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Trade and Growth with Digital Data

Kyu Yub Lee

Korea Institute for International Economic Policy

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Korea Institute for International Economic Policy
370 Sicheong-daero, Sejong-Si 30147, Korea
Tel: 8244) 414-1213 / Fax: 8244) 414-1144
URL: http://www.kiep.go.kr

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KOREA INSTITUTE FOR
INTERNATIONAL ECONOMIC POLICY (KIEP)
Building C, Sejong National Research Complex, 370,
Sicheong-daero, Sejong-si, Korea
Tel: 82-44-414-1118 Fax: 82-44-414-1144
URL: http://www.kiep.go.kr

Siwook Lee, President

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Executive Summary

This paper introduces a newly developed model that examines the interplay between trade, growth, and digital data, emphasizing data's dual role as both a driver of growth and a source of privacy concerns. Departing from existing trade and growth models that have largely overlooked digital data's unique characteristics, this paper provides the first comprehensive analysis of how data influences growth through data flows and knowledge diffusion, while simultaneously introducing associated privacy trade-offs.

A key novelty of this model lies in its clear distinction between digital data and traditional "ideas." Both concepts share the characteristics of non-rivalry and stock-like accumulation, meaning they are cumulative and can be used by multiple entities with negligible additional cost. However, ideas are generally understood to produce only positive externalities, whereas digital data uniquely generates both positive and negative externalities simultaneously, including privacy and cybersecurity concerns for consumers.

The model is built within a dynamic general equilibrium framework that incorporates international trade and endogenous technological change, extending the work of Rivera-Batiz and Romer (1991) by integrating the evolution of digital data. Consumption activities, both domestic and a portion of foreign consumption, actively contribute to a country's evolving data stock. This generated data then acts as a negative externality in the utility function of privacy-conscious consumers, reducing their welfare, even as it serves as a primary input for the R&D sector, fueling the growth engine.

Key findings from this new model highlight significant impacts: First, (economic growth) the model shows that unrestricted cross-border data flows are a significant stimulant for economic growth. This positive effect is further magnified by stronger knowledge spillovers and an increased number of trading partners. Conversely, stricter restrictions on data flows directly impede economic growth. The paper notes that trade liberalization alone, without the diffusion of ideas or data flows, only generates a level effect and does not affect long-term economic growth.

Second, (trade-off with individual welfare) another central finding is the inherent

trade-off between economic growth and individual welfare. While open data flows promote economic expansion, they simultaneously intensify privacy concerns, leading to a reduction in individual welfare. This conflict is particularly pronounced in scenarios with limited or inefficient knowledge diffusion. Conversely, the model indicates that stricter data regulations, while hindering growth, can enhance individual welfare by mitigating these privacy risks.

To navigate the identified trade-off between growth and privacy, the paper advocates against data localization and strongly supports the implementation of deep digital trade agreements. These agreements are proposed as crucial mechanisms to facilitate freer data flows and knowledge sharing, thereby mitigating the inherent conflict and unlocking the full potential of the digital economy.

Keywords: digital data, privacy, trade, endogenous growth, welfare
JEL Classification: D33, E00, J23, O41

Contributors

Kyu Yub Lee

Research Fellow in the Department of International Trade, Investment and Economic Security at the Korea Institute for International Economic Policy (KIEP). He received a Ph.D. in Economics from Michigan State University (MSU). His fields of research are international trade and digital trade. Before joining KIEP, He served as an instructor teaching Survey of International Economics in the Department of Economics at MSU.

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1. Introduction

As digital data gains recognition as a key component of global trade, increasing attention has been given to its dual role in driving economic growth while intensifying privacy concerns.[1] Despite this, existing trade and growth models have largely overlooked the unique characteristics of data as a productive input for knowledge creation—particularly its non-rivalrous nature and its capacity to generate both positive and negative externalities. This paper bridges this gap by incorporating digital data into a traditional trade and growth framework, providing the first comprehensive analysis of how digital data influences growth through data flows and knowledge diffusion while introducing the associated privacy trade-offs.

The novelty of this paper lies in the fact that it distinguishes between data and ideas. Both have two similar characteristics: non-rivalry and stock. An idea, recognized as technology or knowledge, is non-rival. In other words, there is a negligible cost if an additional firm uses the idea. Non-rivalry is also applied to data (Jones and Tonetti 2020). In addition, an idea is a stock, not a flow. Ideas are cumulative, so that a new idea can be created on top of an existing idea available in the world. Like ideas, data is cumulative so that new data can be stored and

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[†] Department of International Trade, Investment, and Economic Security, Korea Institute for International Economic Policy, Building C, Sejong National Research Complex, 370 Sicheongdae-Ro, Sejong 30147, South Korea. Phone: +82-44-414-1233. Email: kylee@kiep.go.kr

[1]At the heart of these discussions, both in private and public spheres, are cross-border data flows. Proponents who view digital data as a new engine of growth argue that freer data flows enhance economic performance. In

merged with old data (Abis and Veldkamp 2019, Ichihashi 2020, Faboodi et al. 2019). Ideas can become outdated, and data may be lost accidentally or intentionally.

The two concepts share overlapping characteristics, making it challenging to clearly distinguish between data and ideas. However, they differ in an important way: ideas produce only positive externalities, while data can generate both positive and negative externalities simultaneously. Unlike ideas, data can also raise privacy and cybersecurity concerns. Furthermore, while digital data by itself is not typically considered an idea, it can serve as a productive input in generating one. These distinctions are essential for a deeper understanding of the economic implications of data flows within the context of international trade and growth.[2]

The paper addresses the question: What is the impact of digital data on economic growth and individual welfare? It explores this issue within a dynamic general equilibrium framework that includes international trade and endogenous technological change. In this paper, digital data is considered non-rival, accumulating over time as a stock rather than a flow, and acting as a key input in knowledge production, similar to ideas. However, unlike ideas, data can generate negative externalities, such as privacy and cybersecurity risks. Based on these characteristics, the paper offers several key findings. Trade liberalization, in the absence of the diffusion of ideas and data flows, does not impact economic growth. Without the integration of knowledge spillovers and data flows, the benefits of trade remain limited, and growth rates are unaffected. Unrestricted cross-border data flows promote economic growth, with the effect being stronger when there are greater knowledge spillovers and more trading partners. On the other hand, stricter data flow restrictions, while enhancing individual welfare, hinder economic growth. This trade-off reveals a potential conflict between data-driven economic growth and individual privacy, especially in situations with limited or inefficient knowledge diffusion. To mitigate

contrast, critics who see digital data as a privacy risk warn that unrestricted flows may harm citizens. This tension creates a fundamental conflict: privacy protection, as a non-economic objective, appears to clash with economic growth. The trade-off suggests that achieving higher economic growth may come at the cost of individual privacy. This divide is evident in public forums, such as the WTO e-commerce talks, where members have struggled to reach a consensus on data-related regulations, including cross-border data flows. While many countries recognize the economic benefits of data mobility, they remain concerned about the privacy risks associated with cross-border data transfers.

[2]Ideas have other characteristics that differ from data. The returns to investment in new technology (idea) are partly private and partly public, and innovators deliberately allocate resources to the invention of new products and processes (Keller 2004).

this trade-off, the paper proposes a comprehensive digital trade agreement that facilitates freer data flows and knowledge sharing.

This paper builds the framework established by Rivera-Batiz and Romer (1991ab) by introducing the evolution of digital data. The main feature of the model is to build increasing returns with digital data as a productive input and knowledge spillovers in the R&D sector, increasing returns with specialized inputs in goods-and-services sector, but negative externality due to privacy concerns by consumers. Each country engages in consumption, which serves as an input for data generation. In particular, not only domestic consumption but also a portion of foreign consumption contributes to the growth of a country's data stock. This generated data acts as a negative externality for consumers, but serves as a crucial input for the R&D sector. Using non-rivalrous data and knowledge available at the time of production, new knowledge is created. Given the existing knowledge, final goods are produced, and through trade in intermediate goods, countries continue to integrate. As the number of trading countries increases, the stock of data grows, leading to an increase in the growth rate. While data acts as a negative externality in the utility function, reducing consumer welfare, it plays a crucial role as a primary input in the growth engine. This modification highlights the dual nature of data, where its accumulation and sharing contribute to economic growth even as they impose privacy costs on individuals. By incorporating this dynamic, the model provides a more nuanced understanding of how digital data can simultaneously act as a source of innovation and a challenge to consumer welfare. In short, a greater variety of goods lowers the cost of creating new products in the presence of knowledge spillovers. Extending this idea, the paper argues that a higher per capita volume of data similarly reduces the cost of developing new varieties even in the absence of knowledge spillovers.

Relating to the literature: Privacy has become a key topic across various fields, including economic growth, international trade, industrial organization (in the context of online platforms), and other domains. Data has also appeared under different terms such as information, ideas, and knowledge in many literatures. Jones and Tonetti (2020) introduced the idea that data, like knowledge, is also non-rival but comes with negative externalities in a dynamic general equilibrium setting. They formalized this concept within a general equilibrium framework, assuming that data fully depreciates in each period. Their idea is similar to Romer (1990) who established that knowledge is a non-rival input, a foundational insight in growth theory. The key difference between them is that Jones and Tonetti (2020) consider disutility by negative externality due to privacy violation. Their model is insightful but limited due to the fully depreciated nature of data. Data as stock or capital has been emphasized by many others (Abis and Veldkamp 2019, Ichihashi 2020, and Faboodi et al. 2019). However, all these models are confined to a closed-economy setting.

Globalization can affect long-run economic growth by: international knowledge diffusion (Rivera-Batiz and Romer 1991ab), competition (Baldwin and Robert-Nicoud 2008), product quality improvement (Grossman and Helpman 1991), learning by doing (Young 1991), technology diffusion (Grossman and Helpman 2015). In particular, Rivera-Batiz and Romer (1991ab) laid the foundation for international trade and endogenous growth theory by emphasizing the importance of knowledge diffusion through trade in driving long-term economic growth. However, up to date, there are only a very limited number of papers that examine the role of digital data in the framework of trade and growth.

Digital data has been studied actively in the privacy literature. It has long been understood as a source of privacy violation (see Acquisti et al. 2016; Goldfarb and Tucker 2024 for a survey). Recently, Tucker (2019) explains succinctly how data functions as a resource and a source of negative externalities in AI. Persistent data, stored indefinitely due to low costs, enables predictive insights but can conflict with evolving privacy preferences, causing discomfort over time. Data spillovers occur when one individual's data creation, such as genetic testing or public recordings, unintentionally impacts others by revealing sensitive information or capturing them without consent. As she observes, these dynamics underscore the importance of privacy frameworks that address the persistence and spillover effects of data in an increasingly interconnected world. Our work aligns with her argument by treating digital data as a non-rival and productive input in the growth process while also recognizing the negative externalities arising from privacy concerns.

This paper contributes to three key strands of the literature. First, it extends the trade and growth literature by incorporating the dual role of data as both an input to economic growth and a potential source of negative externalities related to privacy. Traditional models, such as Rivera-Batiz and Romer (1991ab), primarily emphasize the diffusion of knowledge through trade. This study, however, introduces digital data as a central driver of innovation and productivity, deepening our understanding of how cross-border data flows shape trade dynamics and growth. While Chang et al. (2024) considers an open economy where data is non-rival and accumulates as a stock, their framework does not treat data as a productive input. In contrast, this paper explicitly models data as a productive R&D input.

Second, this paper contributes to the privacy literature by examining privacy within the broader context of trade and growth. While privacy concerns have traditionally been analyzed through the lens of consumer protection, this study highlights implications of their long-run growth and individual welfare. In particular, it explores how privacy, often seen as a barrier to data flows, is deeply intertwined with economic growth. By integrating privacy into a dynamic growth model with trade, this paper underscores the trade-off between leveraging data for innovation and mitigating privacy risks, offering new insights into the intersection of privacy regulation and economic development.

Third, this paper advances the literature on economic growth with data. For example, Jones and Tonetti (2020) introduce non-rivalrous data into a dynamic general equilibrium model, analyzing welfare implications under different ownership structures, including consumer and firm ownership compared to the socially optimal allocation. However, their model treats non-rivalrous data as a flow rather than a stock, limiting its implications for long-run growth. In contrast, this paper highlights how, in an economy engaged in international trade, cross-border data flows can serve as a powerful engine of economic growth.

The paper is structured as follows: Section 2 introduces the model, outlines the dynamic competitive equilibrium, describes the stationary allocation on a balanced growth path, and determines the equilibrium long-run growth rate along with a welfare measure. Section 3 presents a quantitative analysis, exploring economic integration under various scenarios, policy approaches such as non-tariff barriers, data regulation, and digital trade agreements. Section 4 concludes the paper.

2. The model

This study examines a global economic system composed of $N + 1$ interconnected countries engaged in the exchange of goods, ideas, and data. While both ideas and data exhibit non-rivalry, this analysis distinguishes data by its unique capacity to generate privacy concerns. Each country has three sectors: R&D, final good, and intermediate input. The R&D sector generates new ideas that drive economic growth. The final good sector takes those ideas and produces physical capital and a consumption bundle of goods by assembling intermediate inputs and using labor. Intermediate input sector supplies intermediate inputs to final sector. Each economy within this framework includes four key actors: privacy-conscious consumers, innovators who use both non-rivalrous data and knowledge, final output producers, and differentiated intermediate input producers.

The population in each country remains constant over time. The total number of workers in each country is normalized to one at all times. Labor is allocated between the final output sector and the R&D sector within each country, with the total labor supply in each country at any given time being equal to one at all times. Within each country, economic activity unfolds over an infinite time horizon. The model explicitly excludes the cross-border movement of labor and capital. All notation is written in terms of country i (home).

2.1 The evolution of digital data

Digital data are generated as a by-product of economic activities (e.g., consumption) in each country at each time t.[3] A country's total stock of data consists of two components: (i) Domestic data: data generated within the country's own economic activities. (ii) Cross-border data: data received from other countries. The volume of cross-border data a country collects depends on its degree of economic interdependence with other countries and the intensity of cross-border data flows originating from these countries. While digital data are inexpensive to store, making intentional deletion rare, digital data may still depreciate due to accidental or incidental factors. Firms often retain digital data even when it is not immediately useful, anticipating future value. For simplicity, we do not formalize the depreciation rate in detail and instead assume an exogenous depreciation rate.

Given the initial level of digital data, the dynamics of digital data in country i at time t is described by the following equation:

$$\dot{x}_{it} = \mu \left[\hat{c}_{it} + \sum_{j \neq i}^{N+1} \phi_j \hat{c}_{jt} \right] - \delta x_{it}, \tag{1}$$

where a dot over a variable represents the time derivative, $\hat{c}_{it}$ is the average of aggregate consumption at each country i and time t; $\mu > 0$ is the intensity of the digital data formation; $\phi_j \in [0, 1]$ represents the degree to which country i can access data from country j. If ϕ_j goes to zero, it means no data accessibility. If ϕ goes to one, it means perfect data accessibility.[4] ; $\delta > 0$ is the depreciation rate of digital data stock. Several papers treat data as a flow by assuming data are fully depreciated (Jones and Tonetti 2020, Cong et al. 2021, 2022). Since this paper treats data as a stock, the depreciation rate of digital stock is strictly less than one.[5]

Equation (1) shows the dynamics of digital data generation, driven by domestic and foreign economic activities and subject to depreciation. The main features of this equation are: (i) domestic consumption ($\hat{c}_{it}$) serves as a direct input into the generation of digital data within country i and time t. (ii) cross-border data flows: The parameter ϕ_j is closely related to the intensity of cross-border data flow regulations imposed by country j. As country j's regulations on the transfer of domestic data to other countries become more stringent, the parameter ϕ_j tends to zero for all countries. (iii) $\sum_{j \neq i}^{N+1} \phi_j \hat{c}_{jt}$ captures the aggregate impact of economic activity in other countries (excluding country i) on country i's digital data generation, where N is the total number of foreign countries.

[3]Data emerge as by-products of consumption (e.g., Varian 1997, Jones and Tonetti 2020) and can also be generated in the production process (e.g. Farboodi and Veldkamp 2020). Regardless of the source, our main qualitative results remain unchanged.

[4]ϕ can be interpreted in many ways. It can cover digital trade barriers including filtering, blocking, data localization and so on.

[5]Tucker (2019) highlights that data live longer than before due to the drastic fall in storage costs.

2.2 Privacy-conscious consumer

The consumer derives utility from consumption c_{it} and and experiences disutility from privacy concerns. Here, privacy concerns should be interpreted broadly to include cybercrime, cybersecurity, and many other concerns. We model privacy concerns as a function of the total stock of digital data and an intensity parameter that reflects the disutility from privacy loss. As discussed, digital data includes both domestically generated data and data transferred from foreign countries. This implies that domestic consumers experience disutility not only when domestic individuals or firms access their data but also when foreign entities do so. The same logic applies symmetrically to foreign consumers. However, we assume that the intensity of privacy concerns remains constant regardless of changes in the total size of digital data. Formally, the consumer's lifetime utility is represented by:

$$U_i = \int_0^{\infty} \left[\frac{1}{1-\sigma} \left(\frac{c_{it}}{x_{it}^{\gamma}} \right)^{1-\sigma} \right] e^{-\rho t} dt, \tag{2}$$

where $\rho > 0$ represents the rate of time discounting. $\sigma \in [0, \infty)$ denotes the inverse of intertemporal substitution, $\gamma \in [0, 1]$ captures the intensity of disutility from privacy concerns. Here we have two comments: First, regarding the sign of γ, if γ is negative, it implies that the representative consumer derives utility from the availability of digital data, creating a pure positive externality. In this framework, there are no trade-offs in data usage since data serves as a universal benefit for all countries. Second, regarding the interpretation of γ, Goldfarb and Tucker (2024) distinguish between two types of privacy preferences: intrinsic and instrumental. Intrinsic value reflects a fundamental preference for privacy, independent of economic consequences, while instrumental value arises when individuals seek privacy to avoid economic disadvantages, such as price discrimination or other negative outcomes of data exposure. Within this framework, γ can be interpreted as capturing intrinsic privacy concerns.

The representative consumer earns income by supplying financial assets and labor, consuming final outputs, and making investments for the future. She supplies assets a_{it} to the market, with the initial holdings denoted as a_{i0}. These assets generate a return of $r_{it} a_{it}$, where r_{it} is the market interest rate. Additionally, the consumer supplies labor to both the final goods sector l_{it}^{y} and the data-driven R&D sector l_{it}^{A}. Given competitive market prices, the consumer's budget constraint is:

$$\dot{a}_{it} = r_{it} a_{it} + w_{it} l_{it}^{y} + w_{it} l_{it}^{A} - c_{it}. \tag{3}$$

The consumer maximizes his/her lifetime utility (2) subject to the budget constraints (3), the dynamics of digital data (1), and the transversality condition. The Euler equation is

$$\frac{\dot{c}_{it}}{c_{it}} = \frac{r_{it} - \rho}{\sigma} + \frac{\gamma(\sigma - 1)}{\sigma} \left[\left(\frac{\mu \hat{c}_{it}}{x_{it}} + \sum_{j \neq i}^{N+1} \frac{\mu \phi_j \hat{c}_{jt}}{x_{it}} \right) - \delta \right]. \tag{4}$$

Consumption dynamics are shaped by two key factors: (i) the standard intertemporal trade-off: captured by the weighted difference between the interest rate and the time discount rate, (ii) the impact of privacy concerns, where the spillover effects of privacy concerns influence consumer's utility and, in turn, consumer's behavior. The latter effect is weighted by $\gamma(1 - 1/\sigma)$, reflecting the sensitivity of consumption to changes in digital data accumulation.

2.3 Data-driven R&D sector

We model a growth engine comprising two non-rival factors—knowledge and data—and one rival factor—researchers. In our specification of knowledge production, innovators in the R&D sector use not only labor and existing knowledge but also data as a productive input. For instance, an AI programmer develops computer code that integrates vast datasets. More broadly, data is employed to profile and target consumers, optimize systems, manage and control processes, model probabilities, develop new products, and enhance the value of assets (Sadowski 2019).[6] Data-driven knowledge production $\dot{A}_{it}$ can be written as:

$$\dot{A}_{it} = \theta \left[A_t^{world} \right] \left[\frac{x_{it}}{k_{it}} \right] l_{it}^{A}, \tag{5}$$

[6] At the plant level, firms rely heavily on data. Brynjolfsson and McElheran (2016), using Census Bureau data from a large representative sample of U.S. manufacturing plants, show that data-driven decision-making nearly tripled from 11% to 30% between 2005 and 2010.

where θ is the productivity of data-driven R&D production. The global knowledge stock at time t is given by $A_t^{world} \leq \sum_{i=1}^{N+1} A_{it}$ where the inequality accounts for redundancy in knowledge. This redundancy plays a crucial role in economic growth by influencing the marginal productivity of labor in data-driven R&D. To mitigate scale effects, k_{it} is introduced. Notably, the ratio x_{it}/k_{it} represents the total stock of digital data per capital (e.g., bytes per computer) in country i at time t.

Equation (5) defines a direct link between newly created technology $\dot{A}$, the global knowledge stock A^{world}, and a country's digital data. While the knowledge stock is globally accessible, digital data collected by domestic and foreign sources remains usable only within national borders. This model builds on the R&D production framework of Rivera-Batiz and Romer (1991b), but extends it by incorporating digital data as a productive input without introducing additional spillovers. In essence, it distinguishes between accessibility in data creation and accessibility in data usage.

To better understand R&D production in equation (5), we consider two other specifications. First, **global data accessibility**: Here, $\dot{A}_{it} = \theta A_{it} x_t^{world} l_{it}^A / k_{it}$ meaning that technological advances follow the same pattern over time but are directly linked to the global digital data stock x^{world}. This model assumes perfect foreign digital data accessibility ($\phi = 1$ in equation (1)). However, given that regulatory constraints limit accessibility of foreign digital data ϕ, this specification is infeasible unless full data access is granted. Second, **no external effects**: In this extreme case, $\dot{A}_{it} = \theta A_{it} x_{it} l_{it}^A / k_{it}$, again implying identical technological advances over time. While both knowledge and digital data are non-rival, they remain restricted within national borders, benefiting only domestic individuals or firms and preventing international spillovers.

This paper's framework highlights how data accessibility shapes growth. The degree of accessibility influences innovation efficiency, international knowledge spillovers, and long-term growth. Examining these variations provides deeper insights into the interplay between trade integration, data governance, and technological progress.

The data-driven R&D market is perfectly competitive. An innovator maximizes his profit: $\pi_{it}^A = p_{it}^A \dot{A}_{it} - w_{it} l_{it}^A$ subject to (5) given the market price of a new idea p_{it}^A. The first-order condition with respect to researcher is

$$p_{it}^A = \frac{w_{it}}{\theta A_t^{world}\left(\frac{x_{it}}{k_{it}}\right)}. \tag{6}$$

The productivity of data-driven R&D production θ is inversely related to the price of a new idea. Additionally, the equilibrium wage w_{it} and the global stock of existing knowledge A_t^{world}, digital data per capital (x_{it}/k_{it}) in the data-driven R&D sector affects the price of knowledge, holding other factors constant.

2.4 International trade sector

The final good is homogeneous, whereas intermediate inputs are differentiated. Both the final good and intermediate inputs are traded internationally. Final good producers demand intermediate inputs from domestic and foreign markets. Given this demand, intermediate input producers supply intermediate inputs and set prices in both markets. The ability of an intermediate input producer to set prices stems from purchasing a blueprint for a unique capital good, supplied by an innovator in the data-driven R&D sector.

Throughout this paper, we assume that the intermediate input producer's monopoly power is protected by a global patent system. By earning monopoly rents from supplying the durable good, the producer can compensate the innovator for the cost of the blueprint.

Final output sector: The final output is produced by using labor and various intermediate inputs from domestic and foreign markets according to the CES production technology. The final output production is defined as

$$y_{it} = (l_{it}^y)^{\alpha}(X_{it})^{1-\alpha}, \tag{7}$$

where X_{it} is an intermediate input aggregator in country i at time t. Specifically, we specify X_{it} as

$$X_{it} = \left[\int_0^{A_{it}} [h_{it}(v_i)]^m dv_i + \sum_{j\neq i}^{N+1} \int_0^{A_{jt}} [f_{jt}(v_j)]^m dv_j\right]^{\frac{1}{m}}$$

where $h_{it}(v_i)$ represents the domestic use of the intermediate input $v_i \in [0, A_{it}]$ produced in country i at time t, while $f_{jt}(v_j)$ represents country i's use of intermediate input $v_j \in [0, A_{jt}]$ produced in country j at time t. A_{it} and A_{jt} represent the set of all input varieties available at time t in countries i and j, respectively, for all $j \neq i$. For example, the first v_i in $[0, A_{it}]$ may be a two nano semi-conductor chip in country i and the last v_j in $[0, A_{jt}]$ may be a 5G fiber cable in country j. The parameter $m \in (-\infty, 1)$ represents the constant elasticity $1/(1-m)$ of substitution between intermediate inputs.

Let y_{it} be the numeraire. Given the market wage w_{it} and the prices of intermediate input from domestic and foreign sources, the final good producer chooses labor and intermediate inputs to maximize its profit π_{it}:

$$\pi_{it} = y_{it} - w_{it} l_{it}^{y} - \int_{0}^{A_{it}} p_{it}^{h}(v_i) h_{it}(v_i) dv_i - \sum_{j \neq i}^{N+1} \int_{0}^{A_{jt}} p_{jt}^{f}(v_j) f_{jt}(v_j) dv_j.$$

where p_{it}^{h} is the price of domestic intermediate input in country i, and p_{jt}^{f} is the price that foreign producers in country j receive for their exports.

The first-order condition with respect to labor is

$$w_{it} = \alpha \frac{y_{it}}{l_{it}^{y}}, \tag{8}$$

where the labor income $w_{it} l_{it}^{y}$ represents the α fraction of final output in equilibrium.

The first-order conditions with respect to the intermediate input h_{it} from country i and f_{jt} from country j (for all $j \neq i$) are

$$p_{it}^{h} = (1-\alpha) \frac{y_{it}}{X_{it}} \frac{\partial X_{it}}{\partial h_{it}}, \quad p_{jt}^{f} = (1-\alpha) \frac{y_{it}}{X_{it}} \frac{\partial X_{it}}{\partial f_{jt}}, \quad \forall\ j \neq i \tag{9}$$

Using equations (9), we derive the demand for $h_{it}(v_i)$ and $f_{jt}(v_j)$:

$$h_{it} = [p_{it}^{h}]^{-\frac{1}{1-m}} [P_{it}]^{\frac{1}{1-m}} X_{it}, \quad f_{jt} = [p_{jt}^{f}]^{-\frac{1}{1-m}} [P_{it}]^{\frac{1}{1-m}} X_{it}, \quad \forall\ j \neq i$$

where P_{it} is the aggregate price for the set of intermediate inputs for country i at time t.

Intermediate input sector: To produce one unit of any intermediate input, the producer must forgo one unit of consumption. In other words, we assume one unit of foregone consumption results in the production of one unit of any capital good. Additionally, the intermediate input producer must contend with non-tariff barriers (NTBs), which include data localization, technical barriers, local contents requirements and so on.[7] The cost of NTBs, τ, is reflected by a reduction in revenue earned from selling goods to foreign countries. Formally, the intermediate input producer's maximization problem can be written as:

$$\pi_{it}^{x} = p_{it}^{h}(h_{it})h_{it} + \sum_{j\neq i}^{N+1}(1-\tau_j)p_{jt}^{f}(f_{jt}^{*})f_{jt}^{*} - r_{it}\left(h_{it} + \sum_{j\neq i}^{N+1} f_{jt}^{*}\right).$$

where f_j^* represents the demand of country j. The first term on the right-hand side corresponds to the revenue from the domestic market, the second term is the total revenue generated from all foreign markets, and the last term is the total fixed investment cost in terms of consumption (final output). For instance, if variety v_i represents a cloud computing service, then $r_i f_j^*(v_i)$ represents the fixed investment costs with leasing computing facilities located in foreign countries.

The optimal pricing strategy for supplying intermediate inputs is

$$p_{it}^{h} = \frac{r_{it}}{m}, \quad p_{jt}^{f} = \frac{r_{it}}{(1-\tau_j)m} \ \forall\ j \neq i \tag{10}$$

where p_{it}^h is set by markup over marginal cost, while p_{it}^f is set by markup over marginal cost and adjusted by $1/(1-\tau_j)$. This indicates that intermediate input producers do not set identical prices for domestic and foreign markets. From equation (10), it is clear that the producer sets a higher price for foreign markets than for domestic ones. This price discrimination arises due to the NTBs imposed by foreign countries. The ex-post monopoly rent is given by: $\pi_{it}^{x} = \frac{1-m}{m} r_{it}(h_{it} + \sum_{j\neq i}^{N+1} f_{jt}^{*})$.

[7]From 1995 to 2022, the WTO TBT Committee recorded 60 Specific Trade Concerns related to digital trade, with a notable increase in concerns over ICT, telecommunications, and cybersecurity regulations. As of Q3 2023, WTO members reported 898 new technical regulations, bringing the total number of active regulations to 2,951. Also note that Romer (1994) interprets τ as encompassing tariff and non-tariff barriers to the imports of key inputs and components, excessive tax rates, restrictions on ownership, domestic content requirements, corruption, and bureaucratic regulation among others.

For later reference, we define aggregated capital k_{it} as the total sum of fixed investment costs for country i and at time t: $k_{it} \equiv \int_0^{A_{it}} h_{it}(v_i)dv_i + \sum_{j\neq i}^{N+1} \int_0^{A_{jt}} f_{jt}(v_j)dv_j$. This concludes the description of the trade and growth model with cross-border data flows and privacy.

2.5 Equilibrium

To simplify the analysis, this paper assumes all countries are identical in every respect. From this point onward, I will drop the country and time notation. In equilibrium, interest rates are equalized across countries due to the free trade in final goods. This section determines the decentralized market prices that ensure market clearing in the dynamic competitive equilibrium.

Aggregate capital is given by $k = Ah[1 + (1-\tau)^{\frac{1}{1-m}}]$ due to the symmetry across countries. Equation (10) shows the relationship between domestic demand and foreign demand for intermediate input:

$$f = (1-\tau)^{\frac{1}{1-m}} h.$$

This relationship indicates that foreign demand for a variety decreases as the cost τ of NTBs to exports increases. When $\tau = 0$, home and foreign demand are equal. When $\tau = 1$, foreign demand is zero.

By using the first order condition (9) for final output producer and the optimal pricing strategy (10) for the intermediate input producer, we can derive the equilibrium market interest r.

$$r = (1-\alpha)m\beta(\tau)\frac{y}{k} \tag{11}$$

where $\beta(\tau) = \frac{1+(1-\tau)^{\frac{1}{1-m}}}{1+(1-\tau)^{\frac{m}{1-m}}}$ is a convex function of τ over the interval $[0,1]$, with $\beta(0) = 1$ and $\beta(1) = 1$.

Using the equilibrium interest rate (11), the ex-post profits π^x are given by

$$\pi^x = (1-\alpha)(1-m)\beta(\tau)\frac{y}{A} \tag{12}$$

Note here that the ex-post monopoly rent reaches the maximum value at $\tau = 0$ or $\tau = 1$ ceteris paribus.

The value of a new blueprint in the data-driven R&D sector, p^A, is determined by equating the price of a new blueprint in knowledge production to the expected present-value profit in intermediate input production:

$$p^A = \frac{\alpha y}{l^y}\left[\frac{k}{\theta x A^{world}}\right]. \tag{13}$$

Data-driven knowledge production (5), the equilibrium interest rate (11), ex-post profit (12), and the value of a new blueprint (13) together describe the dynamics of the value of a blueprint (we use the relationship $rp^A = \pi^x + \dot{p}^A$):

$$\frac{\dot{p}^A}{p^A} = (1-\alpha)m\beta(\tau)\frac{y}{k} - \frac{(1-\alpha)(1-m)(1-l^A)}{\alpha l^A}\frac{\dot{A}}{A}. \tag{14}$$

The consumer's financial wealth is defined $a = k + p^A A$, consisting of aggregate capital and the value of the blueprint. An instantaneous increase in financial wealth, $\dot{a}$, is $\dot{k} + \dot{p}^A A + p^A \dot{A}$. In the equilibrium, labor income wl is α fraction of final output. Interest income rk is $(1-\alpha)m\beta(\tau)$ fraction of final output. Aggregated monopoly rents $A\pi^x$ are $(1-\alpha)(1-m)\beta(\tau)$ fraction of final output. The initial fixed investment wl^A (sunk cost) is equal to $p^A_{it}\dot{A}_{it}$.

In equilibrium, the consumer's budget constraint becomes:

$$\dot{k} = [\alpha + (1-\alpha)\beta(\tau)]y - c \tag{15}$$

Recall that NTBs incur pure costs in this paper. In the presence of NTBs, resources amounting $(1-\alpha)[1-\beta(\tau)]y$ are dissipated. However, no real output is dissipated when $\tau = 0$ or $\tau = 1$.

Before describing the dynamic competitive equilibrium in the trade and growth model with digital data, we first summarize the fundamental parameters $\{\mu, \phi, \delta, \tau, \sigma, \alpha, m, \theta, N, N_a\}$. These parameters provide a concise presentation of key economic factors: (Digital data) the intensity of digital data formation μ, the degree of accessibility to foreign digital data ϕ, the depreciation rate of digital data δ, (Barriers) the cost of NTBs such as data localization to exporter τ, (Utility) the inverse of intertemporal substitution σ, (Technology) labor share of final good α, the constant elasticity of substitution between intermediate inputs $1/(1-m)$, the productivity of data-driven R&D production θ, (Multi-country) the number of trading partners N and the degree of knowledge spillovers N_a.

Dynamic equilibrium: The dynamic competitive equilibrium of the world economy is characterized by the evolution of digital data, consumption, capital, R&D labor, and technology $\{x, c, k, l^A, A\}$ such that (i) consumers, final good and intermediate input producers, and innovators optimize their economic objectives subject to relevant constraints, (ii) all markets clear at decentralized prices, and (iii) the transversality conditions are satisfied, given the initial endowments of financial assets and digital data.

Given the fundamental parameters and the initial stocks of digital data and capital, the system of dynamic equilibrium allocations - including digital data, consumption, capital, researchers, and technology $\{x, c, k, l^A, A\}$ - can be expressed as follows:

The evolution of digital data is from equation (1)

$$\frac{\dot{x}}{x} = \mu(1+\phi N)\frac{c}{x} - \delta \tag{16}$$

The dynamics of consumption is from equation (4)

$$\frac{\dot{c}}{c} = \frac{1}{\sigma}\left[(1-\alpha)m\frac{y}{k} - \rho\right] + \gamma\left(1 - \frac{1}{\sigma}\right)\left[\mu(1+\phi N)\frac{c}{x} - \delta\right] \tag{17}$$

The economy-wide resource constraint is from equation (15)

$$\frac{\dot{k}}{k} = [\alpha + (1-\alpha)\beta(\tau)]\frac{y}{k} - \frac{c}{k} \tag{18}$$

The dynamics of researchers is from equations (13)-(14)

$$\begin{aligned}\frac{\dot{l}^A}{l^A} = \frac{1-l^A}{(1-\alpha)l^A}\Bigg\{&(1-\alpha)m\frac{y}{k} + \left[\mu(1+\phi N)\frac{c}{x} - \delta\right] - (2-\alpha)\left[[\alpha + (1-\alpha)\beta(\tau)]\frac{y}{k} - \frac{c}{k}\right] \\ &- \left[\frac{(1-\alpha)(1-m)(1-l^A)}{\alpha l^A} + \frac{(1-\alpha)(1-m)}{m} - 1\right]\theta(1+N_a)\frac{x}{k}l^A\Bigg\}\end{aligned} \tag{19}$$

The dynamics of final output is from equation (7)

$$\frac{\dot{y}}{y} = (1-\alpha)\left([\alpha + (1-\alpha)\beta(\tau)]\frac{y}{k} - \frac{c}{k}\right) + \frac{(1-\alpha)(1-m)}{m}\left[\theta(1+N_a)\frac{x}{k}l^A\right] - \alpha\frac{\dot{l}^A}{l^A} \tag{20}$$

The dynamics of data-driven R&D production is from equation (5)

$$\frac{\dot{A}}{A} = \theta(1+N_a)\frac{x}{k}l^A \tag{21}$$

where $N_a \in [0, N]$ represent the degree of knowledge spillovers. The global knowledge stock A^{world}, at any time t, is defined as the total knowledge stock generated across all countries. If all knowledge produced is unique, A^{world} reaches $(1+N)A$ in a symmetric world, where N is the number of trading partners. Conversely, if all knowledge generated is identical across countries, A^{world} equals A. Thus, the global knowledge stock varies between A to $(1+N)A$, depending on the degree of knowledge redundancy. In particular, $N_a = 0$ indicates complete redundancy of digital data. Equations (16)-(21) complete the dynamic competitive equilibrium.

2.5.1 Economic growth

To further analyze the system of dynamic equations (16)-(21), we introduce new variables: $c_x \equiv c/x$, $c_k \equiv c/k$, and $y_k \equiv y/k$. Next, we consider stationary allocations $\{\bar{c}_x, \bar{c}_k, \bar{y}_k, \bar{l}^A, \bar{g}_A\}$ of the dynamic equations above by imposing $\dot{c}_x/c_x = 0$, $\dot{c}_k/c_k = 0$, $\dot{y}_k/y_k = 0$, and no change in the number of researchers $\bar{l}^A$ and constant technology growth $\bar{g}_A$. The equilibrium variables in the trade and growth model with idea spillovers and data flows between symmetric countries are fully determined by solving for final good per capital, $\bar{y}_k$. After some algebraic manipulation, the exact solution for $\bar{y}_k$ is obtained. In the system of dynamic equations (16)-(21), a unique trade and growth equilibrium exists, where the balanced growth path's growth rate $\bar{g}^*$ is determined by the following equation (see the Appendix A1.1):

$$\bar{g}^* = \Psi\frac{\zeta_2}{2\zeta_0} - \frac{\rho}{2(\zeta_0+\zeta_1)} - \frac{\delta}{2}$$

$$+\frac{1}{\zeta_0}\sqrt{\left\{\frac{1}{2}\left(\Psi\zeta_2 + \rho\frac{\zeta_0+2\zeta_1}{\zeta_0+\zeta_1} - \delta\zeta_0\right)\right\}^2 + \rho\frac{\Psi\zeta_o(1-\alpha)(1-m)\beta(\tau)/\alpha - \zeta_1(\rho-\delta\zeta_0)}{\zeta_o+\zeta_1}} \tag{22}$$

where $\zeta_0 = \sigma + \gamma(1-\sigma)$, $\zeta_1 = \frac{\alpha m-(1-\alpha)(1-m)[1-\beta(\tau)m]}{(1-\alpha)(1-m)}$, $\zeta_2 = \frac{(1-\alpha)(1-m)\zeta_0\left[\left(\beta(\tau)+\frac{\alpha}{(1-\alpha)m}\right)\zeta_0-\beta(\tau)\right]}{\alpha(\zeta_0+\zeta_1)}$ and

$$\Psi = \mu\theta(1+\phi N)(1+N_a).$$

The explicit solution facilitates comparative statics across different parameter sets, allowing key insights to be derived from equation (22). The following corollary summarize the results:

Corollary. Under the data-driven R&D production,

$$\frac{\partial\bar{g}^*}{\partial\phi} > 0,\ \frac{\partial\bar{g}^*}{\partial N} > 0,\ \frac{\partial\bar{g}^*}{\partial N_a} > 0$$

Proof. This follows directly from equation (22).

The corollary, based on mathematical results, indicates that increased cross-border data accessibility, a larger number of trading partners, along with stronger knowledge spillovers, all contribute to a higher growth rate. This allows for deeper insights into the model.

Autarky growth rate: The autarky growth rate, $\bar{g}_{autarky}$, is determined by assuming the absence of cross-border data accessibility ($\phi = 0$), no trading partners ($N = 0$), and complete redundancy ($N_a = 0$). Under these conditions, $\bar{g}_{autarky}$ is obtained by substituting Ψ with $\Psi_{autarky} = \mu\theta$ in equation (22).

Impact of trade liberalization: opening trade alone has no effect on economic growth when $\phi = 0$ and N increases from 0 to 1. In this case, trade occurs without knowledge spillovers or data flows, leaving the growth rate unchanged. This result follows from the fact that the dynamic equations (16)-(21) remain unaffected. In this framework, trade liberalization generates only a level effect rather than influencing long-term growth.

Role of cross-border data flows: When countries are allowed to collect digital data from one another ($\phi > 0$), economic growth is enhanced. Specifically, if the number of trading partner, N, increases from 0 to 1, trade opens, and in the absence of knowledge spillovers, cross-border data flows drive growth. The growth rate under data openness, $\bar{g}_{data}$, is obtained by replacing Ψ with $\Psi_{data} = \mu\theta(1 + \phi)$ in equation (22). Since $\Psi_{data} > \Psi_{autarky}$, the growth rate with data flows always exceeds the one without them.

This outcome stems from the dual role of digital data examined in this paper: first, as a source of privacy concerns, and second, as an additional input driving economic growth. If digital data serves only as a source of privacy concerns, it would affect individual welfare but not the growth rate (see Appendix A2 for an analysis of data's single role). Without knowledge spillovers, a greater variety of goods reduces the cost of creating new ones. Extending this idea, this paper argues that in the absence of knowledge spillovers, a higher per capita volume of data similarly lowers the cost of developing new product varieties.

Effect of changes in data accessibility: In an open economy where $\phi > 0$, further increasing data accessibility ($\phi \uparrow$) leads to sustained higher growth rates. Conversely, tighter restrictions on data flows ($\phi \downarrow$) slow growth.

Effect of more trading partners: An increase in the number of trading partners ($N \uparrow$) also fosters higher economic growth, with $\Psi_{data,N} = \mu\theta(1 + \phi N)$. This outcome reflects a network effect driven by expanded data flows. However, a key caveat is that newly trading partners must grant foreign data access at a level of ϕ to all other countries for this effect to materialize.

Amplification by knowledge spillovers: The effects of trade liberalization, data accessibility, and increased trading partners are further amplified by knowledge spillovers ($N_a \uparrow$). This amplification effect aligns with the findings of Rivera-Batiz and Romer (1991ab).

2.5.2 Individual welfare

Beyond its impact on growth, this paper also explores the effects on individual welfare. Both consumption and digital data grow at the growth rate of $\bar{g}^*$ on the balanced growth path (BGP). To compare two BGPs, we analyze the preserved value of discounted lifetime utility at the start of their initial equilibria. Let t^* represent the initial period of the original BGP with $\bar{g}^*$ and t^{**} denote the first period of the post-BGP with $\bar{g}^{**}$, characterized by a different set of fundamental variables. Using the lifetime utility function and equilibrium results, welfare changes can be assessed as follows (see the derivation A1.2 in Appendix):

$$\Delta W \equiv \frac{U^{**}}{U^*} - 1 = \left[\left(\frac{\bar{c}(t^{**})}{\bar{c}(t^*)}\right)^{1-\gamma}\left(\frac{\bar{g}^{**}+\delta}{\bar{g}^*+\delta'}\right)^{\gamma}\left(\frac{\mu(1+\phi N)}{\mu'(1+\phi' N')}\right)^{\gamma}\right]^{1-\sigma}\frac{\rho-(1-\gamma)(1-\sigma)\bar{g}^*}{\rho-(1-\gamma)(1-\sigma)\bar{g}^{**}} - 1 \tag{23}$$

where the prime ($'$) denotes variables of the post-equilibrium state. This measure reflects welfare changes as a geometrically weighted average of the consumption level ratio, the growth rate ratio, and parameters associated to cross-border data.

One final remark concerns the size of the inverse of intertemporal substitution (σ). It should be set to align with empirical evidence on the effect of trade liberalization. Our model shows that opening trade does not alter the growth rate. Specifically, equation (23) shows $\Delta W = [\bar{c}(t^{**})/\bar{c}(t^*)]^{(1-\gamma)(1-\sigma)} - 1$. Opening trade leads to a higher consumption level $\bar{c}(t^{**})$ compared to the autarky consumption level $\bar{c}(t^*)$, $\bar{c}(t^{**}) > \bar{c}(t^*)$. To ensure positive gains from trade liberalization ($\Delta W > 0$), the inverse of intertemporal substitution (σ) should be less than one. This paper employs a constant relative risk aversion (CRRA) utility function, unlike international trade models with homothetic preferences, such as Krugman (1980) and Melitz (2003), which use constant elasticity of substitution (CES) utility functions to explain trade gains. While traditional trade models focus on static long-run equilibria, this analysis emphasizes the dynamic interaction between economic growth and international trade.

The magnitude of welfare improvement after opening trade diminishes as γ increases. When γ reaches one, opening trade has no effect on welfare ($\Delta W = 0$). Since the model does not provide specific information about consumption levels ($\bar{c}(t^{**})$ and $\bar{c}(t^*)$), it mainly offers solutions into growth rates along the balanced growth path. To further the analysis, we opt to use models with $\sigma < 1$ (ensuring welfare gains from autarky to free trade) and $\gamma = 1$ (focusing on welfare changes). The chosen welfare measure is then as follows.

$$\Delta W \equiv \left[\left(\frac{\bar{g}^{**}+\delta}{\bar{g}^*+\delta'}\right)\left(\frac{\mu(1+\phi N)}{\mu'(1+\phi' N')}\right)\right]^{1-\sigma} - 1 \tag{24}$$

Simulations play a crucial role in understanding how variations in key parameters influence growth and welfare. First, the relationship between non-tariff barrier costs and growth rates remains uncertain. Second, the connection between changes in key parameters and welfare shifts is also unclear. Building on equations (22) and (24), we extend our analysis to examine the effects of trade integration, encompassing goods, ideas, and data flows.

3. Quantitative analysis

This paper explores a broader concept of economic integration, one that takes into account the impact of data flows across the Internet, connecting personal computers, tablets, the Internet of Things, and various other electronic devices. We aim to address questions such as: What would be the effect on economic growth and individual welfare if data flows between countries were restricted (eased) by data regulation? Can digital trade agreement be designed to promote economic growth without compromising individual welfare?

With the equations derived above and quantitative analysis, we are now equipped to answer these questions. For simplicity, let us consider a world with two countries: the EU and the US. These two countries are assumed to be identical in all respects.

3.1 Economic integration

We present a series of thought experiments on partial integration across different scenarios, emphasizing the distinct dynamics of goods, ideas, and data flows. To isolate these effects, we assume zero non-tariff barriers.

The autarky equilibrium serves as a baseline in this subsection. The autarky scenario maintains the same structure as described in this paper. In autarky, there is no cross-border data accessibility ($\phi = 0$), no trading partners ($N = 0$), complete redundancy ($N_a = 0$), resulting in minimal growth at 0.04% (see equation 22). As the autarky serves as the baseline, welfare change (ΔW) is not applicable.

Table 1 summarizes the changes in growth and welfare by examining the transition from autarky to trade with different levels of integration. By isolating scenarios without idea spillovers and/or data flows, we can better understand the independent contributions of data flows.

3.1.1 Opening trade

The free trade-only scenario ($N = 1$, $N_a = 0$, $\phi = 0$) represents a standard exercise in international trade theory. In this case, the EU and the US can trade intermediate inputs, allowing

Table 1: Autarky to integration: goods, ideas, and data

	Growth ($\bar{g}^*$)	Welfare (ΔW)
Autarky equilibrium	0.04%	-
$N = 0$, $N_a = 0$, $\phi = 0$		
I. Free trade only	0.04%	*
$N = 1$, $N_a = 0$, $\phi = 0$	(level effect only)	
II. Economic integration with free trade		
A. Free trade with idea spillovers	0.22%	0.14%
$N = 1$, $N_a = 1$, $\phi = 0$		
B. Free trade with data flows	0.09%	-12.26%
$N = 1$, $N_a = 0$, $\phi = 0.3$		

Remarks: (i) Growth rate is calculated by equation (22) and W is calculated by using the welfare measure from (24), (ii) Initial parameter values are chosen by $\rho = 0.005$, $\sigma = 0.5$, $\gamma = 1$, $\mu = 0.05$, $\alpha = 0.65$, $m = 0.75$, $1/\theta = 0.03$. (iii) In general, the welfare measure (23) shows $\Delta W = (c'/c) - 1$. Since the consumption level c' after opening trade is larger than the consumption level c in autarky ($c' > c$), the welfare change is positive ($\Delta W > 0$). If we use welfare measure (24) instead of (23), there is no change in welfare.

us to observe the effects of market integration. It turns out that free trade alone (I) maintains a growth rate of 0.04%, with only a level effect and no growth effect. Free trade without data flows or idea spillovers positively impacts individual welfare by increasing output and reducing the price index. However, the increase in output reflects only a level effect, not a growth effect, which aligns with Rivera-Batiz and Romer (1991a).[8]

Beyond the free trade-only case, it is useful to explore additional thought experiments. The first scenario considers the situation where only idea flows occur without any trade. While such cases are rare, they are not unprecedented. Rivera-Batiz and Romer (1991a) mention the spread of gunpowder and the compass from China to Western countries during the Middle Ages as an example.

The second thought experiment explores a scenario involving only data flows, without trade. A pertinent example can be drawn from the COVID-19 pandemic, when countries imposed restrictions on the movement of people and goods across borders. During this period, there were debates on whether governments should disclose individual infection data to the public. While such disclosures risked privacy violations, they could have sped up vaccine de-

[8]Consider a scenario where iceberg trade costs are used in international trade. Autarky equilibrium occurs when trade costs are infinitely high. To facilitate trade, we lower these costs between countries. This results in a growth effect rather than a level effect. For clarity, we keep our model simple without emphasizing trade costs.

velopment. This tension between privacy and public health illustrates the complex trade-offs inherent in data governance.

Even with reduced international trade, economic activity on the Internet flourished during the pandemic. Industries offering digital services, such as TikTok, YouTube, and Netflix, saw rapid growth. Likewise, social media platforms and cloud computing services—both for private and public use—expanded significantly. In fact, digital transformation emerged as a key term, encapsulating the shift toward an increasingly digital economy.

3.1.2 Ideas and data

To examine the impact of cross-border data flows in the context of trade liberalization, I break down the process of openness into two scenarios as outlined in Table 1:

A. Free trade with idea spillovers ($N = 1$, $N_a = 1$, $\phi = 0$): This scenario analyzes the effects of knowledge spillovers while isolating the influence of data flows on the economy.

B. Free trade with data flows ($N = 1$, $N_a = 0$, $\phi = 0.3$): This scenario examines the impact of data flows while isolating the effect of knowledge spillovers on the economy.

In the first scenario, knowledge spillovers occur through an increase in the stock of knowledge facilitated by international trade. Introducing knowledge spillovers into free trade (II.A) leads to gains in both economic growth (0.22%) and welfare ($\Delta W = 0.14$). Specifically, knowledge production follows the equation $\dot{A}/A = \theta(1+N_a)xl^A/k$ where domestic innovators rely solely on domestic data, represented as: $\dot{x}/x = \mu c/x - \delta$. The growth rate is influenced by knowledge spillovers but remains unaffected by the opening of data flows. Similarly, welfare changes are determined exclusively by shifts in the growth rate driven by knowledge spillovers, captured by the equation: $\Delta W = [(\bar{g}^{**} + \delta)/(\bar{g}^{*} + \delta)]^{1-\sigma} - 1$.

In the second scenario, incorporating cross-border data flows into free trade (II.B) increases the growth rate by 0.37% but results in a welfare decline of $\Delta W = -12.26$. Here, knowledge production follows the equation: $\dot{A}/A = \theta x l^A/k$. Unlike the first scenario, domestic innovators use both domestic and foreign data, modeled as: $\dot{x}/x = \mu(1+\phi N)c/x - \delta$. In this case, growth and welfare are driven by cross-border data flows rather than knowledge spillovers. The availability of larger stocks of digital data serves as a productive input in the growth engine of each country, leading to a higher growth rate. However, the welfare effects diverge significantly from the first scenario. Welfare is now measured by: $\Delta W = [(\bar{g}^{**}+\delta)/(\bar{g}^{*}+\delta)(1+\phi' N')]^{1-\sigma} - 1$. A key distinction in this scenario is that the expansion of digital data stocks due to cross-border data flows creates negative externalities. EU consumers experience disutility not only from EU innovators using their private data but also from US innovators accessing it, and the same holds true for US consumers. Because digital data is a non-rival resource that can be transferred and used across borders, its unrestricted use amplifies privacy concerns and erodes consumer welfare. As a result, opening data access paradoxically reduces welfare despite fostering economic growth. These findings underscore the inherent trade-offs between digital-driven expansion and individual privacy. In particular, the welfare loss in II.B highlights the urgent need for policies—such as privacy protection and data governance frameworks—to mitigate the potential downsides of cross-border data flows in international trade.

3.2 Policy exercises

What are the key features of recent data regulation? Three key data sources offer valuable insights into recent policy trends in data regulation. First, data localization measures have expanded significantly worldwide. Between 2017 and 2021, the number of such measures grew from 67 to 144, while the number of countries enforcing them increased from 35 to 62 (see Cory and Dascoli 2021). By 2022, over 60 countries had implemented policies restricting or prohibiting certain types of cross-border data flows. By the end of 2023, 12 U.S. states had enacted comprehensive privacy laws, many incorporating data localization requirements, with another seven states set to introduce similar legislation in 2024.[9]

Second, new data regulations have emerged even among advanced economies. Between 2020 and 2024, there were 15,363 events resulting in 8,443 policy or regulatory changes across the G20 and EU.[10] Of these, 3,387 changes were related to data regulation, covering areas such as data protection, cybersecurity, cross-border data transfers, data protection authority governance, and data localization requirements. Notably, cybersecurity-related regulations have contributed to a rise in technical barriers to digital trade.

Lastly, the Digital Services Trade Restrictiveness Index underscores growing barriers to digital trade, including data flow restrictions, localization mandates, and content filtering. The OECD's 2023 update highlights a significant rise in restrictions across key sectors such as broadcasting, computer services, and telecommunications. Together, these trends reflect a global shift toward stricter data flow regulations.

Recent changes in data regulations are closely linked to the accessibility of foreign data (ϕ) and the costs of non-tariff barriers (τ) in this paper. While these changes impact both ϕ and τ simultaneously, we analyze them separately for clarity. This subsection shows how the model can be applied to assess policy approaches, including behind-the-border measures in digital trade and personal data transfers. Additionally, we explore ways to mitigate growth and welfare trade-offs by examining an alternative policy measure known as digital trade agreements.

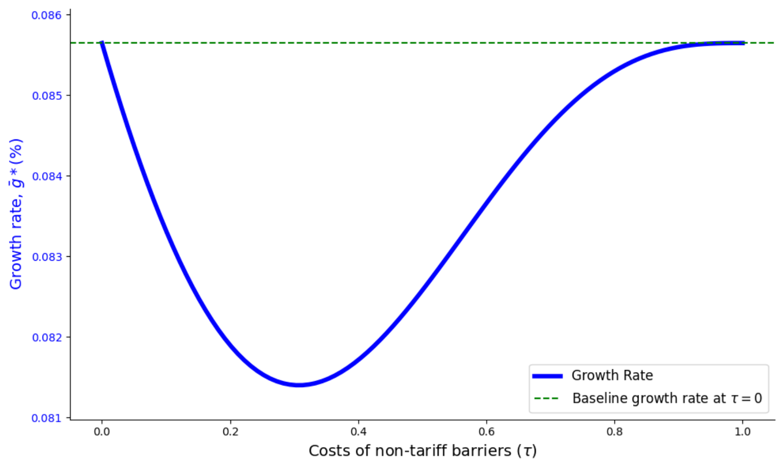
How do growth rates relate to data localization? This paper examines behind-the-border measures that functions as non-tariff barriers (NTBs), with data localization serving as a key example in the digital economy.

Figure 1 shows the relationship between NTBs and economic growth. The horizontal axis represents the cost imposed by these barriers, denoted as τ, while the vertical axis shows the growth rate $\bar{g}^*$. The blue curve depicts how the growth rate evolves as NTB costs increases. A key reference point is the green dashed line, which marks the baseline growth rate of 0.086%

[9]The report by OECD/WTO(2025) uses the WTO Global Trade Model to conduct policy exercises, including those related to data flows and data localization. While the simulations yield interesting results, the model does not incorporate features related to economic growth and privacy in utility.

[10]For further details, visit Digital policy alert at https://digitalpolicyalert.org/

Figure 1: Data localization and growth rates



Remarks: (i) Initial parameter values are $\rho = 0.005$, $\sigma = 0.5$, $\gamma = 1$, $\mu = 0.05$, $\alpha = 0.65$, $m = 0.75$, $1/\theta = 0.03$, $N = 1$, $N_a = 0$, and $\phi = 0.3$. (ii) As a baseline, free trade with data flows is chosen (see Table 1). (iii) Growth rate is calculated by equation (22) and ΔW is calculated by using the welfare measure from equation (24).

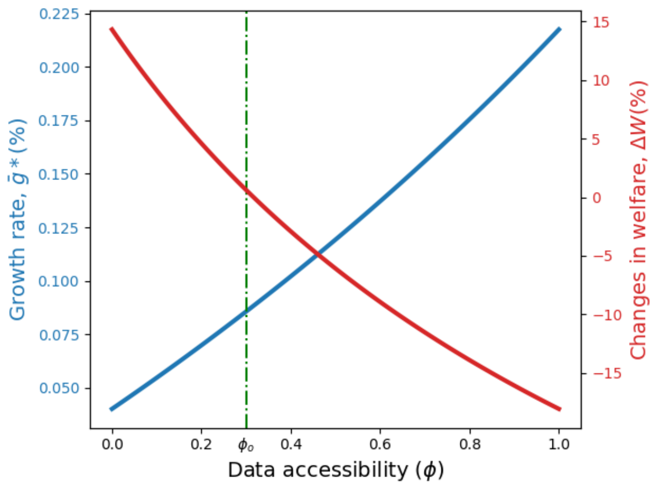
when NTBs ($\tau = 0$) are absent.

Figure 1 reveals that even small NTB costs reduce the growth rate, highlighting the negative impact of trade barriers on economic growth. Initially, as τ rises, the blue curve declines, reflecting the dampening effect of NTBs on growth. However, beyond a certain threshold, the growth rate begins to recover, though it remains below the baseline.

This suggests that while extremely high barriers may foster niche market formation, their overall effect remains negative compared to a free-trade scenario. Figure 1 highlights the critical role of minimizing NTBs to sustain long-term economic growth.

How do growth and welfare relate to rules on cross-border data flows? One particular example is the EU-US Data Privacy Framework. The EU-US Privacy Shield, created in 2016, regulated personal data transfers between the EU and the US for commercial purposes. It replaced the invalidated Safe Harbor agreement, addressing privacy concerns about US surveillance. The framework was designed to align with EU privacy standards, requiring safeguards, transparency, and annual reviews. In 2020, the Court of Justice of the EU

Figure 2: Data regulation: economic growth vs. individual welfare



Remarks: (i) Initial parameter values are $\tau = 0$, $\rho = 0.005$, $\sigma = 0.5$, $\gamma = 1$, $\mu = 0.05$, $\alpha = 0.65$, $m = 0.75$, $1/\theta = 0.03$, $N = 1$, $N_a = 0$, and $\phi = 0.3$. (ii) At ϕ_o, the growth rate is 0.086% ($\bar{g}^*$) and the change in welfare is zero (ΔW). This is the equilibrium with free trade and data flows in Table 1. (iii) Growth rate is calculated by equation (22) and ΔW is calculated by using the welfare measure from equation (24).

invalidated the Privacy Shield in the Schrems II case, citing insufficient protection against US surveillance. Despite its invalidation, the framework highlighted the need for cross-border data protection. US firms participating in the Privacy Shield had to comply with its principles and ensure third-party processors followed to similar standards. In 2023, the EU adopted the EU-US Data Privacy Framework, featuring enhanced safeguards to limit US intelligence agencies' access to EU data.

Figure 2 illustrates the relationship between data openness, economic growth, and individual welfare, highlighting the trade-offs involved in shaping data policies. A baseline level of data openness is denoted as ϕ_o, with the equilibrium growth rate at 0.0856% in the absence of idea spillovers. Tightening restrictions on cross-border data flows ($\phi = 0.3 \rightarrow 0.15$) reduces growth from 0.086% to 0.062%. However, despite this decline, welfare increases by 0.61%, suggesting that regulatory interventions can provide non-economic benefits, such as enhanced data security and privacy. This finding supports the argument that prioritizing data privacy can yield significant welfare gains, even at the cost of slower economic growth. Stricter data regulations (lower ϕ) reduce the total stock of digital data, impacting the economy in two ways. First, a smaller data stock lowers the marginal productivity of labor in the R&D sector, prompting some R&D labor to shift to the final goods sector. As a result, innovators face weaker incentives due to lower marginal returns, leading to a decline in monopoly rents and, ultimately, slower technological progress. This gradual decline reduces final output and lowers the growth rate. Second, as the data stock shrinks, the disutility associated with digital data also decreases. While a lower growth rate generally reduces welfare, a lower ϕ simultaneously raises it. Quantitative analysis based on the general equilibrium model shows that stricter domestic regulations (ϕ decreases) result in lower growth but higher welfare.

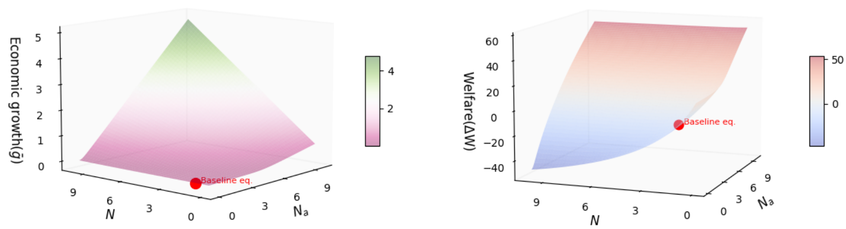
As the degree of data openness increases (ϕ exceeds the baseline ϕ_o), the growth rate increases, suggesting that greater openness can foster innovation and economic expansion. However, this is associated with a decline in individual welfare, likely due to factors such as increased privacy risks, data breaches, or unevenly distributed benefits from data use. On the other hand, as the degree of data openness decreases, economic growth slows, reflecting the potential stagnation caused by insufficient data sharing. While this reduced data openness improves individual welfare by minimizing risks, it could hinder long-term growth prospects.[11]

Can we resolve growth and welfare trade-offs by digital trade agreement? Cross-border data flows are a key driver of economic growth, yet their impact on welfare remains complex and requires careful evaluation. As digital trade agreements become more prevalent, policymakers must navigate the trade-offs between efficiency gains and potential welfare losses. Figure 3 shows the importance of designing policies that not only promote data flows but also mitigate the unintended negative externalities of technological progress. The contrast between different spillover scenarios highlights the crucial role of policies that facilitate cross-border knowledge sharing. When idea spillovers are limited, economic efficiency may improve, but welfare gains remain uncertain or even negative. Conversely, when strong knowledge-sharing mechanisms are in place, both economic growth and welfare benefits become more pronounced. This suggests that the effectiveness of data-driven growth strategies

[11] Data generation and data depreciation work in a similar way as data regulation. See A1.3 in Appendix.

hinges not just on the volume of data flows but on the extent to which they translate into meaningful innovation and productivity gains.

Figure 3: The impact of digital trade agreement on growth and welfare



Remarks: (i) Growth rate is calculated by equation (22) and W is calculated by using the welfare measure from (24), (ii) Initial parameter values are chosen by $\tau = 0$, $\rho = 0.005$, $\sigma = 0.5$, $\gamma = 1$, $\mu = 0.05$, $\alpha = 0.65$, $m = 0.75$, $1/\theta = 0.03$. (iii) Data accessibility is set to be $\phi = 0.3 \rightarrow 0.4$.

To maximize the benefits of cross-border data flows, policymakers must complement them with initiatives that encourage research collaboration at the firm and industry levels. Strengthening global knowledge networks, fostering cooperative innovation ecosystems, and addressing structural barriers to knowledge diffusion can ensure that digital trade leads to broad-based welfare improvements. By aligning digital trade agreements with policies that support idea spillovers, economies can fully harness the transformative potential of data-driven globalization while safeguarding long-term welfare gains.[12]

[12]The effects of changes in the productivity of data-driven R&D production (θ) are both qualitatively and quantitatively similar to variations in the stock of A.

4. Conclusion

This paper examines how integrating goods, ideas, and data into the economy influences growth and individual welfare. In a closed economy with no trade or data sharing, growth remains low. Traditional trade liberalization without data access has no lasting impact on growth, only providing a one-time boost. However, when data flows freely across borders, innovation increases, leading to faster economic growth. Despite these benefits, data openness raises privacy concerns, which can reduce individual welfare.

There is a trade-off between economic growth and privacy. More access to data helps the economy grow, but it can also lead to negative effects, such as loss of personal privacy. In contrast, strict data policies can improve welfare even if they slow growth. Additionally, non-tariff barriers, such as data localization, limit trade and innovation, further restricting economic progress.

Balancing growth and privacy is key in the digital economy. While data-driven trade promotes long-term economic expansion, policymakers must consider risks like privacy loss and unequal benefits. Future policies should aim to allow data flows while protecting privacy. Well-designed trade agreements can help countries grow their economies without losing public trust. By supporting innovation while safeguarding personal data, governments can unlock the full potential of digital globalization while ensuring long-term welfare.

Appendix

A1. Dual role of data

A1.1 Growth rate

The difference between the growth rate of consumption and the growth rate of data is from equations (16)-(17)

$$\frac{\dot{c}_x}{c_x} = \frac{1}{\sigma}[(1-\alpha)m\beta(\tau)y_k - \rho] - \frac{\sigma + \gamma(1-\sigma)}{\sigma}[\mu(1+\phi N)c_x - \delta], \tag{1}$$

The difference between consumption growth rate and capital growth rate is from equations (17)-(18)

$$\frac{\dot{c}_k}{c_k} = \frac{1}{\sigma}[(1-\alpha)m\beta(\tau)y_k - \rho] + \frac{\gamma(\sigma-1)}{\sigma}[\mu(1+\phi N)c_x - \delta] - \Big\{[\alpha + (1-\alpha)\beta(\tau)]y_k - c_k\Big\}, \tag{2}$$

The difference between final output growth rate and capital growth rate is from equations (18) and (20)

$$\frac{\dot{y}_k}{y_k} = \frac{(1-\alpha)(1-m)}{m}\left[\theta(1+N_d)(1+N_a)\frac{c_k}{c_x}l^A\right] - \alpha\frac{\dot{l}^A}{l^A} - \alpha\Big\{[\alpha + (1-\alpha)\beta(\tau)]y_k - c_k\Big\} \tag{3}$$

The dynamics of researchers is from equation (19)

$$\begin{aligned}\frac{\dot{l}^A}{l^A} = \frac{1-l^A}{(1-\alpha)l^A}\Big\{&(1-\alpha)m\beta(\tau)y_k + [\mu(1+\phi N)c_x - \delta] - (2-\alpha)\Big\{[\alpha + (1-\alpha)\beta(\tau)]y_k - c_k\Big\} \\ &- \left[\frac{(1-\alpha)(1-m)(1-l^A)}{\alpha l^A} + \frac{(1-\alpha)(1-m)-m}{m}\right]\theta(1+N_d)(1+N_a)\frac{c_k}{c_x}l^A\Big\}\end{aligned} \tag{4}$$

The growth rate of technological progress is from equation (21)

$$\frac{\dot{A}}{A} = \theta(1+N_a)\frac{c_k}{c_x}l^A \tag{5}$$

Next, we consider stationary allocations $\{\bar{c}_x, \bar{c}_k, \bar{y}_k, \bar{l}_A, \bar{g}_A\}$ of the dynamic equations above by imposing $\dot{c}_x/c_x = 0$, $\dot{c}_k/c_k = 0$, $\dot{y}_k/y_k = 0$, and no change in the number of researchers $\bar{l}_A$ and constant technology growth $\bar{g}_A$.

Consumption per digital data is

$$\bar{c}_x = \frac{\delta}{\mu(1+\phi N)} + \frac{(1-\alpha)m\beta(\tau)\bar{y}_k - \rho}{\mu(1+\phi N)[\sigma + \gamma(1-\sigma)]}. \tag{6}$$

Consumption per capital is

$$\bar{c}_k = [\alpha + (1-\alpha)\beta(\tau)]\bar{y}_k - \frac{(1-\alpha)m\beta(\tau)\bar{y}_k - \rho}{\sigma + \gamma(1-\sigma)}. \tag{7}$$

Final good per capital is

$$\bar{y}_k = \frac{\theta(1+N_a)}{(1-\alpha)m\beta(\tau)}\left[\frac{(1-\alpha)(1-m)\beta(\tau)}{\alpha} + \frac{(1-\alpha)(1-m)[1-\beta(\tau)m] - \alpha m}{\alpha m}\bar{l}^A\right]\frac{\bar{c}_k}{\bar{c}_x}. \tag{8}$$

Researchers in the data-driven R&D production are

$$\bar{l}^A = \frac{\alpha m}{\theta(1-\alpha)(1-m)}\left\{[\alpha + (1-\alpha)\beta(\tau)]y_k - c_k\right\}\left(\frac{\bar{c}_x}{\bar{c}_k}\right). \tag{9}$$

Technological growth is

$$\bar{g}^A = \theta(1+N_a)\frac{\bar{c}_k}{\bar{c}_z}\bar{l}^A. \tag{10}$$

The equilibrium variables in the trade and growth model with idea spillovers and data flows between symmetric countries are fully determined by solving for final good per capital, $\bar{y}_k$. After some algebraic manipulation, the exact solution for $\bar{y}_k$ is obtained:

$$\bar{y}_k^* = \frac{1}{(1-\alpha)m\beta(\tau)}\left\{\frac{1}{2}\left(\Psi\zeta_2 + \rho\frac{\zeta_0 + 2\zeta_1}{\zeta_0+\zeta_1} - \delta\zeta_0\right)\right.$$

$$\left. + \sqrt{\left\{\frac{1}{2}\left(\Psi\zeta_2 + \rho\frac{\zeta_0 + 2\zeta_1}{\zeta_0+\zeta_1} - \delta\zeta_0\right)\right\}^2 + \rho\frac{\Psi\zeta_o(1-\alpha)(1-m)\beta(\tau)/\alpha - \zeta_1(\rho - \delta\zeta_0)}{\zeta_o+\zeta_1}}\right\} \tag{11}$$

where $\zeta_0 = \sigma + \gamma(1-\sigma)$, $\zeta_1 = \frac{\alpha m - (1-\alpha)(1-m)[1-\beta(\tau)m]}{(1-\alpha)(1-m)}$, $\zeta_2 = \frac{\zeta_0(1-\alpha)(1-m)}{(\zeta_0+\zeta_1)\alpha}\left[\left(\beta(\tau) + \frac{\alpha}{(1-\alpha)m}\right)\zeta_0 - \beta(\tau)\right]$

and

$$\Psi = \mu\theta(1 + \phi N)(1 + N_a).$$

Finally, we can derive all other steady-state variables, using the solution $\bar{y}_k^*$.

A1.2 Welfare measure

Both consumption and digital data grow at the growth rate of $\bar{g}^*$ on the balanced growth path (BGP). Suppose t^* is the initial period of the original BGP. The lifetime utility function on the BGP yields:

$$U^* = \frac{1}{1-\sigma}\left(\frac{\bar{c}(t^*)}{[\bar{x}(t^*)]^\gamma}\right)^{1-\sigma} \int_{t^*}^{\infty} e^{(1-\gamma)(1-\sigma)\bar{g}^*(t-t^*)} e^{-\rho(t-t^*)} dt.$$

Evaluating the integral results in:

$$U^* = \frac{1}{1-\sigma} \frac{\bar{c}(t^*)^{1-\sigma}[\bar{x}(t^*)]^{-\gamma(1-\sigma)}}{\rho - (1-\gamma)(1-\sigma)\bar{g}^*},$$

with the transversality condition $(1-\gamma)(1-\sigma)\bar{g}^* < \rho$.

We compare the two BGPs by examining the preserved value of discounted lifetime utility at the start of their initial equilibria. Let t^{**} denote the first period of the post-BGP, characterized by a different set of fundamental variables.

The lifetime utility function on the post-BGP is:

$$U^{**} = \frac{1}{1-\sigma} \frac{\bar{c}(t^{**})^{1-\sigma}[\bar{x}(t^{**})]^{-\gamma(1-\sigma)}}{\rho - (1-\gamma)(1-\sigma)\bar{g}^{**}},$$

Define the welfare measure as:

$$\Delta W = \frac{U^{**}}{U^*} - 1$$

This expands to:

$$\Delta W = \left(\frac{\bar{c}(t^{**})}{\bar{c}(t^*)}\right)^{1-\sigma} \left(\frac{\bar{x}(t^{**})}{\bar{x}(t^*)}\right)^{-\gamma(1-\sigma)} \frac{\rho - (1-\gamma)(1-\sigma)\bar{g}^*}{\rho' - (1-\gamma')(1-\sigma')\bar{g}^{**}} - 1$$

From equation (16), we have

$$\bar{x}(t^*) = \frac{\bar{c}(t^*)\mu(1+\phi N)}{\bar{g}^* + \delta}, \quad \bar{x}(t^{**}) = \frac{\bar{c}(t^{**})\mu'(1+\phi' N')}{\bar{g}^{**} + \delta'}$$

This implies that $[\bar{x}(t^*)]^\gamma = \left(\frac{\bar{c}(t^*)\mu(1+\phi N)}{\bar{g}^*+\delta}\right)^\gamma$ and $[\bar{x}(t^{**})]^\gamma = \left(\frac{\bar{c}(t^{**})\mu'(1+\phi' N')}{\bar{g}^{**}+\delta'}\right)^\gamma$. This gives the following relationship.

$$\left(\frac{\bar{x}(t^{**})}{\bar{x}(t^*)}\right)^{-\gamma} = \left(\frac{\bar{g}^{**} + \delta}{\bar{g}^* + \delta'}\right)^\gamma \left(\frac{\bar{c}(t^*)\mu(1+\phi N)}{\bar{c}(t^{**})\mu'(1+\phi' N')}\right)^\gamma$$

After simplification,

$$\Delta W = \left[\left(\frac{\bar{c}(t^{**})}{\bar{c}(t^*)}\right)^{1-\gamma}\left(\frac{\bar{g}^{**} + \delta}{\bar{g}^* + \delta'}\right)^\gamma\left(\frac{\mu(1+\phi N)}{\mu'(1+\phi' N')}\right)^\gamma\right]^{1-\sigma}\frac{\rho - (1-\gamma)(1-\sigma)\bar{g}^*}{\rho - (1-\gamma)(1-\sigma)\bar{g}^{**}} - 1.$$

For the special case where $\sigma < 1$ and $\gamma = 1$, we obtain:

$$\Delta W = \left[\left(\frac{\bar{g}^{**} + \delta}{\bar{g}^* + \delta'}\right)\left(\frac{\mu(1+\phi N)}{\mu'(1+\phi' N')}\right)\right]^{1-\sigma} - 1$$

which corresponds to the equation (24).

A1.3 Growth and welfare: data technology

In the absence of idea spillovers, increasing the intensity of data generation (μ) boosts growth by 0.55% and lowers welfare by 8.58%. In addition, increasing the depreciation rate of data reduces growth to 0.27% while causing a large increase in welfare of 7.89%.

Table 2: Growth and welfare: data technology

	w/o idea spillover		w/ idea spillover	
	$\bar{g}$	ΔW	$\bar{g}$	ΔW
Baseline equilibrium	0.09%	N/A	0.37%	N/A
Data technology				
A. Data generation	0.13%	-8.68%	0.55%	-8.57%
$\mu = 0.05 \to 0.06$				
B. Data depreciation	0.06%	7.98%	0.27%	7.88%
$\delta = 0.6 \to 0.7$				

Remarks: (i) Growth rate is calculated by equation (22) and W is calculated by using the welfare measure from (24), (ii) Initial parameter values are chosen by $\rho = 0.005$, $\sigma = 0.5$, $\gamma = 1$, $\mu = 0.05$, $\alpha = 0.65$, $m = 0.75$, $1/\theta = 0.03$.

A2. Single role of data

The knowledge production $\dot{A}_{it,N}$ is

$$\dot{A}_{it,R} = \theta[\sum_{i=1}^{N+1} A_{it}]l_{it}^{A}.$$

When an innovator is bound to use the R&D production. In the first case, an innovator chooses labor to maximize its profit: $\pi_{it,N}^{A} = p_{it,N}^{A}\dot{A}_{it,N} - w_{it}l_{it,N}^{A}$ subject to the knowledge production given the market price of a new idea $p_{it,N}^{A}$. The first-order condition is

$$p_{it,N}^{A} = \frac{w_{it}}{\theta A_{t}^{world}}.$$

Dynamic competitive equilibrium: We describe the case where data play a single role single: data stock affects consumers with privacy concerns, but is not used in the R&D sector. Under the R&D technology, the system of dynamic equilibrium allocations $\{c_R, x_R, k_R, l_R^y, l_R^A, A_R\}$ is summarized given the initial stocks of digital data and capital.

The evolution of digital data is

$$\frac{\dot{x}_R}{x_R} = \mu(1+\phi N)\frac{c_R}{x_R} - \delta$$

The dynamics of consumption is

$$\frac{\dot{c}_R}{c_R} = \frac{1}{\sigma}\left[(1-\alpha)m\frac{y_R}{k_R} - \rho\right] + \gamma\left(1-\frac{1}{\sigma}\right)\left[\mu(1+\phi N)\frac{c_R}{x_R} - \delta\right]$$

The dynamics of innovation production is

$$\frac{\dot{A}_R}{A_R} = \theta(1+N_a)l_R^A$$

The economy-wide resource constraint is

$$\frac{\dot{k}_R}{k_R} = \frac{y_R}{k_R} - \frac{c_R}{k_R}$$

The dynamics of R&D labor is

$$\frac{\dot{l}_R^A}{l_R^A} = \frac{1 - l_R^A}{(1-\alpha)l_R^A}\left\{(1-\alpha)m\frac{y_R}{k_R} - (1-\alpha)\left(\frac{y_R}{k_R} - \frac{c_R}{k_R}\right)\right.$$

$$\left. - \left[\frac{(1-\alpha)(1-m)(1-l_R^A)}{\alpha l_R^A} + \frac{(1-\alpha)(1-m)-m}{m}\right]\theta(1+N_a)l_R^A\right\}$$

The dynamics of goods and services output is

$$\frac{\dot{y}_R}{y_R} = (1-\alpha)\left(\frac{y_R}{k_R} - \frac{c_R}{k_R}\right) + \frac{(1-\alpha)(1-m)}{m}\left[\theta(1+N_a)l_R^A\right] - \alpha\frac{\dot{l}_R^A}{l_R^A}$$

Stationary allocations: New variables $c_x^R \equiv c_R/x_R$, $c_k^R \equiv c_R/k_R$, and $y_k^R \equiv y_R/k_R$ are introduced to derive stationary allocations in the model with data acting as a single role. The difference between the growth rate of consumption and the growth rate of data is

$$\frac{\dot{c}_x^R}{c_x^R} = \frac{1}{\sigma}[(1-\alpha)my_k^R - \rho] - \frac{\sigma + \gamma(1-\sigma)}{\sigma}[\mu(1+\phi N)c_x^R - \delta],$$

The difference between the growth rate of consumption and the growth rate of capital is

$$\frac{\dot{c}_k^R}{c_k^R} = \frac{1}{\sigma}[(1-\alpha)my_k^R - \rho] + \frac{\gamma(\sigma-1)}{\sigma}[\mu(1+\phi N)c_x - \delta] - (y_k^R - c_k^R),$$

The difference between the growth rate of final output and the growth rate of capital is

$$\frac{\dot{y}_k^R}{y_k^R} = \frac{(1-\alpha)(1-m)}{m}\left[\theta(1+N_a)l_R^A\right] - \alpha\frac{\dot{l}^A}{l^A} - \alpha(y_k^R - c_k^R)$$

The dynamics of R&D labor is

$$\frac{\dot{l}_R^A}{l_R^A} = \frac{1 - l_R^A}{(1-\alpha)l_R^A}\left\{(1-\alpha)my_k^R - (1-\alpha)(y_k^R - c_k^R)\right\}$$

$$- \left[\frac{(1-\alpha)(1-m)(1-l_R^A)}{\alpha l_R^A} + \frac{(1-\alpha)(1-m)-m}{m}\right]\theta(1+N_a)l_R^A\right\}$$

The growth rate of technology progress is

$$\frac{\dot{A}_R}{A_R} = \theta(1 + N_a)l_R^A$$

The stationary allocations $\{\bar{c}_x^R, \bar{c}_k^R, \bar{y}_k^R, \bar{l}_R^A, \bar{g}_A^R\}$ of the dynamic equations can be obtained by imposing $\dot{c}_x^R/c_x^R = 0$, $\dot{c}_k^R/c_k^R = 0$, $\dot{y}_k^R/y_k^R = 0$.

Consumption per digital data:

$$\bar{c}_x^R = \frac{\delta}{\mu(1 + \phi N)} + \frac{(1 - \alpha)m\bar{y}_k^R - \rho}{\mu(1 + \phi N)[\sigma + \gamma(1 - \sigma)]}$$

Consumption per capital:

$$\bar{c}_k^R = \bar{y}_k^R - \frac{(1 - \alpha)m\bar{y}_k^R - \rho}{\sigma + \gamma(1 - \sigma)}$$

Goods and services output per capital:

$$\bar{y}_k^R = \frac{\theta(1 + N_a)}{(1 - \alpha)m}\left[\frac{(1 - \alpha)(1 - m)}{\alpha} + \frac{(1 - \alpha)(1 - m)^2 - \alpha m}{\alpha m}\bar{l}_R^A\right]$$

Labor in innovation production:

$$\bar{l}_R^A = \frac{\alpha m}{\theta(1 - \alpha)(1 - m)}(\bar{y}_k^R - \bar{c}_k^R)$$

Technological growth:

$$\bar{g}_A^R = \theta(1 + N_a)\bar{l}_R^A$$

Equilibrium variables in trade in goods with idea and data flows among symmetric countries are characterized completely by deriving the solution for final-output per capital: $\bar{y}_k^R$. Given the solution, all other steady state variables, consumption per digital data $\bar{c}_x^D$, consumption per capital $\bar{c}_k^R$, R&D labor $\bar{l}_D^R$ on the balanced growth path are determined across countries.

Single role of data. The equilibrium growth rate along the balanced growth path, denoted by $\bar{g}_R^*$, is derived as:

$$\bar{g_R}^* = \frac{(1+N_a)[\theta(1-\alpha)m(1-m)+2\alpha\rho\zeta_1/\zeta_0]-\alpha\rho}{\alpha[\zeta_0-(1+N_a)\zeta_1]}$$

where $\zeta_0 = \sigma + \gamma(1-\sigma)$ and $\zeta_1 = \frac{\alpha m-(1-\alpha)(1-m)^2}{(1-\alpha)(1-m)}$.

The growth rate $\bar{g}_R^*$ reveals straightforward relationships: stronger knowledge spillovers result in a faster growth rate. A greater accessibility of cross-border data ϕ and a larger number of trading partners N have no impact on economic growth. A larger number of trading partners is meaningful through knowledge spillover N_a.

Corollary. $\frac{\partial \bar{g}_R^*}{\partial \phi} = 0$ *and* $\frac{\partial \bar{g}_R^*}{\partial N_a} > 0$.

Proof. This follows directly from $\bar{g}_R^*$.

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국문요약

이 논문에서는 디지털 데이터가 성장의 동력이자 프라이버시 위험의 원천이라는 이중적 역할을 통합한 무역·성장 모형을 제시한다. 소비 활동에서 생성된 데이터는 국가의 데이터 축적을 늘려 R&D 생산에 필수적이지만, 동시에 소비자 후생에는 부정적 외부효과를 초래한다. 국경 간 데이터의 자유로운 흐름은 지식 파급과 무역 확대를 통해 성장을 촉진하지만, 엄격한 규제는 성장 억제와 후생 개선이라는 상충 효과를 낳는다. 성장과 후생의 상충 관계를 완화하기 위해, 데이터 현지화에 관한 규제 비용을 낮추고자 노력하고 데이터의 자유로운 이동과 지식 공유를 촉진하는 디지털 무역협정을 추진해야 한다.

핵심용어: 무역, 성장, 디지털 데이터, 프라이버시, 데이터 규제

〈책임〉

이규엽

미국 Michigan State University 경제학 박사
前 미국 Michigan State University 경제학과 Instructor
대외경제정책연구원 무역통상안보실 신통상전략팀장
(現, E-mail: kylee@kiep.go.kr)

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