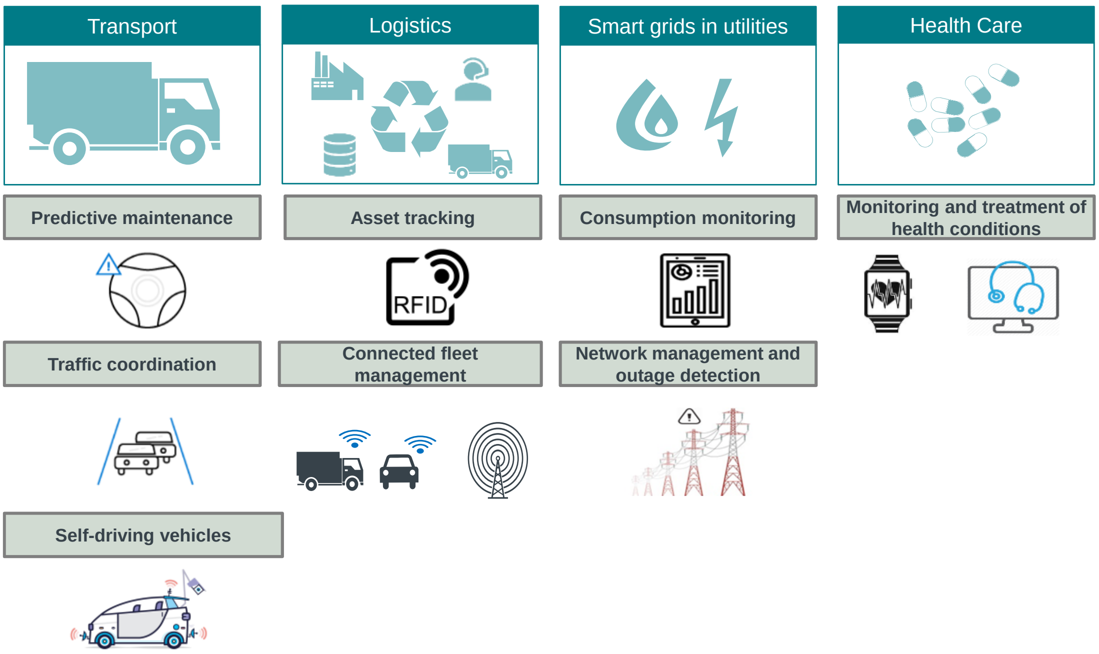
The Economic Impact of IoT

PUTTING NUMBERS ON A REVOLUTIONARY TECHNOLOGY

The Internet of Things (IoT) is a common catch phrase among techies. It conjures up a world of connected devices which will make our lives easier: self-driving cars; wired kitchen appliances; smart cities. Other important applications include fleet tracking, temperature monitoring and the digital transformation of agriculture. The Internet of Things has the potential to disrupt both business and policy. For instance, Amazon is increasingly using connected robots to locate products on its warehouse shelves and bring them to workers, saving time and money. Similarly, the medical sector can be revolutionised by the use of connected devices monitoring the real-time health of patients. [1] [2]

Figure 1. Internet of Things applications



Source: Frontier Economics

The IoT will thus change our way of life and, inevitably, the economic environment. Many people fear it will destroy jobs. Others see the IoT as an opportunity to devote our time to doing "what really matters", leaving boring tasks to smart devices and robots. Only time will tell where the IoT takes us.

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1 Frontier is currently working with the NHS to advise on how best to evaluate the impact of new technology, including the IoT. The IoT interventions studied include using connected health devices (measuring blood pressure, body temperature, pulse, oxygen saturation, weight and hydration) and passive sensors, including 'wearables' (e.g., GPS) to monitor and collect information about people with dementia in real time, 24 hours a day. This information is connected to analytical and visual tools to provide personalised data for each individual in a test area.

2 Special thanks to Antonio Rocamora Marti for his contributions to this article.

But it is here to stay, promising a social and economic transformation that will be gradual and, eventually, significant.

But can we put numbers on the IoT? What will be the impact on GDP as firms ramp up capital spending to take advantage of the new technology?[3] This is the question we have examined.

We find that a 10% rise in IoT investment would result in an increase in GDP of $370bn in Germany and $2.26trn in the US over a 15-year period (2018-2032).[4] We believe that these estimates form a lower bound, since they are based on current economic and technological conditions. The actual impact will depend on what measures policymakers take to promote the digital economy.

The direct impact of IoT on the economy

We face two major challenges in measuring the direct effects of the IoT on the economy: which methodology to use and how to define and thus quantify the IoT.

To answer the first question, we take our lead from how economists have measured the impact of new Information and Communication Technologies (ICT) on GDP.[5] We have drawn on a well-developed approach for estimating the economic impact of technology using a standard growth model. Simply put, we take the basic framework of the aggregate production function, where GDP or total production (Y) is a function of capital (K), labour (L) and a measure of long-term technological change (A).

We have built a database with information for 27 EU and OECD countries[6] between 2012 and 2015 on:

- Aggregate production, calculated using OECD data on GDP as well as sector-specific gross value added in services and industry;
- Capital, derived from OECD data on total gross capital formation disaggregated into ICT and non-ICT capital;
- Labour, based on OECD data on total working hours; and
- Machine-to-machine (M2M) connections, as published by the ITU database.

Figure 2. Country sample

Source: Frontier Economics

[3] There is also an indirect impact as the development of the IoT may also increase productivity and foster economic growth indirectly. However, we don't cover these effects here.

[4] The GDP forecast of these countries is based on OECD data, whereas the forecast of the increase in GDP due to a 10% rise in IoT investment is based on the estimations presented in this paper.

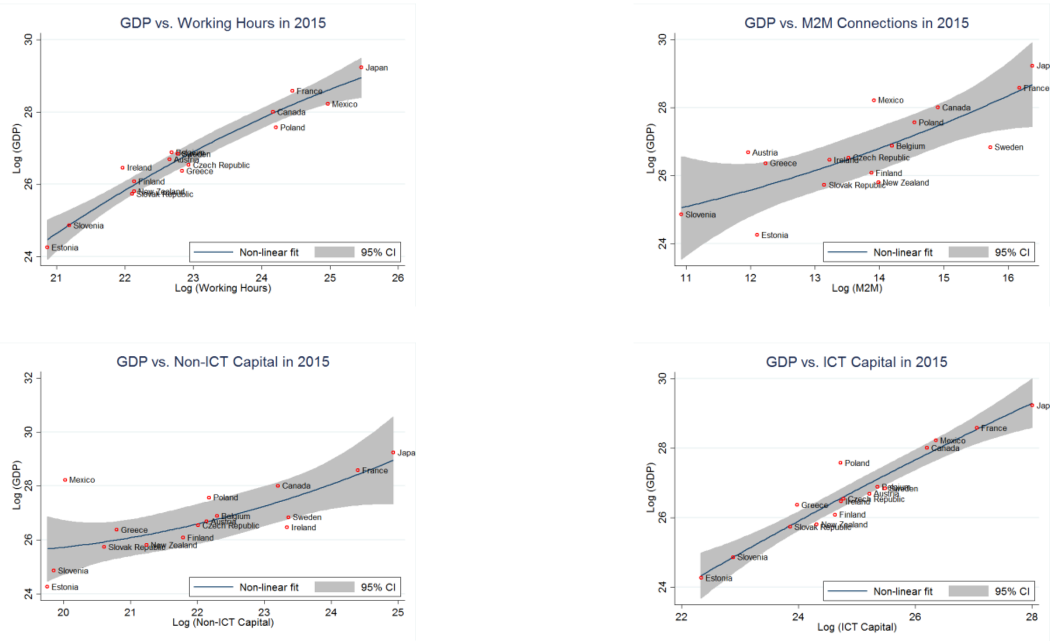
[5] Draca, Mirko and Sadun, Raffaella and Van Reenen, John (2006) Productivity and ICT: a review of the evidence. 749. Centre for Economic Performance, London School of Economics and Political Science, London, UK.

[6] Countries included are: Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Mexico, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden and United States.

The second question, how to measure the IoT, is the trickier issue. After all, the IoT comprises any number of different applications and services. For this reason, we looked into an innovative way of incorporating IoT activity into the growth model, namely taking M2M connections as a proxy for IoT capital investment. This allows us to use quantitative public information to measure the IoT. Although IoT and M2M are not one and the same, they are closely related: the services that the IoT offers, by merging the physical and digital worlds to modify how we interact with the environment, require smart devices to be linked together by M2M. Some liken M2M "to the plumbing of the Internet of Things".[7]

A first visual inspection of the data shows that the variables included in the production function (labour, capital and M2M connections) are positively correlated with GDP.

Figure 3. Aggregate measures



Source: Frontier Economics

The graphs above suggest that prevailing differences in GDP between countries can be explained by differences in endowments of productive factors, including M2M connections. However, the figures only present correlations. They do not imply causality.

In order to check whether our intuition is correct, we apply econometric techniques. We estimate a Cobb-Douglas production function[8] to model the economic impact of the IoT on GDP and gross value added in industry and services, controlling for labour, ICT capital and non-ICT capital.[9]

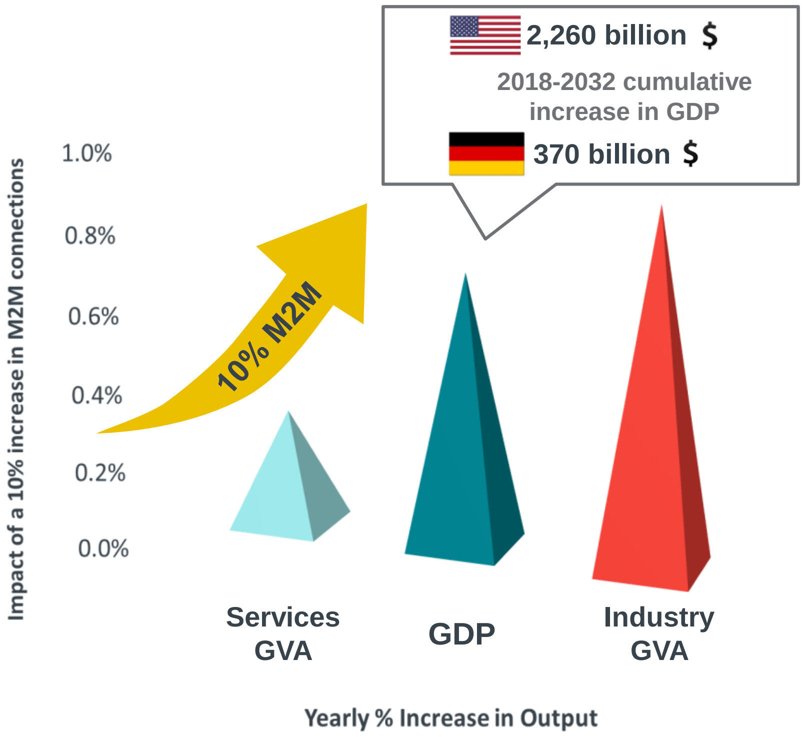
7 https://iot.telefonica.com/blog/what-is-the-difference-between-m2m-and-iot

8 Estimated as a linear relationship after taking natural logarithms: $Y_{it} = \beta_0 + \beta_1 \ln K_{it}^{Non-ICT} + \beta_2 \ln K_{it}^{ICT} + \beta_3 \ln L_{it} + \beta_4 \ln m2m_{it} + \Omega_i + \varepsilon_{it}$, where the variable of interest is $\ln m2m_{it}$, Y_{it} represents GDP and gross value added in industry and services, $\ln L_{it}$ labour, $\ln K_{it}^{ICT}$ represents ICT capital and $\ln K_{it}^{Non-ICT}$ non-ICT capital.

9 Using a panel database allows us to control for unobserved aspects embedded in the heterogeneity of countries (Ω_i), which impact the level of output. Aspects such as institutional quality or culture may potentially be correlated with economic output. We decide to use both random and fixed effects to estimate our equation because of the following reasons: (i) we find that the Hausman test indicates that the fixed effects model is more appropriate for the GDP and industry sector regressions; (ii) however, the same test indicates that the random effects model is more appropriate for the services regression; and (iii) we expect the fixed effects model not to capture adequately the coefficients of capital and labour, since these variables vary only to a limited extent across time. If there is not sufficient within-subject variability in the variables, then the standard errors from fixed effects models may be too large.

The results[10] show that IoT investment (as proxied by the number of M2M connections) has a positive direct impact on GDP and GVA in services and industry. We find that a 10% rise in M2M connections leads to annual increases of around 0.7%, 0.3% and 0.9% in GDP, services GVA and industry GVA, respectively.[11]

Figure 4. Economic impact of IoT



Source: Frontier Economics

If we take the example of the US and Germany over the next 15 years (2018-2032), this means that a 10% increase in M2M connections would generate an increase in GDP of $370bn in Germany and $2.26trn in the US. These results, though impressive, may underestimate the economic effect of the IoT. First, we have worked with data up to 2015; the future impact of M2M may well be more intense. Second, our estimates do not take into account the indirect impact of the IoT on productivity, which would have an additional knock-on effect on economic growth.[12] Even with these caveats, our analysis provides further empirical evidence that investment in IoT technology increases GDP significantly.

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[10] We are happy to provide the table with the results across the different specifications upon request.

We note that, as expected, the results confirm that the random effects model exhibits smaller standard errors for the capital and labour variables and confirms the expectations with regard to the coefficients (output elasticities) of the labour and capital inputs. Under random effects, in the aggregate regression these variables explain, respectively, approximately 66% and 28% of output. In turn, labour has a smaller impact in industry and a higher impact in services, and vice versa for capital.

[11] Given that IoT capital is proxied by the number of M2M connections, we recognise that in principle there could be reverse causation leading higher GDP to cause higher M2M uptake. However, we argue that it is reasonable to expect that the simple magnitude of GDP will not affect technology in a direct way, but rather will have, if any, an indirect effect dependent on other variables related to the characteristic specific to each country. Indeed, the data confirms our reasoning.

Figure 3 shows that, whereas countries are almost on the fit line for labour and capital (which are clearly inputs in the production process and where reverse causation thus does not hold), M2M presents a higher degree of dispersion. Sweden has many more M2M connections than its GDP would predict, whereas Mexico a lot fewer. This implies that the effect of GDP on M2M connections, if any, does not work in a direct, clear-cut way. What can affect M2M connections through GDP are country-specific omitted variables related to both GDP and M2M (for example, the innovation culture of a country). Since, by using fixed effects, we control for those unobserved aspects that cause GDP to be higher and that may be correlated to M2M connections, we believe our results to be robust.

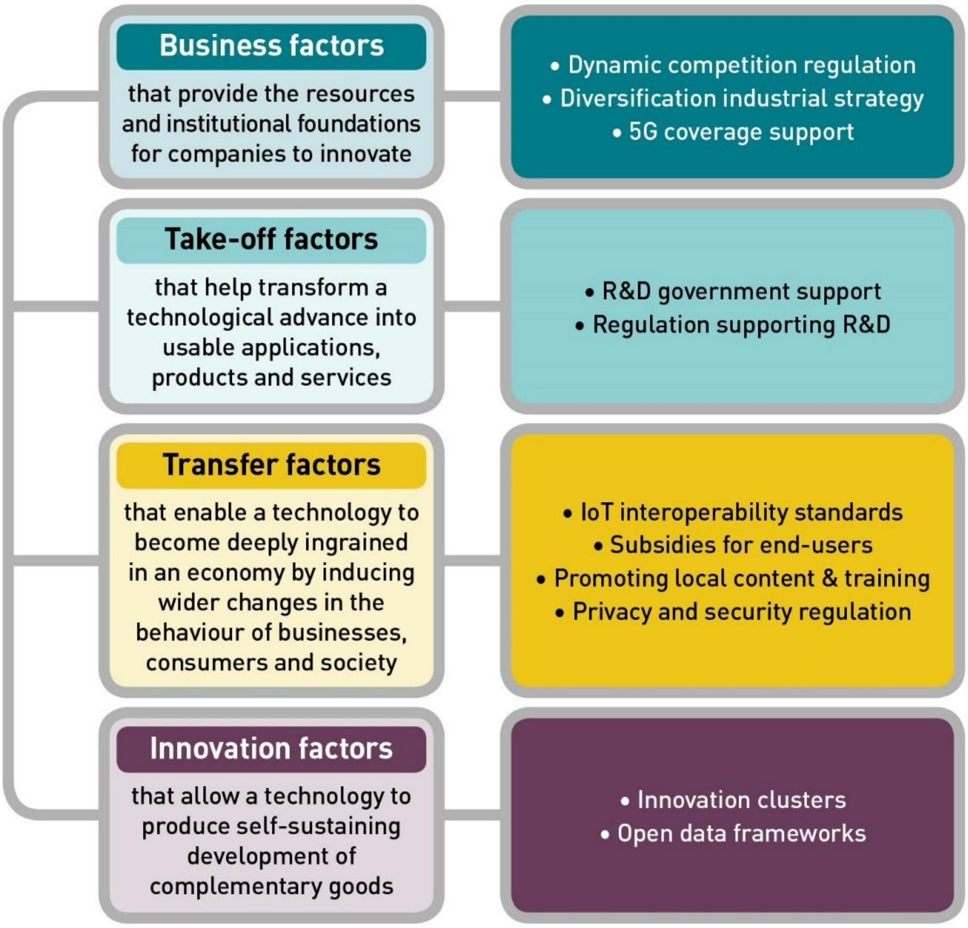
[12] The fact that we are using only historical information and that we do not take into account the effect of IoT on multifactor productivity explains why we arrive at a lower estimate for the impact of IoT on GDP than Accenture and Frontier Economics (2015) in The Growth Game-Changer: How the Industrial Internet of Things can drive progress and prosperity. The authors of that study project IoT will add $593 billion and $6.13 trillion to Germany's and America's GDP over the period 2015-2030.

Policy recommendations

The economic boost from the IoT calculated in the previous section is a static estimate, based on current economic and technological conditions. This impact may increase in the future depending on the specific policies that countries adopt.

As Accenture and Frontier Economics (2015)[13] argue, technological diffusion by itself is not enough to unlock faster growth; countries must have the capacity to capitalise on the potential of new technologies. In particular, the degree to which the IoT becomes ingrained in the economy depends on the following four pillars. As the figure below suggests, these pillars can be reinforced by applying appropriate policies:

Figure 5. Policy recommendations summary

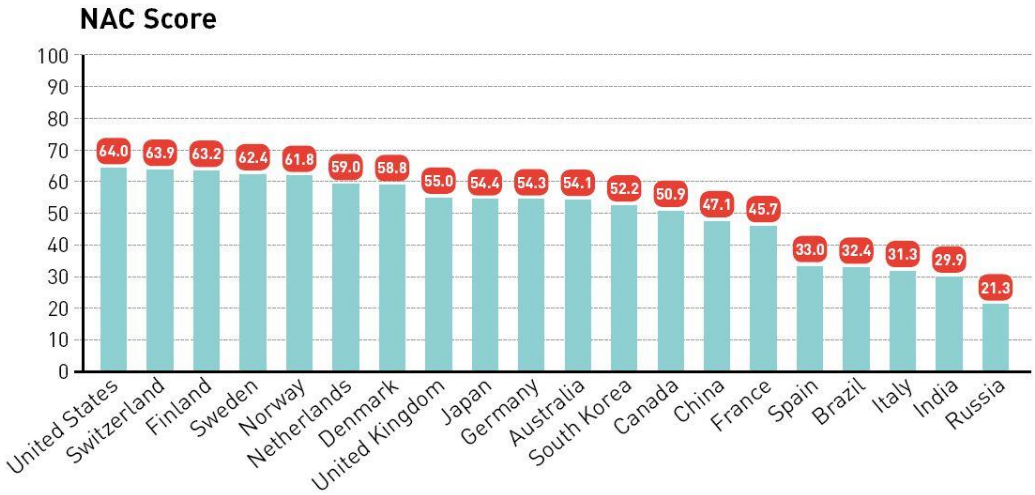


Source: *Accenture and Frontier Economics (2015): The Growth Game-Changer: How the Industrial Internet of Things can drive progress and prosperity; OECD (2016): The Internet of Things: Seizing the Benefits and Addressing the Challenges.*

By focusing on the policies outlined above, policymakers can embed and spread the IoT more rapidly. In doing so, they can help their countries to rise in the National Absorptive Capacity (NAC) Index. Developed by Accenture and Frontier (2015), the index measures a nation's IoT economic diffusion potential. Although some countries (especially, the US, Switzerland and Finland) are better positioned than others and are expected to gain the most from the IoT, no single nation has achieved a score of 100. This implies that regulators and policymakers in every country can work to strengthen the development of the IoT.

[13] Accenture and Frontier Economics (2015): The Growth Game-Changer: How the Industrial Internet of Things can drive progress and prosperity.

Figure 6. The NAC Index



Source: Accenture and Frontier (2015)
Note: The NAC Index assesses a nation's IoT economic diffusion potential.

Conclusion

The IoT will fundamentally reshape our lifestyles and social relationships. The effect on the economy is already tangible, even if the IoT is still in its infancy. The task for policymakers is thus to create an environment which helps the IoT realise its full potential for the benefit of the whole of society.

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