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Impossible trinity: A guideline to shape telecommunication policy by mediating bandwidth supply

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ABSTRACT

Telecommunication policy researchers have long believed that expanding bandwidth supply and decreasing peering fee could facilitate economic activities and investment. However, the results are not always as expected. The staffs of Taiwan government hence developed an "impossible trinity" guideline to shape telecommunication policy by mediating bandwidth supply between ISPs/services. This guideline helps policy-making staff to boost certain industries/businesses or cooling other overheating ones in order to ensure economic growth and stability of the domestic market. This work explores and demonstrates how the staffs of Taiwan government apply impossible trinity to shape telecommunication policies during 2000 ~ 2018. The contributions of this work are: (1) a hypothesis, called impossible trinity hypothesis, was made as an argument framework to harmonize the disputes between the ideas of net neutrality, fair ISP competition, and internet censorship in the TP making arena within government and market; (2) a macroeconomic TP making methodology to mediate the market development was designed; (3) the biological nature embedded in Taiwan TP making process was also discovered and differentiated in three forms, that are disruptive selection, directional selection, and convergent evolution.

1. Introduction

Telecommunication policy (TP) is the government statement of how it intends to manage wire/wireless resources (called bandwidth) for information and communication technology (ICT). The bandwidth management means how the government maintains the market order that "telecommunication sellers" (Internet Service Providers, ISPs) offering their services (bandwidth) in exchange for money from buyers (civilians). Many economists and TP makers, therefore, have long believed that expanding bandwidth supply and liberalizing telecommunication market could decrease the business operation cost, resulting in higher bandwidth usage, economic activities and investment [1–3].

More studies, however, indicate that the results are not always as expected: expanding bandwidth supply and liberalizing telecommunication market may not work well to facilitate economic growth. Fukao demonstrated that the total factor productivity growth in ICT-using service sectors in Japan, such as distribution services, manufacturing (excluding electrical machinery), and finance (excluding real estate) declined substantially, even though telecommunication technology and bandwidth usage are dramatically progressing since 1995 [4]. Moreover, the contribution of telecommunication investments to economic growth in Japan also declined notably after 2000 [4]. This phenomenon has been observed not only in Japan, but in Taiwan, South Korea, France, and Germany [4–5].

Therefore, during 2000–2018, the staffs of Office of Science and Technology (OST) [6] in Taiwan Executive House suggested that it might be more helpful to transform the telecommunication policy from a manufacturing-based industrial policy to a broader macroeconomic policy, just like the monetary policy, as shown in Fig. 1. The reason is that the technological advancements in 4G and upcoming 5G mobile technology provide more direct integration of the physical world into telecommunication-based platform, resulting in improved scale, effectiveness and efficiency of economic benefit for our society [1,7]. This leads that bandwidth is no longer as carriers for documents, but as the medium of exchange for intelligence between different industry sectors in the virtual world, tightening credit and capital gains of most industry sectors, just like money as a medium to exchange goods and service in our real world. Based on this idea, the OST staffs turned their attention macroeconomically on how to mediate bandwidth supply between ISPs/industries in order to boost certain industries or cooling some overheating ones, ensuring economic growth and stability of the domestic market in advance.

Several TP suggestions including net neutrality, fair ISP

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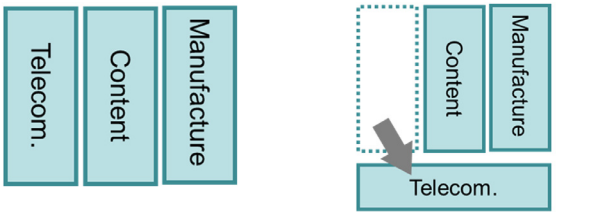


a) Telecom. policy as the industrial policy b) Telecom. policy as the macroeconomic policy

Fig. 1. Positions of telecommunication policy.

competition, and internet censorship [8–12] were afterwards arisen and discussed inside the Taiwan government. However, these TPs are double-sides swords and conflicting with each other. There is no sufficient theoretical framework as a guideline for TP making, to our best knowledge, to explain the competition relationship between them. The OST staffs made a hypothesis, called impossible trinity, attempting to provide a reasoning argument framework to harmonize the conflicts and disputes between these ideas. That is, a government simultaneously may choose any two, but not all, of the three types of TP making intentions that are "independent TP", "stable peering fee", and "open internet." Based on the impossible trinity, the OST staffs furthermore defined a TP making framework, which is called Biological Evolution based Policymaking methodology (BEP), provides insight into how to craft optimal TP to mediate the market development. This study extends the previous study [13] to reviews how impossible trinity cooperated with BEP [13] in the Taiwan government during 2000–2018. It should be noted that we focus on the policy-making process at the decision-making level of the Executive House.

The authors of this study were the telecommunication policy staffs in the OST [6] of the Taiwan Executive House to help the government coordinate nationwide science and technology policies during 2000–2018. The authors have pre-existing relationships with Taiwanese officials and deep engagements in telecommunication policymaking, and, therefore, this study provides the first-hand data and in-depth interviews with major officials who headed the entire telecommunication policymaking in Taiwan during 2000–2018.

The rest of this paper is organized as follows. Section 2 presents the research methods. Section 3 describes the definition of impossible trinity and BEP, and Section 4 demonstrates how BEP operates in Taiwan during 2000–2018. Finally, in Section 5 conclusions are drawn and expected to help stakeholders, whom eager participating in the TP, to estimate which evolved traits of the TP are the most survival of fitness in the changing environment, and then to shape corresponding strategies by linking these traits and their short/long-term business activities.

2. Related works

Several TP making philosophies were proposed and discussed in TP making arena within the government and market, and classified into three categories.

First is to pursue net neutrality, which treats all data on the Internet the same without any discriminating, in order to promote fair evolutionary competition of giving users and innovators the right to access non-harmful network [8]. However, net neutrality would rid policy maker of any TP tool, e.g., adjusting peering fee or regulating data transmission between ISPs, to absorb cross-ISPs/border shocks of telecommunication related economic activities. Net neutrality, therefore, results in that domestic economic might be subject to other country's TP strategies and operations. The dispute between Uber of the USA and local ride-hailing industry of many countries (such as Taiwan) is a typical example [9].

The second type of TP suggestions, in light of the critics of net neutrality, is to ensure fair ISPs competition through allowing ISPs adjusting peering fee dynamically, paving the way for more efficient resource allocation, leading to long-term domestic economic growth. In this way, the authority independently can also regulate peering fee between ISPs to encourage the development of the sector-specific industry through the market operation. For example, Chou and Liu demonstrates that adjusting the peering fee between mobile and fixed ISPs entails policy maker to boost and expand the mobile industry rapidly [10]. However, uncertain peering fee may raise telecommunication expense and corresponding risks, thereby stifling investment in the underserved area, harming innovations from minority communities.

Third, an alternative to the second type of TP is to maintain peering fee stable, but, on the other hand, to regulates/blocks the cross-ISPs/-border data transmission, or further breaks technology dependence on foreigners in order to ensure the domestic economic growth [11]. However, policy authorities might abuse their autonomy to adopt irrational expansionary telecommunication policy to stimulate economic activity, i.e., boosting wireless/wired bandwidth supply or allowing large expansion of certain public telecommunication industry. This might end up destabilizing the domestic telecommunication related economy because of high and volatile inflation. Mainland China is an example that allows Uber China pours $2 billion of investment and gets a $7 billion share in a merged company of Uber China and Didi Chuxing within merely three years, even Uber China has yet to turn a profit in China [12].

However, these TPs are double-sides swords and conflicting each other. A sufficient theoretical framework as a guideline for TP making is required to explain the competition relationship between them.

3. Research method

The case research method is appropriate for this study to understand the nature of the processes taking place and to explore better insights into the interdependencies among the factors in the study [14]. Taiwan telecommunication policies during 2000–2018 (TP00-18) was selected. This case is particularly appropriate for studying a national wide IT project since Taiwan is one of the major countries in the world which is capable to roll out its own mobile Internet service. In addition, Taiwan government experiences three times of peaceful democratic transition of power to an opposition party between 2000–2018, which is an excellent opportunity to observe how TP is built from different perspectives.

Data were collected mainly through 25 personal interviews with key actors associated with telecommunication policy in Taiwan during 2000–2018 (called TP00～18 shortly). We began our interview by asking the former main staffs of Taiwan Executive House to describe the general profiles. In subsequent interviews, we asked the related actors from public, private, and third sector to describe the evolution of TP00～18 and the following development, construction, and business operation. The face-to-face interviews were unstructured; the standard set of questions used was designed only to help initiate and guide the interview process. All the interviews were tape recorded and subsequently transcribed, and notes were taken during the session as well. The primary and secondary information was provided to triangulate the validity of the interview. The analysis incorporated three major phases of description, analysis, and interpretation. The data collection and analysis across the phases helped elicit the BEP and its influence on TP00～18 in order to address our research objective.

4. Proposed framework: BEP with impossible trinity

The OST staffs during 2000–2018 suggested that treated TP as economy-wide policy and bandwidth as a medium of exchange for intelligence between industries. The staffs then turned their attention on to how to mediate bandwidth (even to regulate the transmission rate of certain data) in order to boost certain industries or cooling some overheating ones, achieving policy goals in advance. To be more

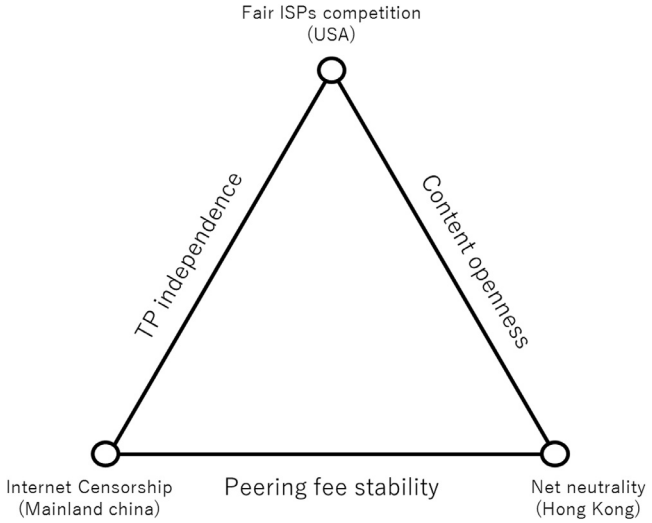


Fig. 2. The impossible trinity.

specifically, the focus of TP was changed to how to regulate the bandwidth supply and peering fee between ISPs/industries in order to boost certain information exchange where the interests may promote the development of targeted economic sector. This proposition can further extend several implications described as follows:

The former OST staffs made an intuitive and helpful TP making hypothesis, named the "impossible trinity," extended from the economic theory first made by Mundell [15], in order to harmonize the conflicts and disputes between these ideas. This hypothesis states that a government simultaneously may choose any two, but not all, of the three types of TP making intentions that are "TP independence", "peering fee stability", and "content openness", as shown in Fig. 2. The arguments are described as follows:

First, a policymaker can indirectly run an independent TP through open market operations or executive order, i.e., dynamic peering fee, in order to absorb cross-ISP/-border macroeconomic shock or to boost certain novel telecommunication-based service. TP authority can further subtly mediate the market by changing the amount of frequency usage fee and telecommunications services reserve fund, just like the interest rates and reserve requirement of the monetary policy, in order to control bandwidth supply and induce the development direction of ISP market. For example, TP authority can raise frequency usage fee or reserve fund to influence ISPs' financial planning, thereby indirectly decreasing the base bandwidth supply and cooling the overheating telecommunication market. However, uncertain peering fee may raise telecommunication expense and corresponding risks, thereby stifling investment in the underserved area, harming innovations from minority communities. The fair ISPs competition system of USA is a typical example.

Second, a TP maker can keep domestic/international peering fee stable to lower uncertainty telecommunication expense, but, on the other hand, apply internet censorship to regulate the information flow cross-ISPs/-border is an inevitable consequence for protecting the investment and trade of domestic telecommunication related industry, leading to stable and sustainable economic growth. The regulations may include criminalizing certain online speech and activities, blocking from view selected websites, and filtering keywords out of searches. However, domestic internet companies nursed by the censorship TP cannot make significant inroads into any major foreign market, because Internet market is based on fairness, namely fair competition under the same conditions [12]. The internet censorship system of Mainland China and its Great Firewall is a typical example.

Third and most contentious one is to ensure all people have equal rights to Internet access, which means free information movement and stable peering fee. In other words, the TP maker should ensure all people exercise and enjoy their rights to freedom of expression and opinion without unreasonable restriction, and all data on the Internet should not be charged differentially by user, content, website, platform, application, type of attached equipment, or mode of communication. However, this TP intention could rid the government of any tools to induce domestic telecommunication related industries. The government will have no "carrot and stick" to trigger the market to launch large-scale network infrastructure or innovate advanced telecommunication service. This will inescapably endanger the development of domestic economic, if the market is prohibited from charging higher preferred access fees to companies or even restrained for information flow that wishes to take advantage of the expanded telecommunication capabilities, just like Google and Facebook of freeloading for using telecommunication infrastructure the ISPs spent billions of dollars to build.

It should be noted that small or developing economic entity, e.g., Taiwan or countries in Southeast Asia, may have problems of establishing an effective TP. The primary difficulty is that they often do not have deep markets of large content and online service demand domestically, and TP maker will, therefore, cooperate with the companies from and follow the TP of neighbor foreign benchmark nations, such as China.

Therefore, the policymaking process in Taiwan is more like a process of biological evolution, as the argument of John Kingdon that policy-making process resembles a process of biological natural selection [16–17]. Fig. 3 shows the Biological Evolution based Policymaking model (BEP) developed in this study, and it demonstrates several characteristics embedded in BEP, which is extended from our previous work [13].

5. Case context: Taiwan telecommunication policy (2000–2018)

This section demonstrates how OST staff made TPs based on BEP model in order to achieve the administration's political goal under the considerations of political/economic reality. As shown in Table 1, TPs with different political philosophies of three periods, that are from 2000–2007, 2008–2015, and 2016–2018, are reviewed in the following subsections.

5.1. TPs in disruptive selection period

A TP is conventionally shaped based on staged based problem-solving policy-making process, as shown in Fig. 4. However, when the administrator and his party at first time grasped the leadership in 2000, the administrator ran into trouble of inheriting a bureaucracy whom his party was unfamiliar with, resulting in that the problem recognizing process was constantly hurdled by the unfamiliar administrative procedure. On the other hand, the administrator only owns a minority legislator seats that difficultly converges different political intentions into TP making consensus, letting his policy be usually blocked in Legislation House. As one respondent summarized:

> "The reasonable way to build national telecommunication infrastructure, taking Electronic Toll Collection (ETC), was run by the government-owned enterprise on behalf of the authority, i.e., Chunghwa Telecom, and regulated by administration contract in order to maintain public interests. However, the administrator was unfamiliar with the implicit insights lies behind, and then he attempted to establish a new rule and change it to BOT (build-operate-transfer) model which is conventionally regulated by private contract. Controversies subsequently happened between Judicial, Execution and Legislation House, and his administration then declared ETC should be regulated by administration contract, resulting in that bureaucrats were caught in the dilemma."

The administrator thought might be that one possible way to break this deadlock is directly pouring budget into expansionary public

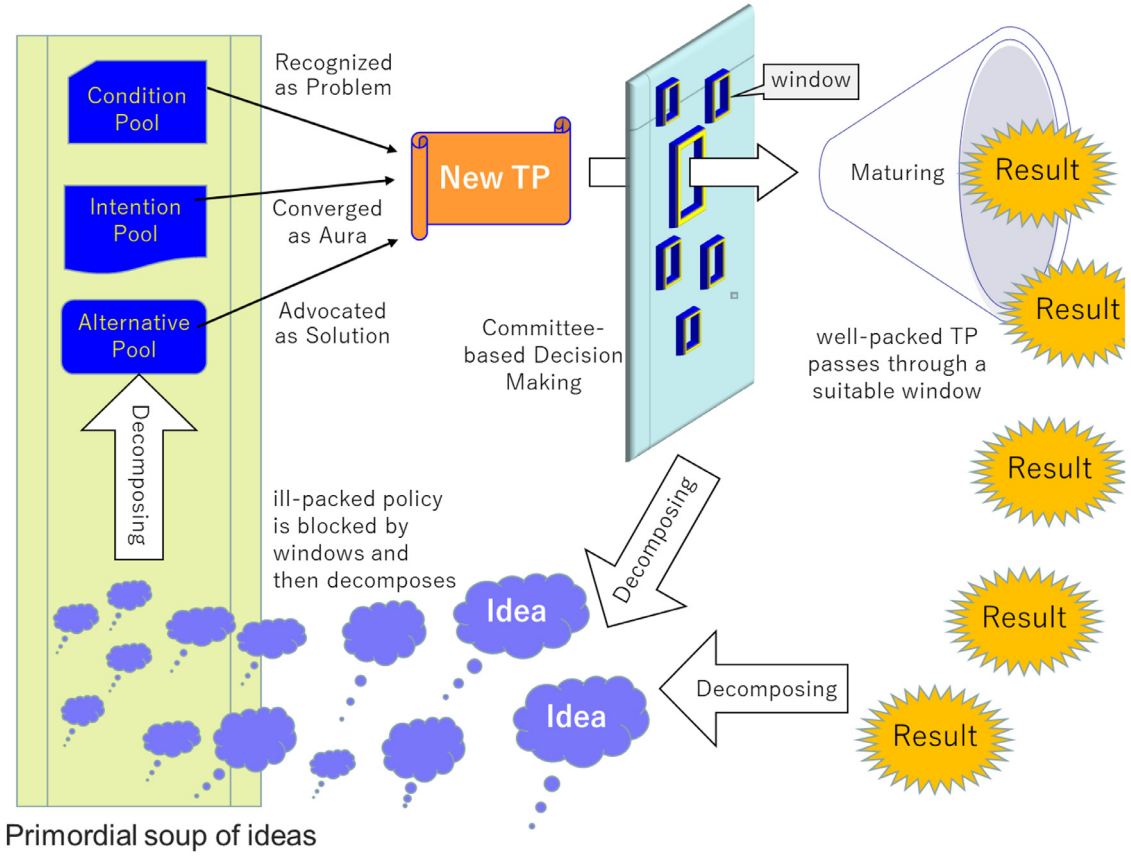
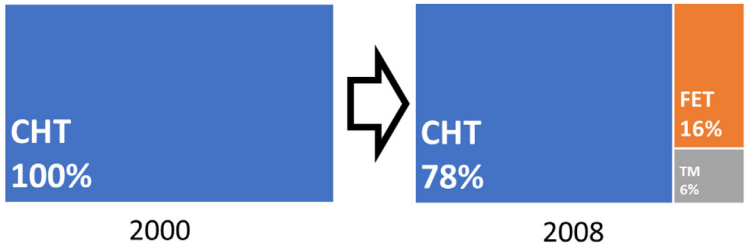


Fig. 3. BEP framework [13].

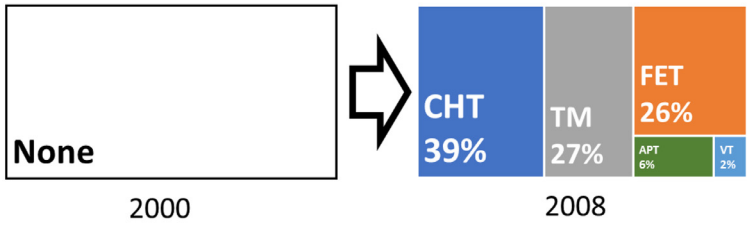
infrastructure construction (called EPIC shortly) based on Keynesian economic theory [18], and bypassing the problem identification process operated by bureaucracy [19]. EPIC attempts to stimulate the telecommunication related industries macroeconomically and adopt two alternatives picked from the alternative pool: (a) increasing public spending on the wire and wireless infrastructure (called fiscal policy), and (b) increasing bandwidth supply. Increasing government investment raises the demand for telecommunication businesses' products and for employment, resulting in boosting the production of telecommunication related industries in Taiwan. Hence, M-Taiwan project with about USD 10 Billion budget (7% national technology budget) was upheld by OST [20]. M-Taiwan contains Broadband Common Duct Construction Plan, which is to append the fiber construction into the current Common Duct Construction Project [21], and this was expected to benefit legislators. Furthermore, M-Taiwan also applies Mobile Taiwan Application Promotion Project to construct WiFi infrastructure

Table 1
Taiwan National Telecommunication Policies in STAG/OST (2000 ~ now).

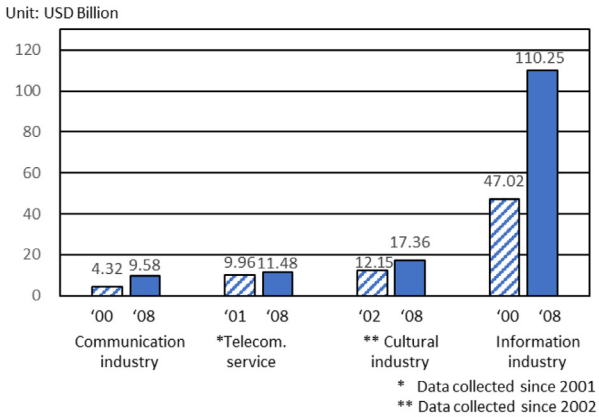
Biological nature	Disruptive selection	Directional selection	Convergent evolution
Period	2000–2008	2008–2016	2016–2018
Policy	**Action Plan** # M-Taiwan Project **New Regulation** # Fundamental Communications Act	**Action Plan** # 4 G Initiate Project **New Regulation** # Spectrum supply plan	**Action Plan** # DIGI + 2025 **New Regulation** # Digital Convergent Act (draft)
Primordial ideas to draft TP			
Intention pool	**Net neutrality** # People pursuit to liberalize the content market to mitigate information asymmetry monopolized by government.	**Fair ISPs competition** # ISPs attempt to conduct fierce competition with dynamic peering fee to pursue market share.	**Internet Censorship** # People argue that content openness making domestic economics vulnerable to global boom-bust cycles.
Condition pool	**Indicator/Focus event**: (scarcely mentioned during TP making)	**Indicator/Focus event:** # unsuccessful M-Taiwan # expired 2 G/3 G license	**Indicator/Focus event**: (under observation)
Alternative pool	**Original idea** # National Science and Technology Program for Telecommunications # Common Duct Act (MOI)	**Original Idea** # M-Taiwan Program # ACMA's spectrum management decision-making framework	**Original Idea** # 4 G Initiate Program
TP making process			
Inertia	Technocracy	Anti-malpractice	Nationalism
Type of TP making	Alternative-oriented	Condition-oriented	Intention-oriented
Method of TP making	Demonstration scenario analysis	Time slice scenario analysis	(Under observation)



(a) Market share in fixed network infrastructure business



(b) Market share in wireless network infrastructure business (ignoring conventional voice service)



(c) Production of telecommunication related industries between 2000~2008.

Fig. 4. The outcomes at 2000–2008 period TP [34].

for the city-wide area and WiMAX infrastructure for the nation-wide area [22–23], and this could benefit the bureaucrats. Noted that adopting WiMAX rather than LTE support by 3GPP is mainly due to the lobbying of Intel, who is the promotor of WiMAX, and endorsed by the scholars/bureaucrats related to "National Science and Technology Program for Telecommunications" [24].

On the other hand, the increased bandwidth supply may cause a deduction of telecommunication service fee at which businesses and consumers can afford. This will make investments which were previously uneconomic become profitable, and novel consumer sales (such as multimedia on demand, e-business portal, and online-to-offline payment) become more affordable. Therefore, the government introduced new competitors in order to break up the monopoly of state-owned incumbent Chunghwa Telecom (CHT) [10], leading the raising of bandwidth supply and deduction of telecommunication service fee. That is, three new charters for fixed network business (also called integrated network business), five new charters for third-generation (3G) mobile communication business, and six charters for pre 4G (WiMAX) mobile communication business were granted and coordinated by OST [24–27]. Noted that, 260 MHz spectrum was released for 3G (170 MHz) and WiMAX (90 MHz) to raise bandwidth supply [28].

Obviously, both methods benefit bureaucrats and legislators in a very short run, as a retired OST senior staff said:

> "If the administration is not familiar with the policy-making procedure governed by bureaucrats or cannot acquire sufficient congressmen seats to form a majority government, it will lose the power to define what problem is its first priority to form a policy or to concrete consensus in the Legislation House. In such circumstance, the administration sometimes chooses not to discuss with staffs or think-tank on selected issues in order to have enough gray space to manipulate the problems defined by the bureaucrats and consensus aggregated by opposition party indirectly—that is pouring budgets into large-scale public infrastructure program which can very directly pinch both bureaucrats and congressmen since most of them may have their personal career stake on it."

This kind of TP making process is categorized as alternative oriented TP making, that is first advocating one idea from the alternative pool as the policy solution, and then seeking the consensus of intentions and coupling it with the problem as a policy.

Once alternative-oriented TP making was anchored, the methodology "Demonstration Scenario" is therefore determined to shaping TP, which is the TP maker first describes a particular end state of the policy and then elaborates a plausible path to achieve this state [29]. The end state was picked from the alternative pool at very beginning described above. Second, elaborating path to achieve the end-state contains two parts of work: (A) to aggregate ideas from intention pool

as the principle that stakeholders should follow to execute the policies, and (B) to identify indications form condition pool as branch point that stakeholders should observe when the policy has to divert or even stepping-down.

While forming principle under the consideration that current administrator was a minority government, an assertion would be most likely boycotted by the opposition parties. The OST staffs had no choice but aggregated the intentions of "content openness", "telecommunication service fee stability," and "non-independent TP" as political aura [30], i.e., Net Neutrality, which confirms to the impossible trinity hypothesis of this study. As one respondent said:

> "Once the administrator attempted to establish an independent administrative organization (The National Communications Commission, NCC) to reestablish the balance of powers in bureaucracy, it immediately faced constitutional challenges from Principles of Separation of Power and Politics of Accountability. That is, if NCC performs its duty to maintain the principle of "freedom of Communication", it would unavoidably reject any national telecommunication policy which intervenes the free market operations. On the other hand, if NCC executes the national telecommunication policy, it would inescapably be curdled by opposition parties who assert it violates the unbiased and independent standpoint."

The principle of Net Neutrality was therefore established by Fundamental Communications Act and The National Communications Commission (NCC) Organization Act which state as follows:

- Content openness & stable peering fee: The Government shall avoid any discriminatory administration of different transmission technologies, and conform to the principles of transparency and non-discrimination regarding the interconnection between and among communications network infrastructure. (Article 7 and 11 in Fundamental Communications Act [31]
- Non-independent TP: The Government shall uphold the philosophy of separating the government (including NCC committee nomination right) from the mass media and regulator to protect the media's independence (Article 4 [32] and 7 [33] in The National Communications Commission Organization Act)

Even though the problem identification process was scarcely mentioned during 2000 ~ 2008 period, the bureaucrats still pick up indications as branch point and prepared alternatives when these indications deteriorated into crisis and forced the policies to be terminated. First is EPIC might fail to meet its policy goals, and then administration might consider that this policy does not work and in advance terminate it before becoming political crisis. Second, unanticipated accident might occur and bowl over everything, such as Intel suddenly and unilaterally ends its own WiMAX project, since Intel is the WiMAX ambassador around the world, the initiator and most prominent cooperator of M-Taiwan project during 2000 ~ 2008. As senior bureaucrats mentioned M-Taiwan:

> "M-Taiwan project is a typical policy that the administration decided the policy solution bypassing any evaluation process and rationalized it afterward if explanations are required for controlling and auditing. This kind of TP making philosophy, of course, affects the integrity and outcomes of M-Taiwan. Some administration and bureaucrats might have interests on this policy and attempted to prevent bad news from spreading, especially if that news might reflect negatively on their program. All we could do then was to shut-up, to observe indications, and to get ready if they were going to get hit on their head and becoming a crisis spreading all around the government."

As a result, the outcome of EPIC during 2000 ~ 2008 period was successfully introducing new competitors and raising bandwidth supply in telecommunication infrastructure business to break the monopoly of Chunghwa Telecom (CHT). That is, in fixed network infrastructure business, FarEasTon (FET) and Taiwan Mobile (TM) successfully acquired 22% market share from CHT, as shown in Fig. 4(a). On the other hand, in the wireless infrastructure business, four private companies (TM, EST, Vibo Telecom, and Asia Pacific Telecom) occupied 60% market share and CHT acquire 40% market share, as shown in Fig. 4(b). The production of telecommunication related industries also rises as shown in Fig. 4(c).

These outcomes also demonstrate that biological nature of disruptive selection was embedded in alternative-oriented TP making: a new industry (the private telecommunication infrastructure company) was favored over the incumbent (government owned CHT), and the population of the ecosystem was divided into two distinct groups, that are CHT and other private companies.

5.2. TP in directional selection period

At the 2008 ~ 2016[1] period, the new administrator and his party retook the leadership of Taiwan and acquired major seats in Legislation House. Some main indicators monitored by bureaucrats suggested an early warning of widespread crisis that EPIC might fail and Taiwan telecommunication related industries is speeding up leaving Taiwan. These indicators were, (1) global telecommunication operators (NTT DoCoMo, AT&T and Verizon) and manufactures (Ericsson, Nokia, and Qualcomm) declared their allegiance to LTE rather than WiMAX which was promoted by former administrator [35–36]; (2) the financial issues and delay of domestic telecommunication development (WiMAX) was inescapable in Taiwan, and Intel, the largest partner of Taiwan government for 4G technology development, was expected to give up WiMAX project very soon [35–38]; (3) the offshoring of Taiwan ICT hardware production continuously raised to 98.7% in 2008, as shown in Fig. 5 [39].

The administration, therefore, established a team to formalize the problem definition, named bandwidth planning research team (BPR) afterward and continued operating during 2008 ~ 2016 period. BPR concluded that these indicators all pointed to and should be transformed into a macroeconomic problem, which is called Bandwidth Supply Problem [40–43]. That is when and how much bandwidth supply for domestic telecommunication economic activities should be mediated in order to keep up the steps of global telecommunication development (LTE), to cool down the overheat un-economic telecommunication investment (WiMAX) and to encourage domestic investment rather than offshoring. This problem statement, though contentious, acquired acquiescence of the government after one-year discussion and seeking public consultant. As one BPR member eloquently stated:

> "Every president has a hundred pages of telecommunication issues in white paper waiting to be solved. But, in practice, only the first issue listed on the first page can be solved, while considering numerous and unknown accidents you will confront in the next four/eight years. One possible way to address this predicament is to project "issues" onto the surface of "one macroscopic problem". Therefore, at 2008 ~ 2016 period, bandwidth supply is the only issue we intend to solve, and other issues should be transformed onto the surface of this issue. Two merits of this strategy are (1) a consistent standpoint for each issue reducing conversation cost inside and outside the government, and (2) controlling the bandwidth supply and keeping technology neutrality without trapping by the details of technology and balance of power between ministries and industries, because there is always something unknown in the details and never stretching out your hands into the area you are

[1] President Ma owned 81 / 113 seats in Legislation House during 2008-2012, 64 / 113 seats from 2012-2016, where 57 seats are needed for a majority.

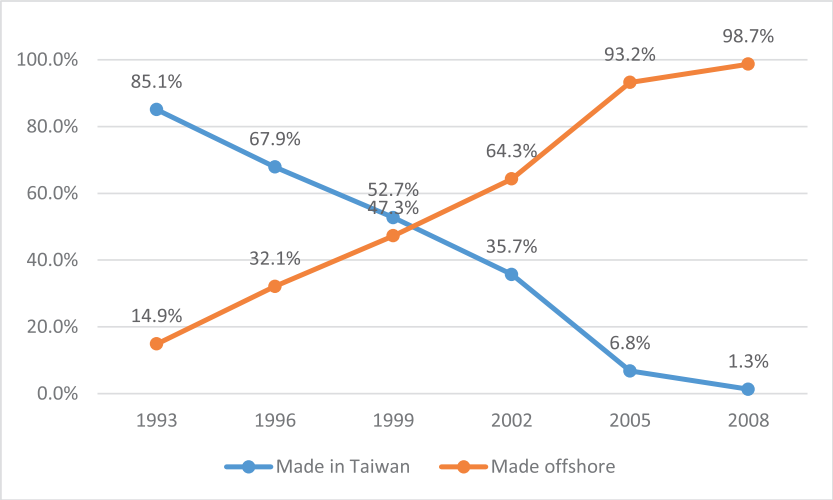


Fig. 5. Taiwan ICT hardware production made in Taiwan and offshore.

unfamiliar with."

This kind of TP making process is categorized as condition oriented TP making, which is first identifying the problem from indication pool, then seeking TP making principle and cooking it with the alternative.

Once condition-oriented TP making was anchored, the methodology "System-Change Scenario" was therefore determined to shaping TP [29], which is first to schedule the TP promotion timing based on the events identified in problem recognition process, then to determine targeted scenario for confirming TP making principle at 2008–2016 period, finally to pick alternative from alternative pool to drive forces to the desired scenario.

First, as shown in Fig. 6, global/domestic events of bandwidth supply and foreseen political events listed. Regarding global events, BPR had anticipated that ITU 5G (IMT-2020) study group would be launched after WRC[2] 12, discuss 5G proposals after WRC 15, and determine 5G specification after WRC 19 [44–45]. On the other hand, the expiration of 2G, WiMAX, and 3G charters could be identified the timing to mediate domestic bandwidth supply in order to ensure the Taiwan TP direction follows the steps of global TP development [42–43]. Based on the above events, three TP windows separated by WRC under the consideration of foreseen political events were identified as the timing to negotiate bandwidth supply plan and promoting corresponding TPs.

Second, in order to determine targeted scenario and TP making principle, three works were performed as shown in the bottom of Fig. 6: (1) BPR identified three forces acting in Taiwan telecommunication related economic activities:

- Independent TP of administration to mediate domestic telecommunication economic activities,
- Stable peering fee to lower uncertainty telecommunication expense and stabilize the telecommunication market order,
- Freedom of information flow to preserve the right to articulate one's opinions and ideas without censorship, government retaliation, or societal sanction on the Internet,

then (2) shaped the states (or called scenario) of the economy over time based on the impossible trinity hypothesis:

- Net Neutrality, which was the state at 2008, formed by free of information flow and stable peering fee with non-independent TP.
- Market Competition formed by independent TP and freedom of information flow with dynamic peering fee.
- Internet Censorship formed by independent TP and stable peering fee with the content-regulation internet.

and (3) the administration decide targeted scenarios were preferred as the TP making principle at 2008～2016 period and post period:

- 2008–2015: Market Competition to encourage certain industry through market operation
- 2016～: Internet Censorship to protect the domestic market by refraining certain application data flow from the economic waves of global and mainland China

The final step was to pick alternatives based on the principle of Market Competition. For independent TP, the present administrator first modified "The National Communications Commission Organization Act" and grasped the nomination right of the commissioners and chairperson of NCC, ensuring NCC will follow national TP made by the present administrator, leading that the power of shaping independent TP is held by Executive House [33]. The present administrator also established Spectrum Policy Planning Group in Executive House and published Spectrum Supply Planning each year in order to hold the power of overall telecommunication policy making [43].

The present administrator then mediated the bandwidth supply to 4G and 5G industries in order to catch up the pace of global LTE development and to cool down the overheat WiMAX investment. Three phases 4G band auctions were scheduled after 2 years of spectrum refarming as shown in Fig. 6 [40–46]. The first phase of 4G band auction reorganized the 2G (GSM) spectrum and granted it to LTE in order to boost LTE related economic activities, triggering Crowding Out Effect[3] toward WiMAX industries in advance. The second phase of 4G band auction harmonized the 2.6 GHz (2500M–2690 MHz) spectrum for telecommunication technology compatible with LTE, which had been the grant to WiMAX at 2000–2008 period, in order to let the shrunk WiMAX industries (compared to LTE) have the opportunity to merge into LTE softly. The third phase of 4G auctions was scheduled in 2017 or 2018 in order to re-farm the 3G spectrum and high-frequency band for 5G industry development. Furthermore, the third phase of 4G spectrum auction was also expected to address the issues of distributive

[2] WRC (World Radiocommunication Conference) is the international treaty governing the use of the radio-frequency spectrum.

[3] Crowding Out Effect means increasing government involvement in a sector of the market economy substantially crowds out the investments on the remainder of the market.

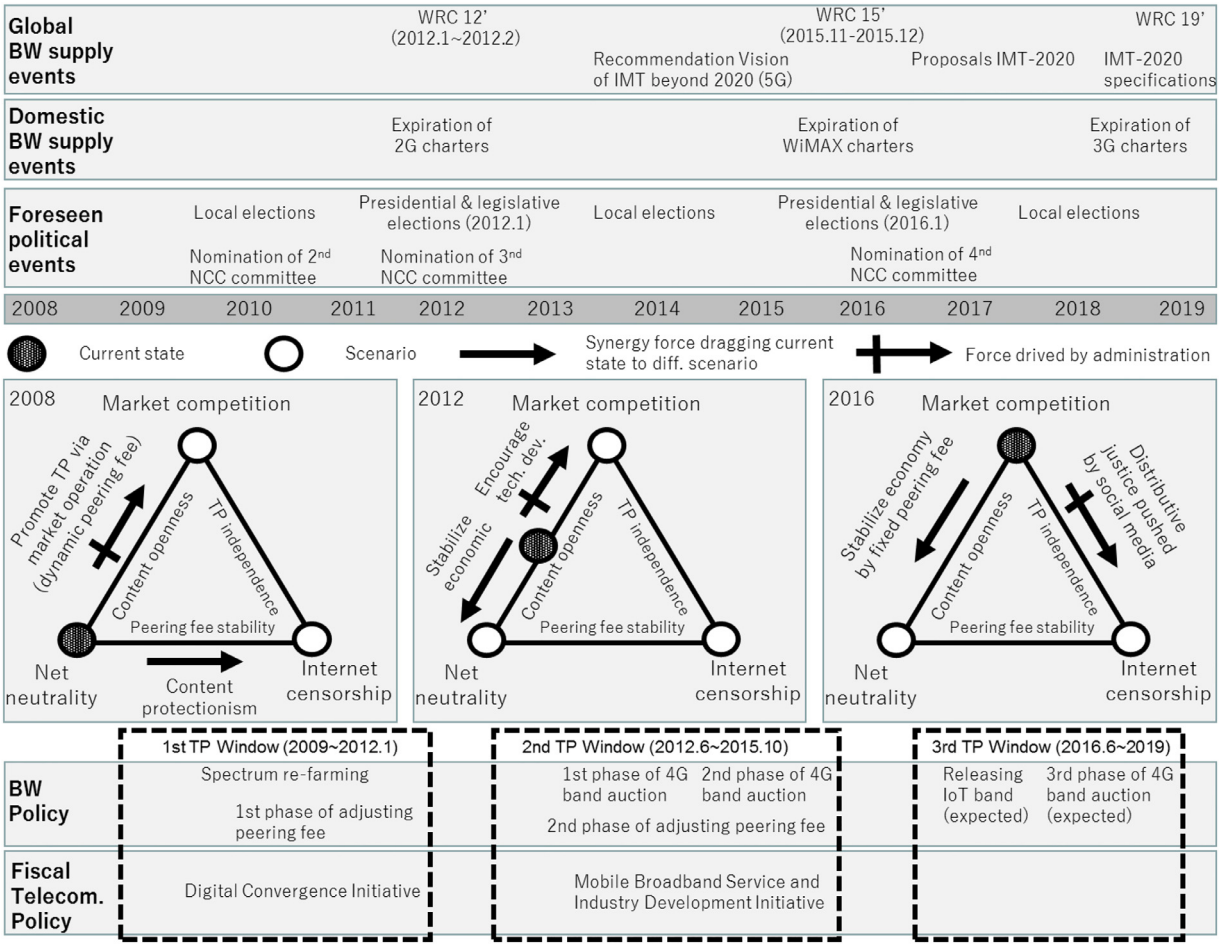


Fig. 6. System-Change Scenario developed at 2008–2016 period.

justice to reallocate telecommunication resource for the disadvantaged or remote area, if the next administration attempts to pay attention to it [47–48].

The present administrator also promoted two fiscal telecommunication policies, as shown in the bottom of Fig. 6, to encourage domestic telecommunication related investment rather than offshoring. Digital Convergence Initiative (DCI) mainly attempted to raise bandwidth supply of the fixed network [40]. Mobile Broadband Service and Industry Development Initiative (MBSIDI) was promoted for speeding up the 4G and 5G development by expanding government investment into Taiwan LTE industries [49]. Furthermore, Executive House controlled the NCC budgets of DCI and MBSIDI as a bargaining power to persuade NCC being in the line of national telecommunication policies.

Regarding the dynamic peering fee to lower entry barriers for new incoming ISPs and novel telecommunication service, as shown in Fig. 7, the present administrator adjusted the peering fee of biggest fixed network ISP, Chunghwa telecom, six times from 2009 to 2016 [50].

As a result, the outcome at 2008–2016 period TP demonstrated that the direction of Taiwan TP shifted from WiMAX to LTE successfully by mediating bandwidth supply, since the 2G/3G/WiMAX subscribers are migrating to 4G-LTE as shown in Fig. 8(a). This strategy also boosted the development of Taiwan domestic communication industry as shown in Fig. 8(b), leading the rising of bandwidth supply and decreasing transmission fee, as shown in Table 2. Furthermore, this can suggest a cause of the raising of cultural industry production and economic sectors sales through the network, paving the foundation of future data economic development, as shown in Fig. 8(c) and Table 3. However, the stagnation of telecommunication service and information industry at 2008–2016 period might partially due to low peering fee and over expanded bandwidth supply. That is, the server side of the Internet always requires peering fee as low as possible to strengthen its unfair market competition, as the member of respondent said:

> "A richly funded content provider definitely needs low peering fee, such as Google, YouTube, or Netflix, who owns a performance advantage over smaller competitors by high-performance servers and high-quality bandwidth resources. This kind of content providers is depleting the limited network resource and crowding out the novel but weak content providers, causing the stagnated development of telecommunication service and information industry. A dynamic peering fee system, but not always decreasing it, is needed to macroeconomically balance the innovation and the economic effectiveness between telecommunication related industries."

On the other hand, raising bandwidth supply conventionally does reduce transmission cost per data unit, stimulating additional demand for capital investment and novel telecommunication services, as shown in Fig. 9(a). However, the out-of-control of bandwidth supply might occur once service already has sufficient bandwidth to transmit data. In this case, as the government continuously increases the base of bandwidth supply, such as the short interval between 4G spectrum auctions, ISPs and corporations foresee high data transmission rate has no effect on the real economy and simply choose to hold cash in hand without any advanced investment. A liquidity trap would, therefore, be characterized by the no real investment and output in response to increases in the bandwidth supply base, as shown in Fig. 9(b). Several respondents including ISPs and legislators also described the phenomena of liquidity trap of out-of-control bandwidth supply:

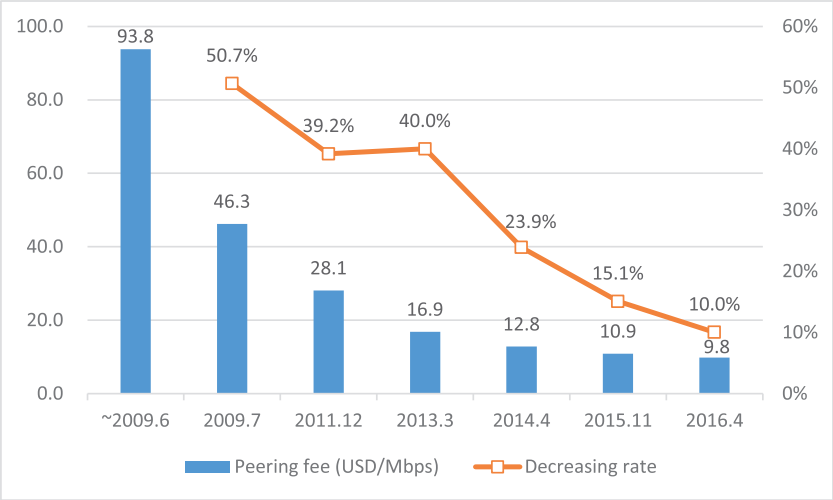


Fig. 7. Peering fee adjusted at 2008–2016 period.

> "The government releases too much spectrum and too many charters for telecommunication and media industry. But we do not need that. First, most people only need 2 Mbps network bandwidth and less than 5 TV channels, instead of 100 Mbps bandwidth or more than 100 TV channels. Second, the domestic content providers cannot provide more data to fill up 100 Mbps bandwidth, causing more importation of foreign content and deficits of the domestic cultural industry."

These outcomes also demonstrate that biological nature of disruptive selection was embedded in condition-oriented TP making: when a crisis occurs and environment changes, an extreme phenotype (4G LTE) was favored over the incumbent but weak phenotypes (2G/3G/WiMAX) and fast increases as a consequence of differences in survival and reproduction in telecommunication ecosystem. Finally, the weak phenotype (2G/3G/WiMAX) was purified and the strong phenotype (4G LTE) dominate the population of telecommunication ecosystem.

5.3. TP in convergent evolution period

The new administrator and her party won the election and obtain major seats[4] in Legislation House in 2016, attributing this success to the assertion that the future of Taiwan should be decided by resident Taiwanese rather than geopolitics (named by "one China policy"), further suggesting that the former administrator failed to manage market order while transiting domestic economic to a more integrated global economy [52–55]. In order to protect people in Taiwan from being hurt by geopolitics and market competition, a series of government statements surrounding nationalism was becoming the axis of TP making of the first year of new administrator and her team, even though they are controversial [56–57], for examples:

Category	Expected outcome	Statement
Independent bandwidth supply	Reduce domestic telecom. investment on novel services in exchange for the disadvantaged or remote area	Reallocating spectrum to Hakka Radio Station and Aboriginal Radio Station for disadvantaged [58] ISPs who will acquire 4 G spectrum should guarantee affordable broadband service for the disadvantaged and remote area [47]
Regulating information flow	Protect the Taiwan content industry by prohibiting foreign content from flowing into Taiwan.	Ministry of Economic Affairs rejected the investment of mainland China content provider, IQiYi, in Taiwan. [59] NCC attempts to regulate the minimal ratio of TV programs mad in Taiwan [60]

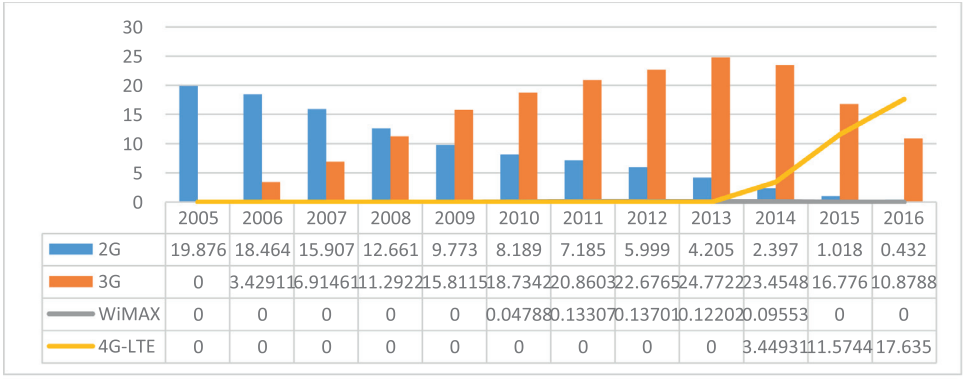
Based on the principle of nationalism, several drafts of act are proposed such as "Act on Protection of Work" [61–62] and "Draft Act on

Information and Communication Security Management" [63] which intend provide law sources to regulate the information flow and monitor the network infrastructure in Taiwan. As a result, the TP making principle of Internet Censorship formed by independent bandwidth supply and content-regulation internet is established in the first year at 2016–2018 period.

This kind of TP making process is categorized as intention oriented TP making, that is first aggregating TP making intentions, which is Internet Censorship as described in Section 3 and Section 4, then identifying the problem and seeking alternatives afterward to cook telecommunication policies. Moreover, the kind of TP making is suggested to demonstrate biological nature of convergent evolution: independent TP evolutions from two different economic entities, i.e., Taiwan and Mainland China, create analogous TP tendency of internet censorship while facing similar environmental factors. However, based on the government policy-making philosophy in the first year, it is difficult to tell us about what TP making methodology will be adopted and what biological nature will evolve in next three or even seven years. As several respondents said:

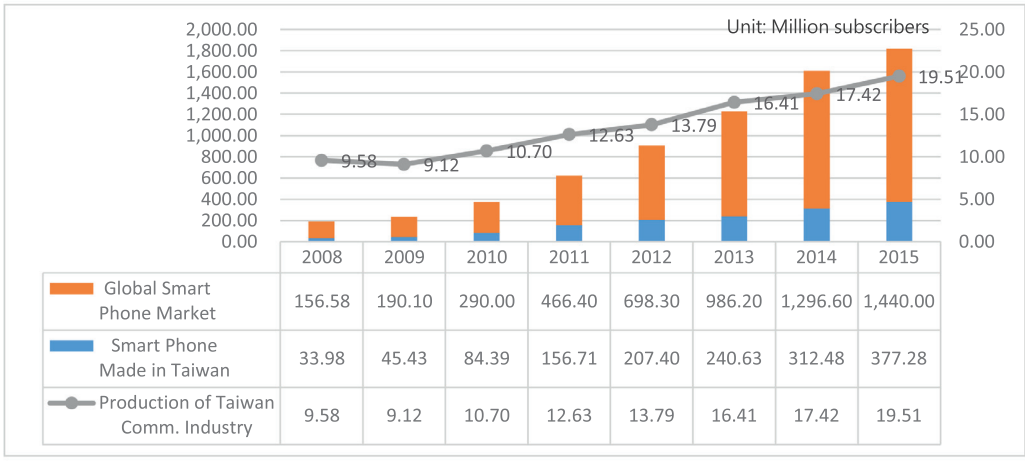
> "When the country not only overwhelmingly elected Tsai president but also handed DPP majorities in the Legislation House, many in the DPP has the sense that a progressive TP agenda could be enacted in the very beginning. However, there is nothing you can do in the first year because too many unsolved controversial issues exist in our country. Each issue has its own complicated history and has already achieved a balance between stakeholders after years' interactions. Any new but impatient intention to break the balance will incur unexpected disputes and turbulence, causing that the approval ratings have nowhere to go but down and people start abandoning the new government. The ideas and optimism of new government, therefore, trail crash into the reality of how things are done in our constitutional system. As a result, every TP can and will be changed by any event or crisis motivating public cries for action, identifying the problem and collecting alternatives for cooking another new TPs

[4] The new administrator and her party owned 68 / 113 seats in Legislation House during 2016-2020, where 57 seats are needed for a majority.



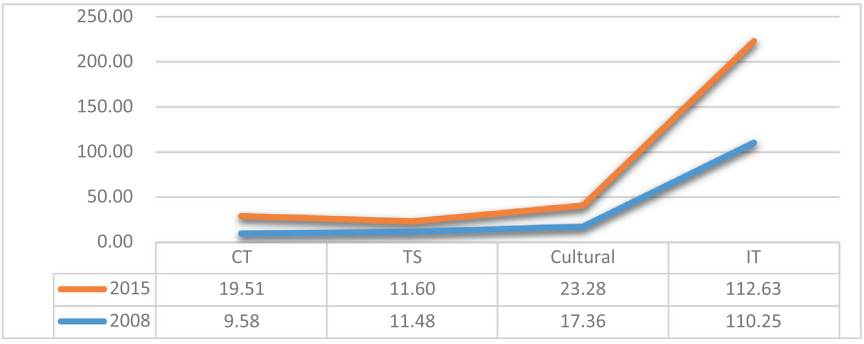
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2G	19.876	18.464	15.907	12.661	9.773	8.189	7.185	5.999	4.205	2.397	1.018	0.432
3G	0	3.42911	6.91461	11.2922	15.8115	18.7342	20.8603	22.6765	24.7722	23.4548	16.776	10.8788
WiMAX	0	0	0	0	0	0.04788	0.13307	0.13701	0.12202	0.09553	0	0
4G-LTE	0	0	0	0	0	0	0	0	0	3.44931	11.5744	17.635

(a) The subscribers of 2G/3G/WiMAX/LTE between 2005~2016



	2008	2009	2010	2011	2012	2013	2014	2015
Global Smart Phone Market	156.58	190.10	290.00	466.40	698.30	986.20	1,296.60	1,440.00
Smart Phone Made in Taiwan	33.98	45.43	84.39	156.71	207.40	240.63	312.48	377.28
Production of Taiwan Comm. Industry	9.58	9.12	10.70	12.63	13.79	16.41	17.42	19.51

(b) Production of Smart Phone in Taiwan



	CT	TS	Cultural	IT
2015	19.51	11.60	23.28	112.63
2008	9.58	11.48	17.36	110.25

(c) Production of telecommunication related industries

Fig. 8. The outcomes at 2008–2016 period TP [39,50].

Table 2
The bandwidth supply at 2008–2016 period [39,50].

(a) Wireless broadband service		
	2012	2016
Downlink transmission rate	1.98 Mbps	49.96 Mbps
Uplink transmission rate	0.32 Mbps	19.39 Mbps
Flat rate	23.75 USD	21.84375 USD
(b) Wire broadband service		
	2010	2016
Coverage of 100 Mbps service	3%	97%
Flat rate	43.7 USD	30.5 USD

is inescapably triggered after the first year of the 2016–2018 period."

6. Conclusion & limitation

This study demonstrates how OST staffs of Taiwan Executive House made telecommunication policies in a macroeconomic way, which is based on the idea of telecommunication policy affects not only telecommunication industry itself but involves industries of second and third economic sectors. Biological Evolution based Policymaking model (BEP) was therefore designed and implemented by OST staffs as a guideline of how central government leverage the bandwidth supply policy to address upcoming macroeconomic telecommunication events or crisis. Through in-depth case studies of the TPs across three periods (2000–2018) in Taiwan, three hypotheses are also examined:

Table 3
the development of Taiwan e-commerce [51].

(a) Sales through network between 2011 and 2015

Economic sectors	Sub sectors	Year		Increasing rate
		2011	2015	
Industry sector		49.00	75.46	54.01%
	Manufactory	48.93	75.37	54.04%
	Others	0.07	0.09	33.70%
Service sector		15.00	25.42	69.52%
	Retail	12.10	19.18	58.58%
	Transportation & warehouse	0.34	1.70	397.11%
	Hospitality	0.29	0.44	50.68%
	Communication	0.53	1.15	118.74%
	Finance	1.02	1.48	44.76%
	Support	0.35	1.03	195.10%
	Others	0.37	0.44	19.42%
Overall e-commercial		64.00	100.89	57.64%

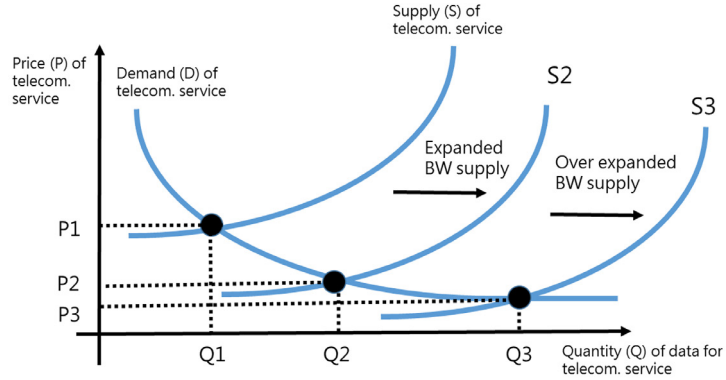
(b) Sales through network as Percentage of Income of manufactory and retail

	Year		Increasing Rate
	2011	2015	
Manufactory	5.89%	9.13%	55.01%
Retail	2.94%	4.47%	52.04%

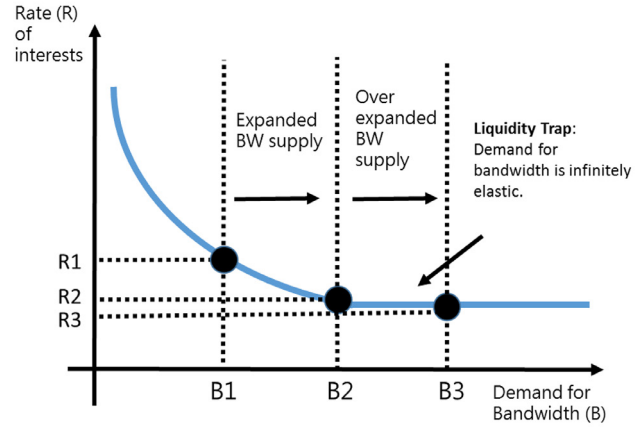
- **Impossible trinity may exist** that government simultaneously can choose any two, but not all, of the three types of TP making intentions that are "bandwidth supply independence", "peering fee stability", and "content openness".
- **Liquidity trap of bandwidth supply may occur** when the government continuously increases the base of bandwidth supply without observing that people already have sufficient bandwidth resource. ISPs and corporations then foresee high data transmission rate has no effect on the real economy and simply choose to hold cash in hand, regardless of the expanded bandwidth supply.
- **Different biological nature may happen** because of different TP cooking sequences, such as alternative-oriented TP making incurs disruptive selection, and condition-oriented TP making causes directional selection.

The outcomes of this study have several implications for researchers and practitioners. First, this study offers a new and comprehensive view of TP making in a macroeconomic way. The TP maker can apply BEP and impossible trinity to develop suitable TP and arguments to harmonize the conflicts and disputes between stakeholders. On the other hand, the telecommunication related industries can also use BEP to understand the motivations of the TP maker to design such a TP, predicting the following TP making strategy and outcomes. Moreover, the industry can better gauge the pros and cons of investment by linking BEP, their short/long-term telecommunication development strategies, and their business activities relative to current administrations' TPs.

This study contains some limitations and requires further investigation. First, this study was conducted upon a related small telecommunication market in a particular geography, Taiwan. The findings may not be uniformly applied without discretion. Second, several novel 5G telecommunication technologies are developed in 3.5 GHz and 28 GHz and involve many specific interest groups. Long-Term observation is required to analyze how they interact with each other.



(a) The relationship between the prices of telecom. service and expended bandwidth supply



(b) The relationship between the rate of interests and expended bandwidth supply

Fig. 9. The relationship between liquidity trap and expanded bandwidth supply.

Third, since this work focused on national policy, the impact of national telecommunication on local economic development considering regional economic differences is still required for further exploration.

Conflict of interest

- All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
- This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
- The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript.

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