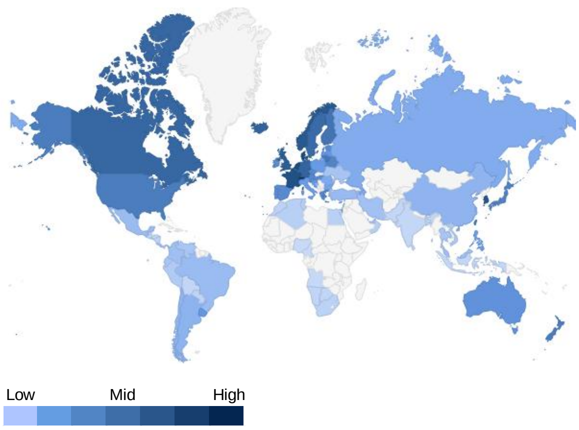
Fixed broadband adoption rates in 2014 and worldwide in 2024

In 2014 the countries with the highest adoption rates of fixed broadband rates are mostly advanced countries in North America, Europe and Asia. In contrast, the lowest adoption rates are observed in African and some Asian countries. Switzerland, Denmark and Netherlands are the three countries on the top, with penetration rates of 46%, 41.4% and 41% respectively. On the bottom of the distribution are countries with nearly 0% penetration such as Nigeria, Cameroon and Angola with 0.001%, 0.1% and 0.4% respectively.

The ten year ahead forecast results from our fixed broadband models rates foresee a very similar world in both relative and absolute terms. This can be observed in Figures 23 and 24 below. In ten years, Switzerland will have a penetration rate of about 48% and Denmark one of 43%. These minor increases are the consequence of these countries being already very close to its saturation point in 2014.

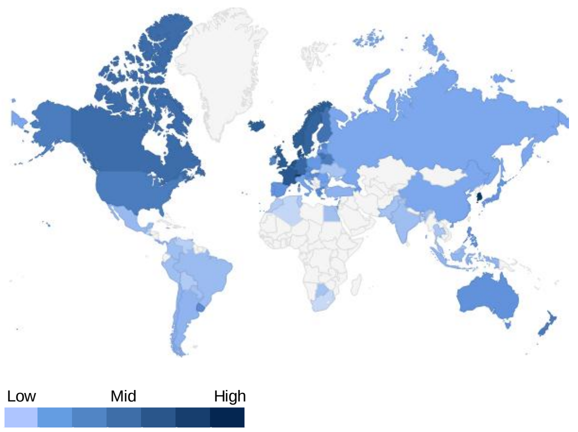
The penetration rate of countries countries at the bottom will obviously increase much more but the difference with countries at the top will still be large. The countries that we expect to increase the most are Indonesia, India, Pakistan and Botswana that will reach penetration rates of 16%, 13%, 11.3% and 11% respectively, surging from current rates that are near 1% for all of them.

Figure 25
Fixed broadband penetration rate in 2014



Source: BBVA Research, ITU and World Bank

Figure 26
Estimated Fixed broadband penetration rate in 2024



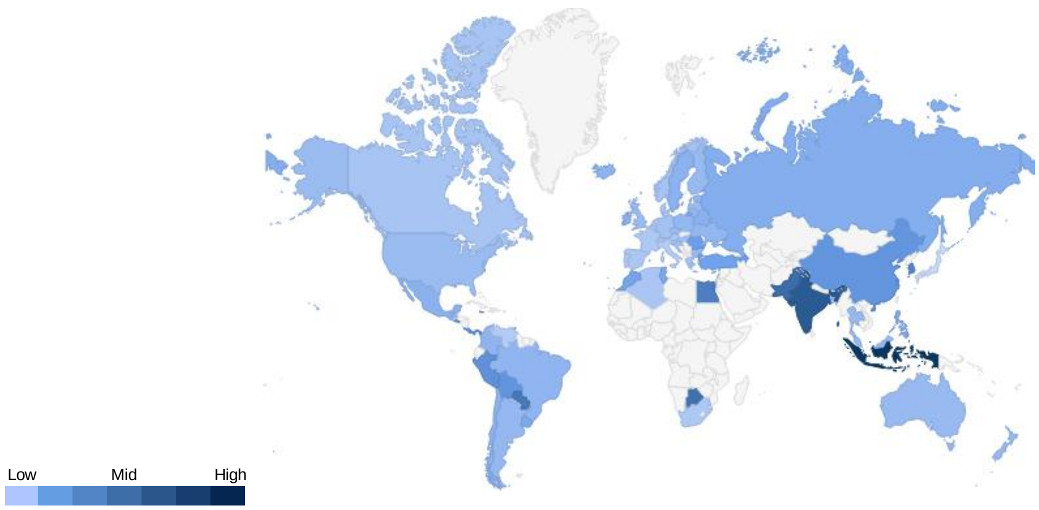
Source: BBVA Research, ITU and World Bank

Many Latin-American countries are among the best estimated performers in the next 10 years. We expect Paraguay and Peru to increase their fixed broadband adoption rates in 10 pp. and 8 pp. respectively. Uruguay will increase its adoption rate in 6 pp., meanwhile Mexico, Chile, Colombia and Brazil will all see increases of about 4 pp.

Eastern European countries will see a more modest increase, although they already have relatively high penetration levels. Turkey will be one of the out-performers in the region, with an increase of 7 pp. that will take it to an 18% penetration rate.

Korea and China will also experience significant increases. Korea will become the country with the highest adoption rate, reaching a 49% level, an increase of 9 pp. with respect to 2014. Chinese adoption rate will increase around 8 pp. which will take it to a 22% rate.

Figure 27
Fixed vs. Mobile Broadband Penetration Rates in OECD Countries



Source: BBVA Research, ITU and World Bank

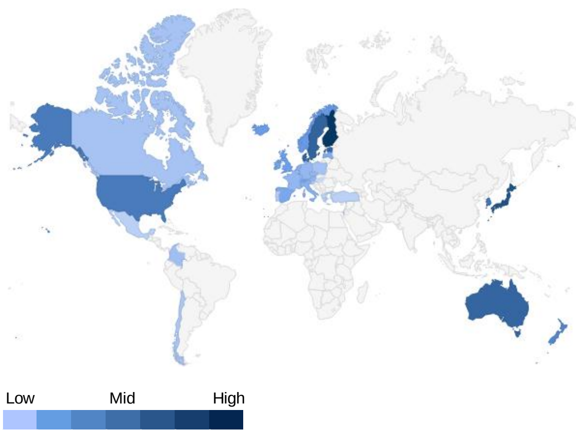
Mobile (wireless) broadband adoption rates in OECD in 2014 and worldwide in 2024

In the case of the mobile technology, we do not have a complete global picture in 2014, since we only have data for 36 countries. However, if we extrapolate our estimated model to the rest of the world, we can obtain an estimate of how the mobile adoption rate will be in 2024 and how much it could change in the next 10 years for a large set of countries.

Within OECD countries the difference in adoption rates are also quite significant between high-income countries and developing countries. There are about 8 countries that have already exceeded the 100% adoption rate. Finland is at the top with a 138% rate, followed by Japan with 124%. Sweden, Denmark, Australia and Estonia all have a rate of about 115%. At the bottom of the OECD countries we have countries such as Hungary, Greece, Turkey and Portugal with rates of 34%, 41%, 42%, 42% and 46% respectively. Some countries have remarkably high rates given their income per capita levels, like Estonia, Latvia (73%) and Colombia (57%), the latter one being the country with the lowest per capita income in the OECD sample.

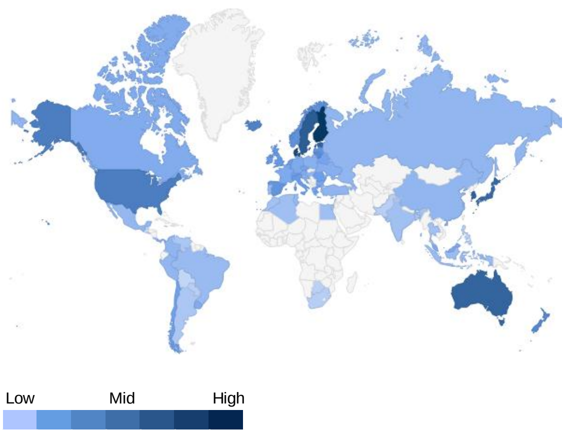
Looking ahead, **the mobile adoption rates will indeed change largely in the next decade because globally the mobile adoption process is in a much earlier phase that in the fixed-broadband case.** However, **the world rank will not change too much as the process will be more or less generalized.**

Figure 28
Mobile broadband penetration rate in 2014 (OECD)



Source: BBVA Research, ITU and World Bank

Figure 29
Estimated Mobile broadband penetration rate in 2024



Source: BBVA Research, ITU and World Bank

Despite that the level of mobile adoption rates will move in tandem some countries will experience sizable increases in the adoption rates (see figure 28).

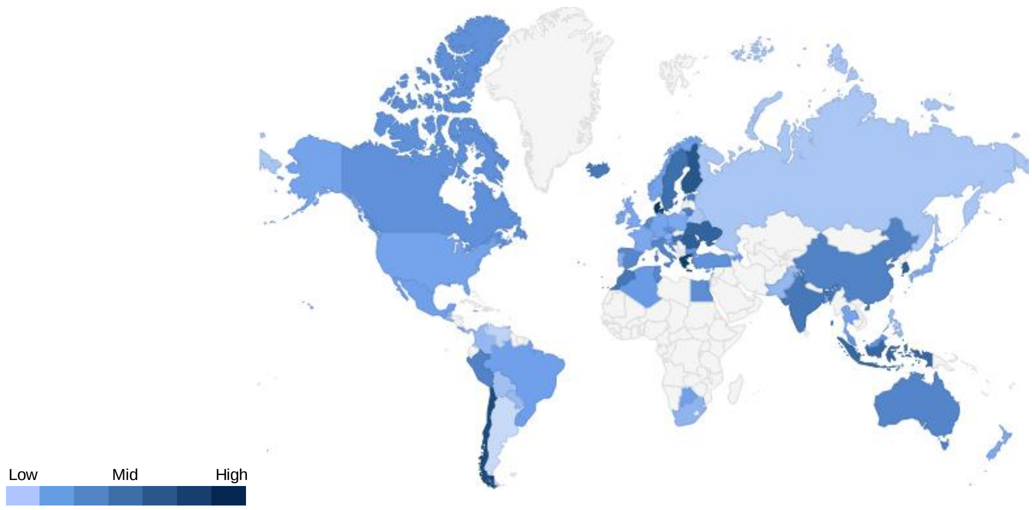
In the next ten years, **Finland will still be the country with the highest adoption rate** (185%) which represents a 47 pp. increase. **Denmark, Sweden, Korea and Estonia will complete the top five positions. They will all experience increments between 40 and 50 pp. Surprisingly, Greece turns out to be the country with the highest increase in its mobile adoption rate due to the relative low current rate** (with a surge of 57 pp. that will make it reach a 104% adoption rate).

Some Emerging countries will perform particularly well such as Chile (+50 pp.), Romania (+45 pp.), Latvia (+44 pp.), Ukraine (+44 pp.), Hungary (+43 pp.), Indonesia (+43 pp.), India (+38 pp.), China (+36 pp.) and Peru (+35 pp.). Turkey will reach a 75% adoption level (+32 pp.). From non-European

countries, Chile will actually be the Emerging economy with the highest wireless broadband adoption rate, around 100%.

Other Latin-American countries will see more modest gains. We expect Brazil, Uruguay and Mexico to increase their penetration rates in 27 pp. Colombia, on the other hand, will only gain 16 pp. in the next 10 years. Argentina and Venezuela will be among the worst performers and their penetration rates will barely increase in the near future.

Figure 30
Change in Mobile/broadband penetration rate from 2014 to 2024 (darker blue color means higher increases)



Source: BBVA Research, ITU and World Bank

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