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Pei-Chang Wen & Shin-Horng Chen
International Division,
Chung-Hua Institution for Economic Research

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Abstract

Although Taiwan made its well-respected economic achievements at the catch-up period, the country is in transition to innovation-driven economic upgrading, which is recently being promoted by a strategic policy package of so-called the Industrial Transformation Program, focusing on 5+N innovative industries. Unlike the previous focus on modularized intermediate goods in the industrialization stage, the new policy package calls for innovation with strong flavor of cross-fertilization, solution-orientation, software and hardware integration. A key issue of this paper is how a latecomer like Taiwan may innovate in a post catch-up manner, which requires a latecomer country to establish new technological trajectories for innovation in a changing competitive environment where scarce opportunity for imitation is present. The paper sets out to examine the ways in which how Taiwanese firms approach or harness IoT innovations, especially via applications at the social sphere. It seems to present more challenges than IoT applications inside the firm (for example Industry 4.0) for the reason that IoT applications at social sphere are related to the aspects of behavior and social interfaces of the broadly-defined customer space. As a result, for innovators in Taiwan, they need to address the social interface involved in an appropriate manner. In many cases, they also need compound innovations, especially in conjunction with business models, not just technological innovation alone. Therefore, innovators in Taiwan have to change the way in which they innovate and interact with the changing innovation ecosystems. Especially in the emerging innovative sectors as 5+N innovative industries targeted by the government, the evolving innovation ecosystems are intrinsically international. Based on two intensive case studies, we would like to draw some lessons learned in Taiwan, which may enrich our understanding of factors underlying industrial innovations in the era of the digital economy, especially for latecomer countries in transition.

Key words: IoT innovation, application at the social sphere, post catch-up, case study
JEL classification codes: JEL: O00, O14, O25, O30

I. Introduction

As a result of Taiwan's catch-up industrialization, the information and communications (ICT) industry has become the paramount engine of export-oriented economic growth in Taiwan. A characteristic feature of Taiwan's ICT industry has much to do with global production/innovation networks connecting cross-border clusters in the ICT industry (Chen, 2004; Ernst, 2005). What underlie this are well-regarded production and R&D capabilities of the Taiwanese ICT producers, which in turn have made Taiwan a major source of contract work for international prominent ICT companies. As a result, the lion's share of

industrial R&D and innovation in Taiwan used to be (or is still) meant primarily for production and export and focus mainly on modularization and "production interfaces" along the value chain.

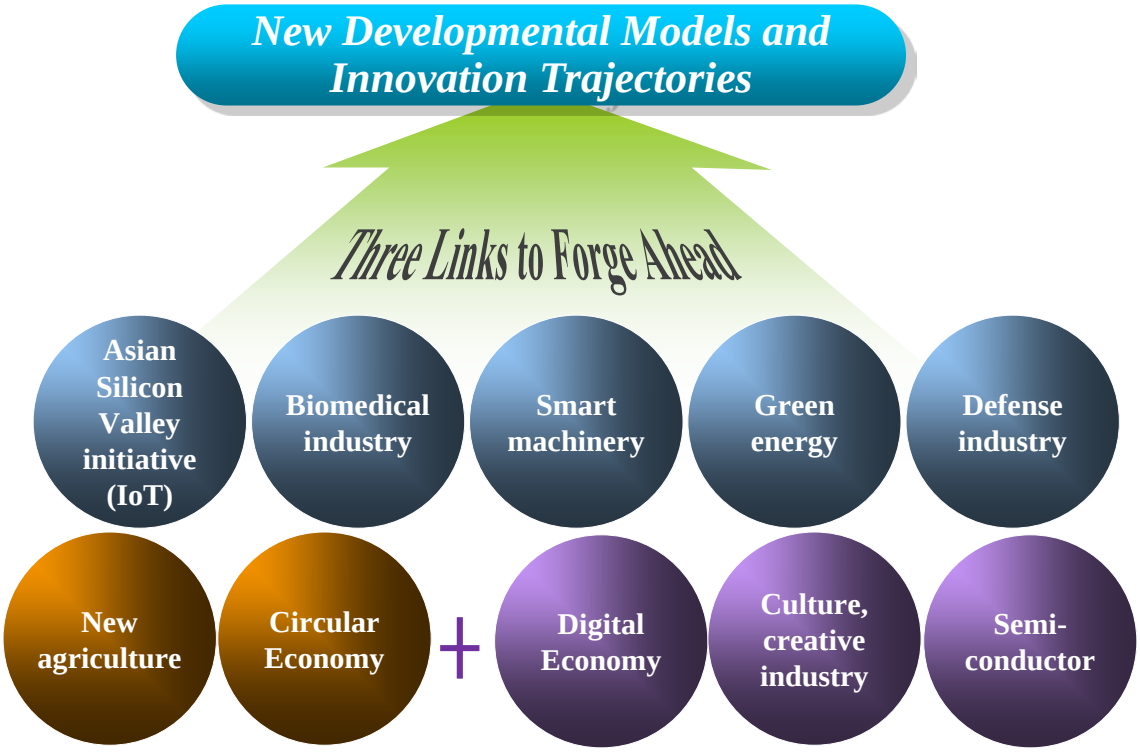
In recent years, Taiwan has embarked on economic transformation, especially by harnessing new digital technologies, such as Internet of Things (IoT) and Artificial Intelligence (AI). On the one hand, those new digital technologies are presumably related to Taiwan's existing strengths of the ICT industry. One the other hand, they are an important part of the digital economy, which is taking shape in many countries, with escalating extent and significance. However, the digital economy is not just about the so-called "digital sector", the evolving ICT sector producing foundational digital goods and services. Taking a broader view on the digital economy, Bukht & Heeks (2017) add two more scopes of relevance. One is the true "digital economy", defined as "that part of economic output derived solely or primarily from digital technologies with a business model based on digital goods or services" (for example the platform economy and sharing economy). The other is related to the use of ICTs in all economic fields, termed as the "digitalized economy". Regarding the latter, China champions the model of "Internet+", while the European Union promotes ICT innovation at the societal level, which often requires applications of new digital technologies at the social sphere. In other words, when it comes to the fields of IoT and AI, industrial innovations in Taiwan, as well as some other peer countries in the world, may set departure from its existing routines and trajectories in the catch-up manner.

Set against the above backdrop, the paper sets out to examine the way in which how Taiwanese firms approach or harness IoT innovations, especially via applications at the social sphere. Based on two intensive case studies, we would like to draw some lessons learned, which enrich our understanding of factors underlying industrial innovations in the era of the digital economy, especially for latecomer countries in transition.

II. Taiwan's Economic Transformation and Innovation Applications

To pursue economic transformation, the Taiwanese government, has recently formulated a strategic framework for industrial innovation, as shown Figure 1. In essence, the government sets the goal to forge ahead with a new development model, different from Taiwan's previous innovation trajectories. With that, innovation will become a driver for Taiwan to promote employment, equitable income distribution, regional balance, and growth. The Industrial Transformation Program sets out to promote the so-called 5+N

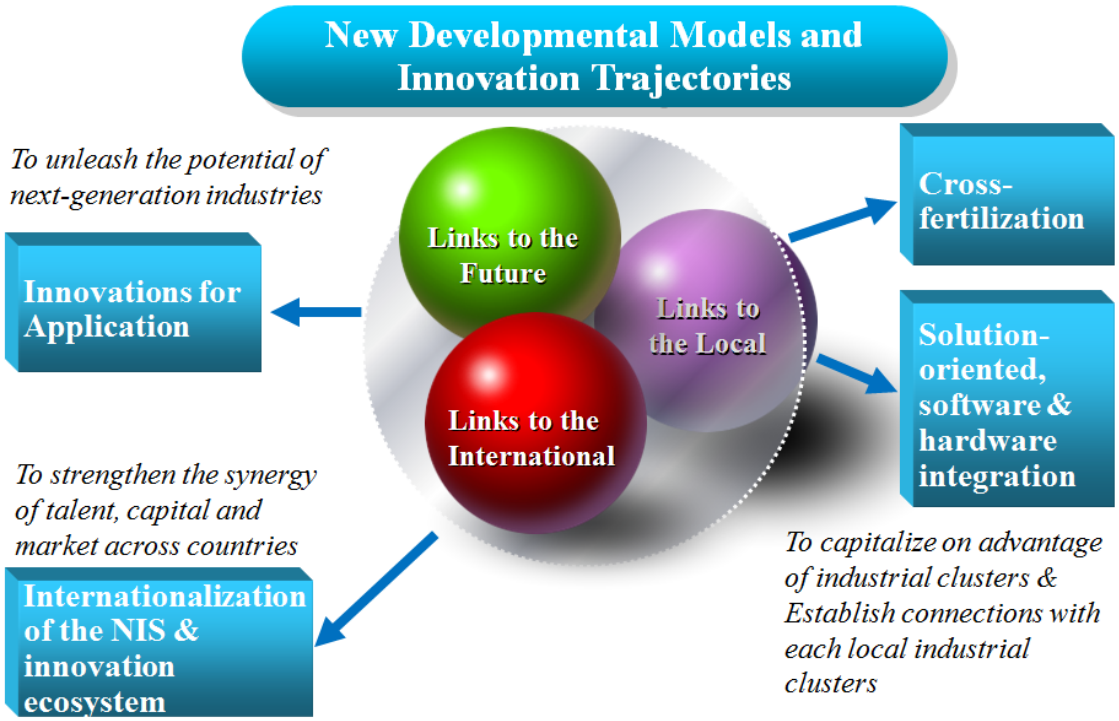
flagship innovative industries, including Asian Silicon Valley Development Initiative for IoT and smart city, green energy (offshore wind power and other kinds of renewable energy), the biomedical industry, the defense sector (cybersecurity included), new agriculture (for example precision agriculture), and the circular economy. The development of these flagship sectors will facilitate the upgrading of Taiwan's backbone industries, such as ICT hardware and the petrochemical industry. For example, despite being among the global leaders of the integrated circuit (IC) industry, the Taiwanese industrial player still have to upgrade their capabilities to come terms with the rising trend of AI. In addition, Taiwan intends to jumpstart the emerging innovative sectors by a few sets of policies, including institutional innovations, innovation friendly regulations, promotion of FDI and so on. For example, Taiwan is to set up a sound framework of regulatory sandbox and social pilot, not just for FinTech but also some other fields. Moreover, Taiwan needs to gear up its entrepreneurial development. In some fields, Taiwan intends to pioneer challenge-driven innovations and provide level playing field of testbed and social pilot. In addition, in such areas as IoT, AI, and the digital economy, the biomedical sector, Taiwan intends to promote first-of-a-kind innovation in Asia, by active engaging with global talents as well as global players.



Source: The authors.

Figure 1 Taiwan's New Policy Focus: 5+N Innovative Industries

Regarding new developmental models and innovation trajectories, a few differences from the existing ones deserve attention (see Figure 2). While innovations in Taiwan are meant primarily for production and export and focus mainly on modularization and "production interfaces" along the value chain, some of the innovative industries are geared to innovations for applications, for example those related to IoT, AI, the digital economy, and offshore wind power. Unlike the previous focus on modularized intermediate goods, Taiwan also needs to promote innovation with strong flavor of cross-fertilization, solution-orientation, software and hardware integration, especially for smart machinery, green energy, the digital economy, and new agriculture. In addition, since a few of the innovative sectors are emerging, their respective ecosystems are still evolving at the international scale, Taiwan's national innovation system (NIS) has to become more internationalized than it is now.



Source: the authors.

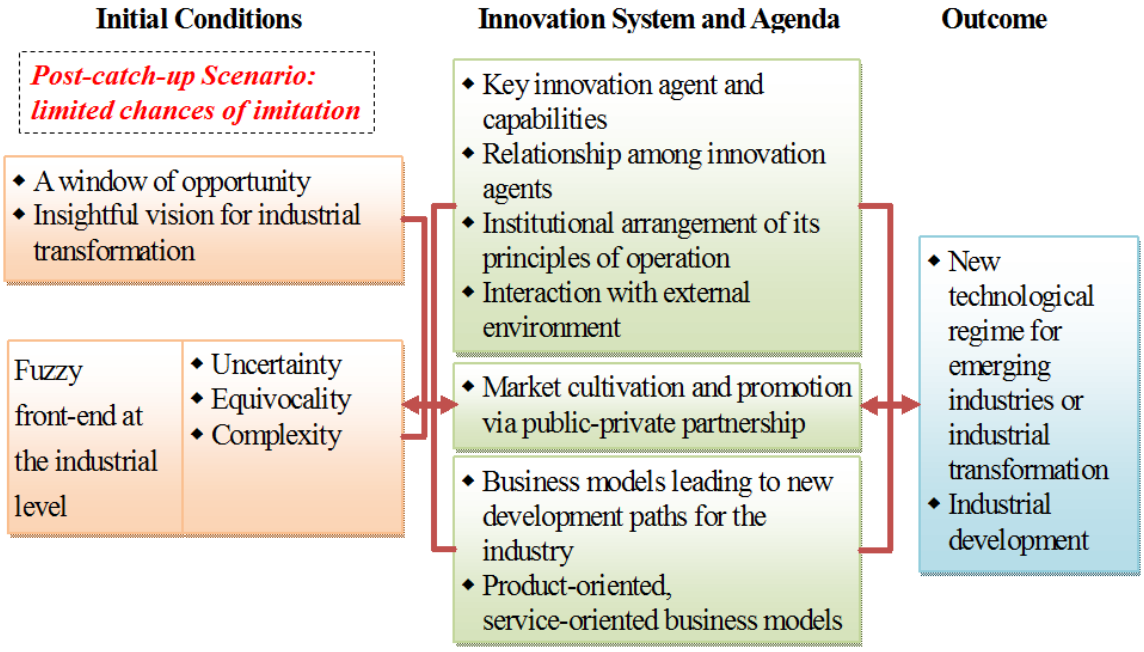
Figure 2 5+N Innovative Industries and Transformation of Taiwan's National Innovation System (NIS)

Therefore, the Industrial Transformation Program and its goal of new developmental models and innovation trajectories have profound implications on Taiwan's NIS. First of all, the promotion of 5+N flagship innovative industries entails Taiwan's developing the industries and forging innovations, with few steps behind the forerunners, and not in a catch-up manner. In this way, Taiwan sets out to conduct R&D and promote innovations in a manner beyond industrialization of catch-up and specialization in intermediate goods. Secondly, Taiwan needs to foster innovative start-ups, by strengthening the link with the international ecosystem, namely for the Asian Silicon Valley Initiative, the biomedical industry, and the digital economy. For some other sectors, such as the green energy and defense sectors, Taiwan may have to work with foreign partners in order to build up required capabilities and forge innovations for applications. A typical case at issue is the offshore wind power industry, where with a national plan to install up to 3GW by 2025, Taiwan has managed to attract some international leading vendors to invest in Taiwan and they have become an important stakeholder for Taiwan to recruit and cultivate talents needed. Above all, the ten innovative sectors are meant for Taiwan to promote new developmental models, different from Taiwan's existing technology trajectories and developmental paths, hence require brand new skills and knowledge bases.

The term "post catch-up" indeed stands out in the above discussions on Taiwan's Industrial Transformation Program. Elsewhere, the authors propose a framework for post catch-up industrial development (Chen and Wen, 2016; see Figure 3). Post catch-up requires "innovation activities in which the latecomer countries establish new technological trajectories for innovation in a changing competitive environment where scarce opportunity for imitation is present." (Choung, Hwang & Song, 2014). Much of the literature tends to focus on the way in which technological capabilities in the leapfrogging country is shaped and transformed to become a forerunner or approach the technological frontier. In our opinion, as a departure from the catch-up model, post catch-up involves a scenario where a latecomer with few steps behind with the advanced country strives to explore "fuzzy front-end" in industrial innovation (Chang, Chen and Wey, 2007; Stevens, 2014), hopefully in a head-to-head manner. To do so, the latecomer has to deal effectively with such issues as market cultivation and the articulation of developmental trajectory with appropriate business models for the new industrial innovation involved. In particular, there is increasing awareness that innovative business models are not only essential to an innovator's value creation and value capture but indispensable to the birth of an emerging industry (Teece, 2010; Kley, Lerch and Dalliner, 2011; Lenfle and Midler, 2009). These issues will become more complicated if the industrial player in the latecomer has stuck to the comfort zone of being part of the existing global production/innovation network

or producing modules/products with open product architecture, as the typical case of the manufacturing industry in Taiwan.

A key issue of the paper is how a latecomer like Taiwan may innovate in a post catch-up manner. The Taiwanese case is interesting in its own right, given the fact that Taiwan's industrial innovation is associated mainly with the technological regime of modular and open architecture and active participation in the global production/ innovation network (Chen, Wen & Chen, 2013).

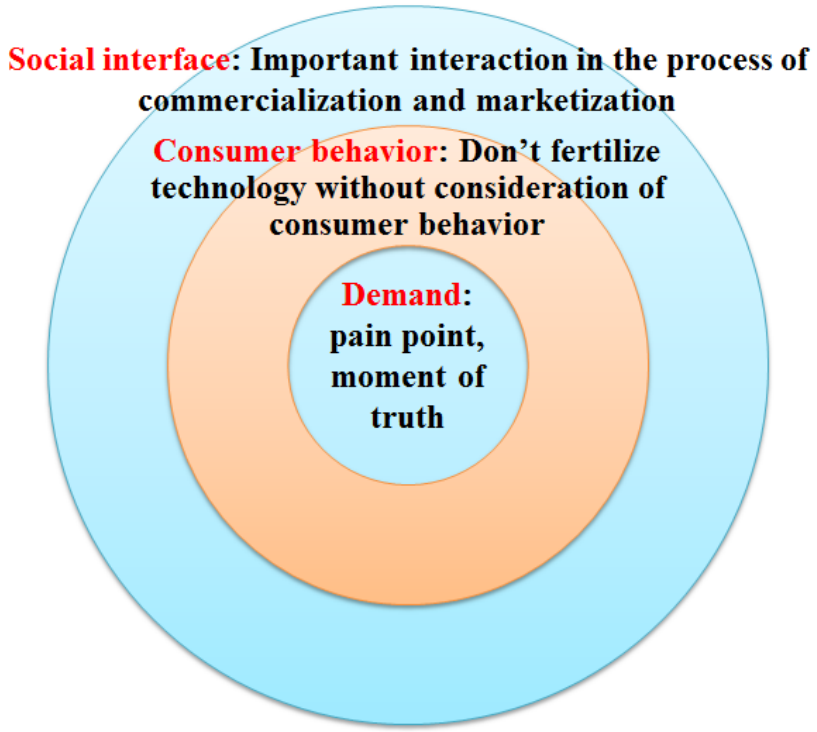


Source: Chen & Wen (2016).

Figure 3 A Conceptual Framework for Post Catch-up Industrial Development

In addition, since we are particularly interested in innovative applications at the social sphere, special account should be given to the scope of "customer space". Quite often, innovative applications are triggered by demand, which are related mainly to the target customer's pain point, moment of truth and alike. However, we suggest to take a broader view on customer space, especially for systemic innovation, living lab, & large-scale pilots (see Figure 4). Apart from demand, systemic innovations need to give special account to "behavior". For one thing, one cannot have clusters of technological innovation without social and behavioral changes. For another, innovators had better not to fertilize technology without consideration of consumer behavior. A vivid case illustrating this point is China's dockless bike sharing services. Within a couple of years, the services expanded at an enormous scale in Chinese major cities. At the same time,

because of oversupply and undue behaviors, huge piles of unused shared bikes have also created bike graveyards somewhere in the cities. The underlying reason has much to do with the neglect of the behavior aspect in designing the business model. In addition, social landing of innovative applications often entail effectively dealing with "social interfaces", which are related to important interactions in the process of commercialization and marketization. Evidence has shown that long-lasting regulations can be obstacles to digital innovations at the societal level. Therefore, digital technologies, as a driver, have to co-evolve with the organizational governance, institutional arrangements and regulatory regime for the economy in an appropriate and desirable manner. A definition of a smart city given by Erik Anderson, a Vice President of the Foxconn group: "A smart city enables new behaviors which redefine urban spaces", lends support to the above-mentioned broader view on customer space.



Source: The authors.

Figure 4 A Broader View on Customer Space

III. Cases of IoT Applications at Social Spheres

IoT applications have been around for a while, but they are still evolving and at the "fuzzy front-end" stage. Many countries, Taiwan included, have jumped on the bandwagon to promote their own IoT

applications, especially in conjunction with the theme of the digital economy and smart city. More importantly, innovations in IoT have much to do application. Compared to IoT applications inside the firm (for example Industry 4.0), IoT applications at social spheres seem to present more challenges, which are related to the aspects of behavior and social interfaces of the broadly-defined customer space. Below we present two cases to discuss the related issues.

III-1. ETC and Its Extended Applications

National freeways in Taiwan are toll ways. With a build-operation-transfer (BOT) project, conducted by Far Eastern Electronic Toll Collection Co. (FETC), the billing system has transferred from manual tolling (via flat-rate toll stations) to nowadays all electronic, multi-lane free flow tolling on all national freeways in the country. As a result, Taiwan is the first country in the world to transfer from flat-rate toll stations to distance-based pay-as-you-go tolling system on all of its freeways. Up to December, 2016, with a penetration rate of more than 94.14% nationwide and tolling accuracy rate as high as 99.9999%, Taiwan also has the longest ETC freeway mileage in the world.

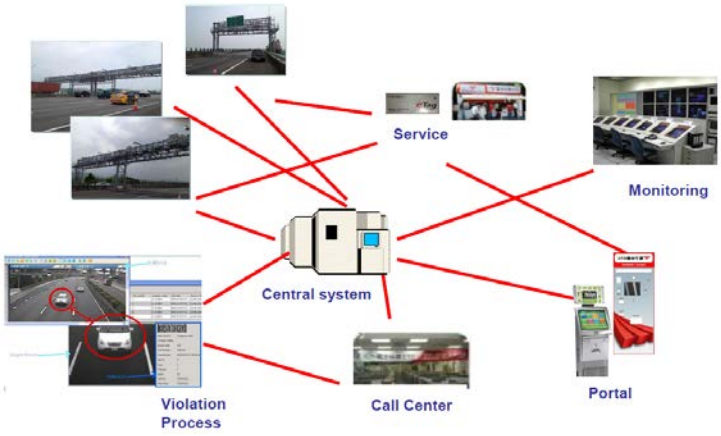
Initially, FETC adopted an infrared-based solution with an over-the-top box inside vehicles and flat-rate manual/electronic hybrid toll stations for the freeway tolling. It failed to meet the competent authority's demanding requirements of high penetration rate, partly because the over-the-top box was relatively expensive. In addition, the government intended to implement distance-based toll collection system. The company then developed an indigenous RFID-based solution, which combined electronic toll collection and technologies of computer and communication (see Figure 5). In December, 2013 the old flat-rate manual/electronic hybrid toll stations were replaced by the distance-based pay-as-you-go all electronic toll collection on all of Taiwan's major freeways. This system can not only expand toll collecting capacity, shorten toll collecting time, reduce air pollution, but also be more convenient and safer for freeway users. In short, the goal of reaching equity by "pay-as-you-go" can be reached by this distance-based electronic toll collecting system. Within two years, the penetration rate of the RFID tolling soared from less than 15% to more than 90%.

Of note is the fact that FETC's RFID-based tolling system can be applied in broader manners than just national freeway tolling. Since the system has a penetration rate as high as more than 94% in Taiwan, for example, FETC has turned it into a billing and monitoring system for private parking lots. Big data

collected through the ETC system also serves the innovative need of telematics, vehicle tracking and so on. In a sense, it comes to resemble a platform for Internet of Vehicles and innovation of Smart City. Though starting with a BOT business of ETC, the FETC solution can find its way to generating more economic and business impacts, for example vehicle-centric access control solutions and logistics flow management and commerce, only if the regulatory hurdles can be removed. In addition, while highway tolling is compulsory, application of ETC outside national highways requires appropriate mechanism, giving consumers' call to make consumption payment via ETC.

More importantly, the total solution is being export to Vietnam and some other ASEAN countries. In light of Taiwan's success in the ETC deployment, the Vietnamese government approached FETC for collaboration. By teaming up with a local partner, TASCO, FETC, supported by a Taiwanese consortium, were working on pilot sites in Vietnam. In addition, according to FETC, its collaborative deals with Malaysia, Indonesia, and the Philippines are underway. However, in search of markets for scaling-up, FETC came to realize that major hurdles in their international outreach included fragmented ownership and operations of national superhighways in some of ASEAN countries.

(1) The Electronic, Multi-lane Free Flow Tolling in Taiwan



(2) Total Solution of the RFID-based ETC Tolling System

(3) A Pilot Site in Vietnam

Source: Company information of FETC.

Figure 5 FETC's ETC Solution in Taiwan and Vietnam

III-2. UPark and O2O Sharing of Urban Parking Spaces

UPark is a startup, pioneering online to online (O2O) sharing business of urban parking spaces in Taipei. So far, the company managed to raise seed funding of NT25 million in Taiwan. In a modern city, like Taipei, ordinary drivers may frequently face the situation where they leave home, leaving their parking spaces unused, but cannot find parking spaces around offices. In light of this commonplace pain point, UPark introduced an IoT-based smart solution for O2O sharing of parking spaces. Its IoT lock (see Figure 6) can be unlocked simply via digital passwords. With smart devices, its subscribers or members can easily

pinpoint online available parking spaces in the neighboring areas. The company was smart enough to start its business by dealing with owners of roadside parking spaces at the first place, because of easy access of their parking spaces. To scale up its business, UPark began to involve parking spaces inside residential complexes, which are often located in the basement. As a result, the company has to deal with new stakeholders, including the management committee and security guards of the resident complex, causing additional problems. Some appropriate mechanisms and revenue-sharing arrangements got to be in place for the new stakeholders to comfortably become part of the UPark's ecosystem. Moreover, when its business reaches certain visible scale, UPark has faced regulatory issues, because long-lasting regulations for parking service operators in the brick-and-mortar world become obstacles to digital innovations at the societal level.

Source: Company information of UPark.

Figure 6 UPark and Its IoT Lock

In the catch-up manner, industrial innovations in Taiwan used to serve primarily for production and export and focus mainly on modularization and "production interfaces" along the value chain. As long as the firm involving in R&D and technology development can tap the global production network, it is relatively easy for the firm to find a way to commercialize its R&D results. In contrast, innovations in IoT, especially those related to system solutions, are geared mostly to applications in real life environment and multi-contextual spheres. This often brings about challenge issues for the innovators.

Quite often, IoT applications at social spheres target initially at specific customer and stakeholders, and their needs. To unleash the economical and business potential, the innovator has to scale up its innovation ecosystem and/or find alternative routes for applications. However, changes in application sphere and stakeholder may present different challenges, which are related to the aspects of behavior and social interfaces.

IV. Concluding Remarks

Although Taiwan made its well-respected economic achievements at the catch-up period, the country is in transition for innovation-driven economic upgrading. While innovations in Taiwan used to serve primarily for production and export and focus mainly on modularization and "production interfaces" along the value chain, some of the new innovative industries are geared to innovations for applications. Unlike the previous focus on modularized intermediate goods, Taiwan needs to promote innovation with strong flavor of cross-fertilization, solution-orientation, software and hardware integration. In addition, since a few of the innovative sectors are emerging, their respective ecosystems are still evolving at the international scale, Taiwan's NIS has to become more internationalized than it is now.

In short, economic transformation in Taiwan has brought about new keywords for innovation. Above all, the promotion of 5+N flagship innovative industries entails Taiwan's developing the industries and forging innovations, with few steps behind the forerunners, and not in a catch-up manner. Instead of simply innovations for production and export in the context of the global production network, Taiwan has to engage more with innovations for applications/solutions. This will require active participation in the evolving innovation system, not just relatively straightforward value chain as before.

Our case studies have demonstrated that innovations in IoT have much to do application. Compared to IoT applications inside the firm (for example Industry 4.0), IoT applications at social spheres seem to

present more challenges, which are related to the aspects of behavior and social interfaces of the broadly-defined customer space. As a result, for innovators in Taiwan, they need to address the social interfaces involved in an appropriate manner. In many cases, they also need compound innovations, especially in conjunction with business models; not just technological innovations alone. Therefore, innovators in Taiwan have to change the way in which they innovate and interact with the changing innovation ecosystem

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