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The Impact of IoT on Economic Growth

A Multifactor Productivity Approach

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***Abstract*—The impact of Information and Communication Technology (ICT) investments in macroeconomic growth via multifactor productivity (MFP) has been characterized as a three-stage process, starting with a period of technical adoption, a plateau of increased productivity, and a diminished returns phase due to saturation. As the Internet of Things expands the ICT application domain, it has the potential to avoid the MFP growth stagnation related to ICT capital surplus observed in industrialized economies. This paper suggests a research direction for analyzing the impact of IoT on economic growth.**

***Keywords*— internet of things; economics; productivity; technological innovation**

I. INTRODUCTION

Economic growth is the result of an increment in the quantity of production factors or a productivity increase [1]. While factor accumulation causes short-term growth increases, productivity improvement has a permanent effect. That's why the analysis of factors that affect productivity has been central to economic growth studies.

At the macroeconomic level, multifactor productivity (MFP) can be defined as the relationship between GDP (as an aggregate measure of production) and all other inputs combined [2]. Since input combinations depend on the technology used, technological progress has been historically linked to productivity increases, and thus, economic growth [3]. From this perspective, particularly interesting cases include general-purpose technologies (GPT) such as electricity, the internal combustion engine, or the production line. All three examples combine methods of production and invention with the potential to transform daily life. The examples also can improve productivity in most industries, with long-term impact. However, direct investment in GPT is not reflected immediately nor as linearly as gains in MFP; it follows an adoption-productivity-stagnation cycle described in section II.

Information and Communication Technologies (ICT) can be classified as a GPT, since they cover most of the productive sectors, maintain continuous improvement, and facilitate the invention of new products and processes associated with that sector [4].

The Internet of Things (IoT), understood as the trend of providing uniquely identifiable physical objects with the means to connect and interact using a communications network[1], expands the ability of ICT to lower the barrier between physical and digital worlds.

ICT adoption has reached the point where capital investments are beginning to show diminishing returns in MFP, as explained in section III. As a new field of application, however, the IoT has the potential to reverse this trend.

II. GENERAL-PURPOSE TECHNOLOGY ADOPTION CYCLE

The transformative effect of a general-purpose technology and its related impact on MFP occurs when it's available at affordable cost for effective use in multiple sectors. Mechanisms for spreading the technology must also be in place, including associated infrastructure, diffusion of usage knowledge, and an ecosystem of investors and inventors looking to leverage it and decrease costs further. When a new technology is introduced most investments focus on building these mechanisms. In this first stage of technology adoption no productivity gains can be observed at aggregate levels. Given that the new technology is often promoted as a productivity enhancement tool, this lack of immediate reward is seen by its detractors as a symptom of its inviability. This occurred during the so called *productivity paradox* of the early ICT days, represented by Solow's phrase "You can see the computer age everywhere but in the productivity statistics" [5].

When the GPT overcomes the adoption phase and actual productivity increments are observed, more players are attracted to the ecosystem, and greater capital and time investments are devoted to the development of new and refined applications of the technology, producing further productivity gains. Similar patterns have been observed for ICT and electricity adoption paths [6].

However, every technology has limits, and inevitably, developmental investments show diminishing returns. At this point, investments will start to decline in favor of alternative technologies, unless new application domains are introduced. When the steam engine became impractical due to size and safety issues, the internal combustion engine rose. Likewise, Tesla and other all-electric cars are now beginning to gain traction in the automotive sector. But when we started seeing diminishing returns on connecting *people* to the internet, we began to connect *things*.

[1] See [17] for a discussion on the definition of IoT.

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III. The Current State of ICT and MFP

Adoption of ICT has not followed a uniform pattern in the world. Industrialized countries could devote more resources, and earlier, while some developing economies are still setting mechanisms for its adoption. As result, we can find examples of countries and industries at different stages of the adoption cycle. The associated historical data has created a body of evidence linking investments in ICT to MFP growth at an aggregate level.

In advanced economies including the USA, EU and Japan, a positive relationship between ICT capital deepening and MFP was observed in the 1990s, peaking in 2000 and then decreasing [4][7][8][9]. This deceleration is attributed to capital ICT saturation, the disappointment with ICT after the dot-com bubble, and ICT's emerging use in less-productive industries.

Comparative studies covering developing countries show that in this group the investments in ICT didn't advance MFP in this period, [10] with two exceptions: ASEAN economies in the early 2000s [11] and the South Korean success story, where the national focus on technology adoption (including ICT) led to large MFP gains and economic development [12].

Additional evidence suggests that select emerging economies – those with some characteristics of developed countries – still receive MFP benefits from their ICT investments [13].

While developing nations still have room for improvement, the diminishing MFP returns associated with ICT investments in industrialized countries is disturbing, as these are the places where most technological progress takes place.

IV. How is IoT Different?

The Internet has already extended the ICT application domain through ubiquitous access to data and computing power. As originally conceived, however, ICT has two limitations: it is designed mainly for human-to-human communication, and it's intended to be accessed using a computer.

Technical innovations now allow computing power in small objects, while advances in communication standards uniquely identify and connect a growing number of objects as Internet-enabled devices, giving birth to the IoT and a new set of applications for ICT. This is a quantitative and qualitative change. On the one hand there are more objects than persons, and the expected number of internet-enabled devices is enormous (25 billion by 2020 according to Gartner [14]).

From the qualitative standpoint, ICT applications can now interact with the physical world, opening the door to a vast variety of new use cases, creating liquid marketplaces of physical assets, and allowing the integration of IoT devices in industries and processes not traditionally seen as technology-intensive [15].

In addition, to fully take advantage of the IoT requires a combination of data transmission, processing and analytics, which in turn raises the demand for ICT services such as cloud computing [16].

V. Conclusion

Because IoT use cases extend the application domain of ICT it's expected that the IoT will help industrialized countries sidestep the reduced MFP gains associated with continued ICT capital investments. We're still witnessing the genesis of the IoT industry. While its effects on productivity can be difficult to perceive, analysis at the sectorial level may help characterize the growth path to ensure it's taking place.

Even in developing countries, where there is not an observable ICT saturation effect, the introduction of IoT can have positive MFP effects by easing access to ICT for both general population and industries.

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