ISSN 0911-1247

Journal of International Economic Studies

(NO.40)
March 2026

Special Issue

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THE INSTITUTE OF COMPARATIVE ECONOMIC STUDIES
HOSEI UNIVERSITY

Tokyo, Japan

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Journal of International Economic Studies (2026), No.40, 1–3
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Editor's Introduction to the Special Issue
Global Production Networks, Trade Policy, and Economic Dynamics in Open Economies

Bin Ni
Faculty of Economics, Hosei University

This special issue brings together three papers that examine open economies from complementary perspectives: global value chains and network structures, environmental trade policy in general equilibrium, and the macroeconomic dynamics of foreign direct investment (FDI). Although the themes differ in scope and methodology, they share a common concern: how openness—through trade, investment, and cross-border production networks—reshapes economic structure, policy effectiveness, and growth dynamics.

Over the past several decades, globalization has fundamentally altered the organization of production and exchange. International trade is no longer primarily an exchange of final goods; rather, it increasingly reflects complex production fragmentation across borders. Countries participate in specific stages of production, often specializing in intermediate inputs within multilayered global value chains (GVCs). At the same time, capital flows—especially FDI—have intensified, reinforcing production networks and deepening macroeconomic interdependence. In parallel, governments face increasingly complex policy challenges, particularly in environmental regulation and industrial policy, where domestic interventions interact with global trade structures.

Understanding these transformations requires analytical approaches that move beyond traditional partial-equilibrium or purely domestic frameworks. The contributions in this special issue respond to this need by integrating network analysis, general equilibrium modeling, and structural macroeconometric methods. Together, they offer new insights into the structural and dynamic consequences of openness.

Trade and the Equivalence between Environmental Taxes and Quotas

The first paper, "Trade and the Equivalence between Environmental Taxes and Quotas", revisits a classic question in environmental economics: whether price instruments (taxes) and quantity instruments (quotas) are interchangeable. While much of the literature focuses on uncertainty or information asymmetry, this study examines the issue in a deterministic two-sector general equilibrium framework.

In the model, pollution arises as a by-product of production and directly reduces sectoral productivity. This production-side externality distinguishes the framework from models in which pollution affects only utility. The analysis considers both autarky and a small open economy, allowing for specialization under trade.

Three key insights emerge. First, taxes and quotas are not generally equivalent; certain environmental targets achievable under quotas cannot be replicated under taxes. Second, the real effects of taxes depend on the choice of numeraire, as taxes operate through relative prices. Third, trade liberalization can alter the conditions under which policy instruments appear equivalent, especially when specialization patterns change.

This contribution underscores the importance of general equilibrium reasoning in environmental policy design. In open economies, policy instruments interact with trade structure and production specialization in ways that may fundamentally alter outcomes. The results highlight that policy evaluation cannot abstract from international linkages and structural transformation.

Vietnam's Position in Semiconductor Global Value Chains

The second paper, "Vietnam's Position in Semiconductor Global Value Chains: A Network Analysis", investigates Vietnam's evolving role in the global semiconductor trade network from 2000 to 2022. The semiconductor industry occupies a central position in modern manufacturing and digital transformation. Participation in semiconductor GVCs is therefore both economically significant and strategically important.

Using bilateral trade data from UN Comtrade, the authors apply Louvain Community Detection (LCD) and various network centrality measures to identify Vietnam's structural position within the global semiconductor network. This approach allows the analysis to go beyond trade shares and export growth rates, focusing instead on structural embeddedness within the network.

The findings reveal several important developments. First, Vietnam's increasing closeness and betweenness centralities indicate improved accessibility and a strengthening intermediary role within the global trade network. Second, higher eigenvector centrality reflects stronger linkages with major economies, including South Korea, Japan, and the United States. Third, the LCD analysis uncovers a structural transformation in Vietnam's trade configuration, marked by a shift toward more regionally concentrated clusters within East and Southeast Asia.

These results highlight how a country's economic significance cannot be fully understood solely through aggregate trade volumes. Structural position within a network—whether as a peripheral participant, a bridge economy, or a core hub—matters for resilience, spillovers, and long-term development. By employing network-based methodology, this paper contributes to the growing literature that treats international trade as a complex system rather than a collection of bilateral flows.

Dynamic Effects of FDI on Exports and GDP in ASEAN Countries

The third paper, *"Dynamic Effects of FDI on Exports and GDP in ASEAN Countries"*, examines the macroeconomic role of inward FDI using a sign-restricted structural VAR framework. Focusing on six ASEAN economies over an extended historical period, the study identifies FDI shocks as short-run aggregate demand disturbances and traces their dynamic effects on exports and GDP.

The empirical results indicate that positive FDI shocks increase GDP in both the short and long run in most ASEAN countries, suggesting that FDI affects not only demand but also supply-side conditions. Exports also respond positively to FDI shocks, although the magnitude and timing of the response differ across countries.

A particularly novel contribution of this paper is the introduction of the FDI multiplier, which measures the cumulative effect of FDI shocks on output. The findings show substantial cross-country heterogeneity and suggest diminishing returns to FDI as FDI-to-GDP ratios increase. By quantifying the dynamic and long-run effects of FDI, the paper advances the empirical literature beyond simple correlation analysis.

Common Themes and Broader Implications

Although the three papers differ in methodology and focus, they converge on several common themes. First, openness complicates policy design. As demonstrated in the analysis of environmental taxes and quotas, policy instruments cannot be evaluated independently of trade structures and general equilibrium effects. Second, structural position matters. Whether in semiconductor trade networks or in broader global production systems, a country's embeddedness within production and trade networks shapes its economic outcomes, resilience, and development prospects. Third, dynamic transmission mechanisms are central. As shown in the analysis of FDI shocks in ASEAN economies, trade, investment, and policy interventions generate effects that propagate over time through macroeconomic and production linkages.

In an era characterized by supply chain restructuring, geopolitical uncertainty, and renewed debates over industrial and environmental policy, understanding these structural and dynamic interactions is more important than ever. By combining general equilibrium modeling, network analysis, and structural time-series econometrics, the contributions in this special issue provide complementary insights into the evolving nature of open economies.

I would like to express my sincere gratitude to the authors for their valuable contributions and to the reviewers for their thoughtful comments. I hope that this special issue will stimulate further research on the structural and dynamic dimensions of globalization and open-economy policy.

Journal of International Economic Studies (2026), No.40, 5–21
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Trade and the Equivalence between Environmental Taxes and Quotas

Gang Li
Faculty of Economics, Toyo University

Abstract

Environmental policy debates often address whether price instruments (taxes) and quantity instruments (quotas) are interchangeable. This study revisits the issue in a two-sector general equilibrium model in which pollution is a by-product of production and lowers sectoral productivity. The analysis considers autarky and a small open economy, with attention to both specialization and diversification under trade. It shows that (i) taxes may fail to achieve outcomes attainable under quotas; (ii) the effects of a tax depend on the choice of numeraire; and (iii) trade liberalization can shift the conditions under which taxes and quotas are equivalent. These findings highlight the importance of implementability, stability, and numeraire choice in the design and evaluation of environmental policy instruments.

Keywords: pollution tax, emission quota, production externalities; numeraire.
JEL classification codes: F18, H23, Q58.

1 Introduction

Price (tax) and quantity (quota) instruments are the workhorses of environmental policy. Under tax regulation the government sets the price of emissions and allows the market to determine the quantity; under quota regulation it fixes the quantity and lets the market determine the price. Comparisons between taxes and quotas often focus on practical issues such as the ease of implementation, both technological and political. Many theoretical studies on this topic, pioneered by Weitzman (1974), focus on uncertainty or incomplete information.[1]

[1] See also Hoel and Karp (2001, 2002), Newell and Pizer (2003), Karp and Zhang (2005), and Grodecka and Kuralbayeva (2015).

This study addresses a more fundamental question in a deterministic setting with perfect information and no implementation frictions: are taxes and quotas interchangeable once production-side environmental damages are incorporated into a general equilibrium framework? More specifically, can an explicit environmental tax, such as an emissions (pollution) tax, replicate the allocation that would arise under an emissions quota, and vice versa?

To address this question, I develop a two-sector model with labor as the single primary factor. Pollution arises as a by-product of production and can be reduced by allocating labor to abatement. Aggregate pollution lowers sectoral productivity; thus, environmental quality directly enters production technology. Policy is analyzed under autarky and in a small open economy (SOE), allowing for both diversified and specialized trade equilibria.

Three main results emerge. (i) In both autarky and the SOE, taxes and quotas are not generally equivalent. Some environmental targets can be achieved under quotas but not under a tax schedule. Intuitively, a quota directly fixes emissions, while a tax changes a relative price whose real effects depend on how the tax is measured and how much pollution reduces productivity. (ii) Taxes operate through relative prices, and their effects depend on the choice of *numeraire* that defines those prices. A wage-denominated tax operates mainly through substitution between abatement labor and emissions, whereas a consumption-good-denominated tax also acts through the productivity-damage channel by changing the relative price of emissions to output. Consequently, taxes denominated in consumption goods are more likely to have regular effects—higher taxes reduce total emissions—than those dominated in wages. (iii) Trade liberalization can reverse the equivalence conclusions. In an SOE, the effects of relaxing a quota on the permit price depend on sectoral income shares and relative pollution sensitivities. Moreover, trade may induce specialization, generating regimes in which marginal policy responses and stability change discontinuously.

In a closely related study, Ishikawa and Kiyono (2006) compare alternative emission regulations in an open economy and show that taxes and quotas are not necessarily substitutes. The mechanisms underlying their results, however, differ from those in this study: they model pollution as reducing utility, whereas I assume that pollution directly impairs production. The latter channel is of practical importance in industries such as forestry, agriculture, fisheries, tourism, and renewable energy. For example, Reddy and Behera (2006) estimate that pollution causes an annual agricultural loss of \$213.2 per household in Kazipalle village, India. This study also differs from Ishikawa and Kiyono (2006) in the type of pollution considered. While they focus on greenhouse gases (GHGs) as transboundary pollutants, I examine non-transboundary pollution, which is also highly relevant in practice. As Sweeney (1993, p.761) notes, many forms of pollution, including noise, radiation, NOx, SOx, and particulates, tend to have relatively localized effects.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 analyzes tax and quota policies under autarky. Section 4 turns to an SOE, distinguishing between diversified and specialized equilibria. Section 5 concludes and discusses possible extensions.

2 The Model

The economy produces two consumption goods—agriculture (A) and manufactures (M)—using a single primary input, labor (L). Production in both sectors generates pollution as a by-product, which firms can reduce by allocating labor to abatement.

Firms If firms undertake no abatement, output of good $j \in \{A, M\}$ is proportional to labor input but is reduced by the aggregate pollution stock:

$$X_j = \frac{L_j}{G^j(Z)},$$

where L_j is labor used in sector j, Z is total pollution discharge, and $G^j(Z)$ captures the adverse productivity effect of pollution with $G^{j\prime}(Z) > 0$. The term $G^j(Z)$ is common to all firms in sector j and is taken as given by price taking firms.[2]

Without abatement, the pollution discharge is proportional to the scale of production activity: $Z_j = \gamma L_j$ with $\gamma > 0$, and $Z = Z_A + Z_M$. With abatement, it is convenient to treat pollution as an "input". Following Copeland and Taylor (1994), express the output as a linearly homogeneous function of labor and pollution:

$$X_j = \frac{F^j(L_j, Z_j)}{G^j(Z)}, \quad Z_j \in (0, \gamma L_j],$$

where F^j is strictly increasing and strictly quasi-concave, twice continuously differentiable, and normalized so that $F^j(L_j, \gamma L_j) = L_j$.

Under perfect competition, firms maximize profit taking Z as given. The linear homogeneity of F^j implies that firms' decisions can be described by the cost minimization problem

$$\min_{a_j, e_j} w a_j + r e_j, \quad \text{s.t.} F^j(a_j, e_j) = 1, \tag{1}$$

where w is the wage and r is the price of pollution (the permit price under a quota or the tax per unit of emissions under a tax regulation); a_j and e_j denote the labor and pollution required per unit of output in sector j, respectively. Because $Z_j \in (0, \gamma L_j]$, the feasible unit coefficients satisfy $e_j/a_j \in (0, \gamma]$. An interior solution occurs only when r/w is sufficiently high; otherwise, firms choose zero abatement, in which case $e_j/a_j = \gamma$:

$$\left(a_j^*, e_j^*\right) = \begin{cases} (1, \gamma) & \frac{r}{w} \in (0, \eta], \\ (a_j(r, w), e_j(r, w)) & \frac{r}{w} \in (\eta, \infty), \end{cases}$$

[2] Pollution reduces productivity on the production side, a "feedback effect" in the sense of Mayeres and Proost (2001). Given functional form restrictions, production and utility externalities can be equivalent because production ultimately feeds into utility through consumption.

where $\eta = F^j_{Z_j}/F^j_{L_j}\Big|_{(L_j,Z_j)=(1,\gamma)}$ with $F^j_{L_j} \equiv \partial F^j(L_j,Z_j)/\partial L_j$ and $F^j_{Z_j} \equiv \partial F^j(L_j,Z_j)/\partial Z_j$.

Define $c^j(r,w) \equiv wa_j(r,w) + re_j(r,w)$ from (1), which is linearly homogeneous. Then the unit cost of good j is $G^j(Z)\,c^j(r,w)$, and the zero-profit Kuhn–Tucker conditions are

$$G^j(Z)\,c^j(r,w) \geq p_j, \quad \left(G^j(Z)\,c^j(r,w) - p_j\right)X_j = 0,$$

so $G^j(Z)\,c^j(r,w) = p_j$ whenever good j is produced. For later use, define the sectoral sensitivity of output to aggregate emissions:

$$\varepsilon_j \equiv -\frac{\partial \ln X_j}{\partial \ln Z} = \frac{d \ln G^j(Z)}{d \ln Z} > 0,$$

which summarizes how rapidly productivity in sector j declines as Z rises.

Households The representative household has Cobb–Douglas preferences:

$$u = C_A^b C_M^{1-b},$$

where C_j is the consumption of good j and $b \in (0,1)$ is the expenditure share on the agricultural good. The government transfers tax revenues to households in a lump-sum manner, so income is $Y = wL + rZ$. Utility maximization subject to the budget constraint $Y = p_A C_A + p_M C_M$ yields the demand functions:

$$C_A = \frac{bY}{p_A}, \quad C_M = \frac{(1-b)\,Y}{p_M}.$$

Quotas and Taxes We consider two instruments. Under a quota, the government issues emission permits Q and enforces $Z \leq Q$. With competitive permit trading, a common permit price r clears the permit market; for $Q < \gamma L$, the constraint binds and $Z = Q$. The model is then a two-factor, two-good Heckscher–Ohlin structure with endowments (L, Q), except that the level of Q also determines sectoral productivities via $G^j(Q)$.

Under a tax, the government directly fixes the price of emissions r. Because only relative prices matter in general equilibrium, the pollution tax must be specified relative to the price of the primary factor or of a consumption good (e.g., r/w or r/p_j), rather than as an absolute r. Equivalently, one may normalize the price of the primary factor or of a consumption good (e.g., set $w = 1$ or $p_j = 1$) and treat r as the policy variable. Otherwise, all other prices could adjust proportionally with r, leaving the real economy unchanged. In what follows, we leave the numeraire unspecified in order to highlight how its choice (wage versus a consumption good) affects the comparative statics of tax policy.

3 Autarky

This section studies quotas and taxes in a closed economy. We first characterize the autarky equilibrium and then derive comparative statics results for a binding quota and for a pollution tax specified in alternative numeraires.

Equilibrium in Autarky Goods market clearing with Cobb–Douglas preferences implies

$$X_A G^A(Z)\, c^A(r,w) = bY, \tag{2}$$
$$X_M G^M(Z)\, c^M(r,w) = (1-b)\, Y. \tag{3}$$

Since both goods are produced in autarky, $G^j(Z)c^j(r,w) = p_j$. Factor market clearing for labor and pollution is given by

$$\sum_j X_j G^j(Z)\, a_j(r,w) = L, \tag{4}$$
$$\sum_j X_j G^j(Z)\, e_j(r,w) = Z. \tag{5}$$

There are six variables (X_A, X_M, Z, Y, w, r) to be determined. At the moment, we have not specified the numeraire, and Y, w, and r are nominal variables with two degrees of freedom.[3] Under a *quota*, $Z = Q < \gamma L$ is exogenous. Under a *tax*, the government sets the relative price of emissions (e.g., r/w or r/p_j); since firms' decisions depend on these relative prices, the choice of numeraire affects the equilibrium outcomes of tax policy.[4]

For the analysis below, let a hat denote proportional changes. Define income shares θ_{ij} (share of factor i in sector j's unit cost) and allocation shares λ_{ij} (factor i used in sector j as a share of the aggregate). Taking the logarithmic differential of (2) to (5) yields

$$\hat{X}_A + \varepsilon_A \hat{Z} + \theta_{ZA}(\hat{r} - \hat{w}) = \hat{Y} - \hat{w}, \tag{6a}$$
$$\hat{X}_M + \varepsilon_M \hat{Z} + \theta_{ZM}(\hat{r} - \hat{w}) = \hat{Y} - \hat{w}, \tag{6b}$$
$$\sum_j \lambda_{Lj}\left[\hat{X}_j + \varepsilon_j \hat{Z} + \hat{a}_j^*\right] = 0, \tag{6c}$$
$$\sum_j \lambda_{Zj}\left[\hat{X}_j + \varepsilon_j \hat{Z} + \hat{e}_j^*\right] = \hat{Z}, \tag{6d}$$

where $dL = 0$, $\partial c^j(r,w)/\partial r = e_j^*$, and $\partial c^j(r,w)/\partial w = a_j^*$ are used.

To further simplify (6c) and (6d), note that the cost minimization implies $\theta_{Lj}\hat{a}_j^* + \theta_{Zj}\hat{e}_j^* = 0$. It then follows that

[3] Walras' law gives $Y = wL + rZ$, which can be obtained from these four conditions.

[4] If we specify p_j as the numeraire, say letting $p_A = 1$, we have an additional equation $G^A(Z)\,c^A(r,w) = 1$ in addition to (2) to (5), which help to determine the five variables (X_A, X_M, Y, w, r) under quota regulation and (X_A, X_M, Z, Y, w) under tax regulation.

$$\hat{a}_j^* = \theta_{Zj}\sigma_j\left(\hat{r} - \hat{w}\right), \quad \hat{e}_j^* = -\theta_{Lj}\sigma_j\left(\hat{r} - \hat{w}\right), \tag{7}$$

where

$$\sigma_j \equiv -\frac{d\ln\left(\frac{e_j^*}{a_j^*}\right)}{d\ln\left(\frac{r}{w}\right)} > 0$$

measures the elasticity of substitution between labor and pollution in good j. Aggregating (7) gives

$$\sum_j \lambda_{Lj}\hat{a}_j^* = \delta_L\left(\hat{r} - \hat{w}\right), \quad \sum_j \lambda_{Zj}\hat{e}_j^* = -\delta_Z\left(\hat{r} - \hat{w}\right), \tag{8}$$

where $\delta_L \equiv \lambda_{LM}\theta_{ZM}\sigma_M + \lambda_{LA}\theta_{ZA}\sigma_A$ and $\delta_Z \equiv \lambda_{ZM}\theta_{LM}\sigma_M + \lambda_{ZA}\theta_{LA}\sigma_A$ have the following economic interpretations: δ_L (δ_Z) measures the aggregate proportionate saving in labor (pollution) given a proportionate rise in r/w, holding all outputs constant.[5] Substituting (8) into (6c) and (6d) and rearranging terms yields

$$\hat{X}_A - \left(\hat{Y} - \hat{w}\right) + \theta_{ZA}\left(\hat{r} - \hat{w}\right) + \varepsilon_A\hat{Z} = 0, \tag{9a}$$

$$\hat{X}_M - \left(\hat{Y} - \hat{w}\right) + \theta_{ZM}\left(\hat{r} - \hat{w}\right) + \varepsilon_M\hat{Z} = 0, \tag{9b}$$

$$\sum_j \lambda_{Lj}\hat{X}_j + \delta_L\left(\hat{r} - \hat{w}\right) + \sum_j \lambda_{Lj}\varepsilon_j\hat{Z} = 0, \tag{9c}$$

$$\sum_j \lambda_{Zj}\hat{X}_j - \delta_Z\left(\hat{r} - \hat{w}\right) + \left(\sum_j \lambda_{Zj}\varepsilon_j - 1\right)\hat{Z} = 0. \tag{9d}$$

Effects of Emissions Quota Under quota regulation, the government determines a binding emissions quota $Q < \gamma L$ so that the total pollution discharge $Z = Q$. Replacing $\hat{Z}$ with $\hat{Q}$ in (9) yields

$$\begin{bmatrix} 1 & 0 & -1 & \theta_{ZA} \\ 0 & 1 & -1 & \theta_{ZM} \\ \lambda_{LA} & \lambda_{LM} & 0 & \delta_L \\ \lambda_{ZA} & \lambda_{ZM} & 0 & -\delta_Z \end{bmatrix} \begin{bmatrix} \hat{X}_A \\ \hat{X}_M \\ \hat{Y} - \hat{w} \\ \hat{r} - \hat{w} \end{bmatrix} = \begin{bmatrix} -\varepsilon_A \\ -\varepsilon_M \\ -\sum_j \lambda_{Lj}\varepsilon_j \\ 1 - \sum_j \lambda_{Zj}\varepsilon_j \end{bmatrix} \hat{Q}. \tag{10}$$

Solving this for $\hat{X}_A$, $\hat{X}_M$, and $\hat{r} - \hat{w}$ yields[6]

$$\frac{d\ln X_A}{d\ln Q} = -\varepsilon_A + a_{12} - \theta_{ZA}a_{22}, \tag{11a}$$

$$\frac{d\ln X_M}{d\ln Q} = -\varepsilon_M + a_{12} - \theta_{ZM}a_{22}, \tag{11b}$$

$$\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q} = a_{22}, \tag{11c}$$

[5] See Chang (1981) and Jones (1965) for more details.

[6] We do not report $\hat{Y} - \hat{w}$, as it is not the focus of the analysis. One can show that $\hat{Y} - \hat{w} = a_{12}\hat{Q}$.

where

$$a_{12} = \frac{\lambda_{LM}\theta_{ZM}(\sigma_M - 1) + \lambda_{LA}\theta_{ZA}(\sigma_A - 1)}{(\lambda_{ZM}\theta_{LM} + \lambda_{LM}\theta_{ZM})(\sigma_M - 1) + (\lambda_{ZA}\theta_{LA} + \lambda_{LA}\theta_{ZA})(\sigma_A - 1) + 1}, \tag{12a}$$

$$a_{22} = -\frac{1}{(\lambda_{ZM}\theta_{LM} + \lambda_{LM}\theta_{ZM})(\sigma_M - 1) + (\lambda_{ZA}\theta_{LA} + \lambda_{LA}\theta_{ZA})(\sigma_A - 1) + 1}. \tag{12b}$$

A useful decomposition is:

$$\begin{aligned}\frac{d\ln X_j}{d\ln Q} &= -\frac{d\ln G^j(Q)}{d\ln Q} + \theta_{Lj}\frac{d\ln L_j}{d\ln Q} + \theta_{Zj}\frac{d\ln Z_j}{d\ln Q} \\ &= \underbrace{-\varepsilon_j}_{\text{TFP}} + \underbrace{\theta_{Lj}\left[a_{12} + (\sigma_j - 1)\theta_{Zj}a_{22}\right]}_{\text{Labor}} + \underbrace{\theta_{Zj}\left[a_{12} - (\theta_{Lj}\sigma_j + \theta_{Zj})a_{22}\right]}_{\text{Permits}},\end{aligned}$$

which highlights three channels: (i) a direct fall in sectoral total factor productivity (TFP) as pollution rises; (ii) labor reallocation across sectors; and (iii) the increase in the aggregate stock of permits and their reallocation across sectors. The net effect on each output and on the permit price is generally ambiguous.

It is also informative to track the permit price relative to consumption goods. Using $p_j = G^j(Z)c^j(r,w) = G^j(Q)c^j(r,w)$, the response of r/p_j to the quota is

$$\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q} = \frac{d\ln\left(\frac{r}{G^j(Q)c^j(r,w)}\right)}{d\ln Q} = -\varepsilon_j + \frac{\hat{r} - \hat{c}^j(r,w)}{\hat{Q}}.$$

Note that $\hat{c}^j(r,w) = \theta_{Zj}\hat{r} + \theta_{Lj}\hat{w} = \hat{r} - \theta_{Lj}(\hat{r} - \hat{w})$, which yields

$$\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q} = -\varepsilon_j + \theta_{Lj}\frac{\hat{r} - \hat{w}}{\hat{Q}}. \tag{13}$$

This together with (11c) gives

$$\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q} = -\varepsilon_j + \theta_{Lj}a_{22}. \tag{14}$$

The sign remains ambiguous. However, note that if $d\ln(r/w)/d\ln Q = a_{22} \leq 0$, it follows that $d\ln(r/p_j)/d\ln Q < 0$. This implies that a higher quota is more likely to reduce the relative price of permits with respect to consumption goods. In what follows, we define the quota as having *regular effects* if a higher quota lowers the permit price, and *irregular effects* otherwise.

Proposition 1. *In autarky, a higher emissions quota can move the permit price in either direction, depending on the unit in which permits are measured and on the signs of (12b) and (14). Moreover, regular effects are more likely when the permit price is measured in a consumption good.*

Consider the special case in which F^A and F^M take the Cobb–Douglas form. This implies $\sigma_A = \sigma_M = 1$ and, by (12a) and (12b), $a_{12} = 0$ and $a_{22} = -1$. It then follows that

$$\frac{d\ln\frac{r}{w}}{d\ln Q} = -1,$$
$$\frac{d\ln\frac{r}{p_j}}{d\ln Q} = -\varepsilon_j - \theta_{Lj}.$$

Corollary 1. *In autarky, given the Cobb–Douglas form of F^A and F^M, the emissions quota has regular effects on the permit price, whether measured in the wage or a consumption good.*

These results have an important implication for tax regulation: as shown in the following analysis, the effects of tax may vary dramatically depending on the choice of numeraire.

Effects of Pollution Tax Under tax regulation the instrument is the relative price of emissions. If the tax is specified in wage units, $\tau_w \equiv r/w$ is exogenous. Rewrite (9) as

$$\begin{bmatrix} 1 & 0 & -1 & \varepsilon_A \\ 0 & 1 & -1 & \varepsilon_M \\ \lambda_{LA} & \lambda_{LM} & 0 & \sum_j \lambda_{Lj}\varepsilon_j \\ \lambda_{ZA} & \lambda_{ZM} & 0 & \sum_j \lambda_{Zj}\varepsilon_j - 1 \end{bmatrix} \begin{bmatrix} \hat{X}_A \\ \hat{X}_M \\ \hat{Y} - \hat{w} \\ \hat{Z} \end{bmatrix} = \begin{bmatrix} -\theta_{ZA} \\ -\theta_{ZM} \\ -\delta_L \\ \delta_Z \end{bmatrix} \hat{\tau}_w. \tag{15}$$

We can directly derive the effects of a tax from the system of equations above, but the results under a quota prove to be very useful:

$$\frac{d\ln X_A}{d\ln\tau_w} = \frac{d\ln X_A}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = \frac{-\varepsilon_A + a_{12}}{a_{22}} - \theta_{ZA}, \tag{16a}$$

$$\frac{d\ln X_M}{d\ln\tau_w} = \frac{d\ln X_M}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = \frac{-\varepsilon_M + a_{12}}{a_{22}} - \theta_{ZM}, \tag{16b}$$

$$\frac{d\ln Z}{d\ln\tau_w} = \left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = \frac{1}{a_{22}}. \tag{16c}$$

Similarly, if the tax is specified in units of good j, $\tau_{p_j} \equiv r/p_j$, combining (11) with (14) gives

$$\frac{d\ln X_A}{d\ln \tau_{p_j}} = \frac{d\ln X_A}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = \frac{-\varepsilon_A + a_{12} - \theta_{ZA}a_{22}}{-\varepsilon_j + \theta_{Lj}a_{22}}, \tag{17a}$$

$$\frac{d\ln X_M}{d\ln \tau_{p_j}} = \frac{d\ln X_M}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = \frac{-\varepsilon_M + a_{12} - \theta_{ZM}a_{22}}{-\varepsilon_j + \theta_{Lj}a_{22}}, \tag{17b}$$

$$\frac{d\ln Z}{d\ln \tau_{p_j}} = \left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = \frac{1}{-\varepsilon_j + \theta_{Lj}a_{22}}. \tag{17c}$$

Note that the sign of a_{22} is ambiguous. Hence, a higher pollution tax imposed in terms of the wage or consumption goods does not necessarily reduce the total amount of pollution discharge. However, similar to the case of an emissions quota, if $d\ln Z/d\ln\tau_w = 1/a_{22} \leq 0$, then it follows that $d\ln Z/d\ln\tau_{p_j} < 0$, which implies that a tax specified in units of consumption goods is more likely to reduce the total pollution discharge. In what follows, we define the tax as having *regular effects* if a higher tax lowers total emissions, and *irregular effects* otherwise.

Proposition 2. *In autarky, a higher pollution tax can change the total pollution discharge in either direction, depending on the numeraire in which the tax is imposed and on the signs of (12b) and (14). Moreover, regular effects are more likely when the tax is specified in a consumption good.*

Intuitively, when the tax is imposed in terms of the wage, a change in the pollution tax corresponds to a change in r/w, which operates through the substitution between labor input and pollution discharge. By contrast, when the tax is imposed in terms of good j, it corresponds to a change in r/p_j, which affects the economy not only through the substitution channel but also through the adverse impact of pollution on productivity.

Similarly, if F^A and F^M take the Cobb–Douglas form, it follows directly from (16c) and (17c) that:

Corollary 2. *In autarky, given the Cobb–Douglas form of F^A and F^M, the pollution tax has regular effects on total pollution discharge, whether imposed in terms of the wage or a consumption good.*

Stability under Tax Regulation Suppose the economy is initially in equilibrium, and consider a small increase in pollution discharge due to an unexpected shock. If the pollution tax has irregular effects, this increase in total emissions raises the market evaluation (imputed price) of emission permits. At the same time, under tax regulation the explicit price of permits (the pollution tax) remains unchanged. Firms therefore have an incentive to "use" more pollution (or reduce abatement effort), resulting in further increases in pollution discharge. This suggests that, under irregular effects, an equilibrium with tax regulation is unstable.

Formally, consider a Marshallian adjustment process for pollution discharge:

$$\dot{Z} = \beta_\tau \left(\frac{r}{w} - \tau_w \right), \tag{18}$$

where $\beta_\tau > 0$ denotes the adjustment speed, τ_w is the pollution tax in terms of the wage (set by the government), and r/w is the market evaluation of emission permits in wage terms, calculated for a given level of pollution Z. If the tax has irregular effects, then by (16c), it holds that $d\left(r/w\right)/dZ > 0$, which implies that (18) is unstable.

If the government instead imposes the tax in terms of good j, we can express the adjustment process as

$$\dot{Z} = \beta_\tau \left(\frac{r}{p_j} - \tau_{p_j} \right),$$

and a similar argument applies. The above discussion can be summarized as follows:

Proposition 3. *Under tax regulation, if the pollution tax has irregular effects, then any equilibrium is unstable (given Marshallian adjustment in pollution discharge).*

4 Free Trade

This section analyzes environmental policy in an SOE that takes the world relative price p_M/p_A as given. I first examine a diversified equilibrium (both sectors active) and then a specialized equilibrium (complete specialization). As in autarky, I contrast quota and tax instruments and track how the choice of numeraire (wage versus consumption good) shapes comparative statics and stability.

4.1 Diversified Equilibrium

If the SOE remains diversified in equilibrium, both sectors are active and the minimized costs satisfy

$$\frac{G^M(Z)\, c^M(r,w)}{G^A(Z)\, c^A(r,w)} = \frac{p_M}{p_A}. \tag{19}$$

The labor market clearing condition (4) and the total pollution discharge (5) still hold. Taking the logarithmic differential of (19) and using $d\left(p_M/p_A\right) = 0$ gives

$$\left(\varepsilon_M - \varepsilon_A\right)\hat{Z} + \left(\theta_{ZM} - \theta_{ZA}\right)\left(\hat{r} - \hat{w}\right) = 0, \tag{20}$$

which, together with (9c) and (9d), characterizes the local responses in the diversified SOE.

Effects of a Quota in Diversified SOE Equilibrium For a binding quota, $Z = Q$ is exogenous. Rewriting (9c), (9d), and (20) gives

$$\begin{bmatrix} 0 & 0 & \theta_{ZM} - \theta_{ZA} \\ \lambda_{LA} & \lambda_{LM} & \delta_L \\ \lambda_{ZA} & \lambda_{ZM} & -\delta_Z \end{bmatrix} \begin{bmatrix} \hat{X}_A \\ \hat{X}_M \\ \hat{r} - \hat{w} \end{bmatrix} = \begin{bmatrix} \varepsilon_A - \varepsilon_M \\ -\sum_j \lambda_{Lj}\varepsilon_j \\ 1 - \sum_j \lambda_{Zj}\varepsilon_j \end{bmatrix} \hat{Q}. \tag{21}$$

Solving this yields

$$\frac{d\ln X_A}{d\ln Q} = -\varepsilon_A - \frac{\lambda_{LM}}{\Delta_\lambda} + \frac{(\varepsilon_M - \varepsilon_A)(\lambda_{ZM}\delta_L + \lambda_{LM}\delta_Z)}{\Delta_\lambda \Delta_\theta}, \tag{22a}$$

$$\frac{d\ln X_M}{d\ln Q} = -\varepsilon_M + \frac{\lambda_{LA}}{\Delta_\lambda} - \frac{(\varepsilon_M - \varepsilon_A)(\lambda_{ZA}\delta_L + \lambda_{LA}\delta_Z)}{\Delta_\lambda \Delta_\theta}, \tag{22b}$$

$$\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q} = -\frac{\varepsilon_M - \varepsilon_A}{\Delta_\theta}, \tag{22c}$$

where $\Delta_\lambda \equiv \lambda_{ZM} - \lambda_{LM} = \lambda_{LA} - \lambda_{ZA}$ and $\Delta_\theta \equiv \theta_{ZM} - \theta_{ZA} = \theta_{LA} - \theta_{LM}$. Using (13) and substituting (22c) into (13) yields

$$\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q} = -\varepsilon_j - \frac{\theta_{Lj}(\varepsilon_M - \varepsilon_A)}{\Delta_\theta}. \tag{23}$$

Proposition 4. *In a diversified SOE, a higher emissions quota can move the permit price in either direction, depending on the unit in which permits are measured and on the signs of (22c) and (23). If the pollution-intensive good is less sensitive to pollution (i.e., Δ_θ and $\varepsilon_M - \varepsilon_A$ have opposite signs), then $d\ln(r/w)/d\ln Q > 0$ (irregular in wage units). Moreover, regular effects are more likely when the permit price is measured in a consumption good.*

Effects of a Tax in Diversified SOE Equilibrium If the tax is set in wage units, $\tau_w \equiv r/w$ is given. It follows from (22a) to (22c) that

$$\frac{d\ln X_A}{d\ln \tau_w} = \frac{d\ln X_A}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = \frac{\varepsilon_A\Delta_\lambda\Delta_\theta + \lambda_{LM}\Delta_\theta - (\varepsilon_M - \varepsilon_A)(\lambda_{ZM}\delta_L + \lambda_{LM}\delta_Z)}{\Delta_\lambda(\varepsilon_M - \varepsilon_A)}, \tag{24a}$$

$$\frac{d\ln X_M}{d\ln \tau_w} = \frac{d\ln X_M}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = \frac{\varepsilon_M\Delta_\lambda\Delta_\theta - \lambda_{LA}\Delta_\theta + (\varepsilon_M - \varepsilon_A)(\lambda_{ZA}\delta_L + \lambda_{LA}\delta_Z)}{\Delta_\lambda(\varepsilon_M - \varepsilon_A)}, \tag{24b}$$

$$\frac{d\ln Z}{d\ln \tau_w} = \left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = -\frac{\Delta_\theta}{\varepsilon_M - \varepsilon_A}. \tag{24c}$$

If the tax is set in good j units, $\tau_{p_j} \equiv r/p_j$ is given. It follows from (23) that

$$\frac{d\ln X_A}{d\ln \tau_{p_j}} = \frac{d\ln X_A}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = \frac{\varepsilon_A\Delta_\lambda\Delta_\theta + \lambda_{LM}\Delta_\theta - (\varepsilon_M - \varepsilon_A)(\lambda_{ZM}\delta_L + \lambda_{LM}\delta_Z)}{\Delta_\lambda(\Delta_\theta\varepsilon_j + \theta_{Lj}(\varepsilon_M - \varepsilon_A))}, \tag{25a}$$

$$\frac{d\ln X_M}{d\ln \tau_{p_j}} = \frac{d\ln X_M}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = \frac{\varepsilon_M\Delta_\lambda\Delta_\theta - \lambda_{LA}\Delta_\theta + (\varepsilon_M - \varepsilon_A)(\lambda_{ZA}\delta_L + \lambda_{LA}\delta_Z)}{\Delta_\lambda(\Delta_\theta\varepsilon_j + \theta_{Lj}(\varepsilon_M - \varepsilon_A))}, \tag{25b}$$

$$\frac{d\ln Z}{d\ln \tau_{p_j}} = \left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = -\frac{\Delta_\theta}{\Delta_\theta\varepsilon_j + \theta_{Lj}(\varepsilon_M - \varepsilon_A)}. \tag{25c}$$

Proposition 5. *In a diversified SOE, a higher pollution tax can change the total pollution discharge in either direction, depending on the numeraire in which the tax is imposed and on the signs of (22c) and (23). If the pollution-intensive good is less sensitive to pollution (i.e., Δ_θ and $\varepsilon_M - \varepsilon_A$ have opposite signs), then $d\ln Z/d\ln\tau_w > 0$ (irregular in wage units). Moreover, regular effects are more likely when the tax is imposed in terms of a consumption good.*

By Proposition 3, irregular tax effects imply local instability. Hence some environmental targets that are attainable by a quota are not achievable under a tax in the diversified SOE:

Corollary 3. *If the pollution-intensive good is less sensitive to pollution in an SOE, the diversified SOE equilibrium under tax regulation is unstable.*

4.2 Specialized Equilibrium

In free trade the SOE may completely specialize. If it specializes in manufacturing, factor feasibility is

$$X_M G^M(Z)\, a_M(r,w) = L,$$
$$X_M G^M(Z)\, e_M(r,w) = Z.$$

Take the logarithmic differential to obtain

$$\hat{X}_M + \theta_{ZM}\sigma_M(\hat{r} - \hat{w}) + \varepsilon_M\hat{Z} = 0, \tag{26a}$$
$$\hat{X}_M - \theta_{LM}\sigma_M(\hat{r} - \hat{w}) + (\varepsilon_M - 1)\hat{Z} = 0. \tag{26b}$$

If, instead, the SOE specializes in agriculture, the counterpart is

$$X_A G^A(Z)\, a_A(r,w) = L,$$
$$X_A G^A(Z)\, e_A(r,w) = Z.$$

It then follows that

$$\hat{X}_A + \theta_{ZA}\sigma_A(\hat{r} - \hat{w}) + \varepsilon_A \hat{Z} = 0, \tag{27a}$$
$$\hat{X}_A - \theta_{LA}\sigma_A(\hat{r} - \hat{w}) + (\varepsilon_A - 1)\hat{Z} = 0. \tag{27b}$$

Effects of a Quota in Specialized SOE Equilibrium Under quota regulation, total pollution discharge is fixed at $Z = Q$. The effects of a quota depend on the sector in which the economy specializes. If the economy specializes in manufacturing, (26a) and (26b) imply

$$\frac{d\ln X_M}{d\ln Q} = (\theta_{ZM} - \varepsilon_M),$$
$$\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q} = -\frac{1}{\sigma_M}.$$

As for the effects on r/p_j, it follows from (13) that

$$\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q} = -\left(\varepsilon_j + \frac{\theta_{Lj}}{\sigma_M}\right).$$

If the economy specializes in agriculture, (27a) and (27b) imply

$$\frac{d\ln X_A}{d\ln Q} = (\theta_{ZA} - \varepsilon_A),$$
$$\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q} = -\frac{1}{\sigma_A}.$$

Again, from (13),

$$\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q} = -\left(\varepsilon_j + \frac{\theta_{Lj}}{\sigma_A}\right).$$

Proposition 6. *If the SOE specializes completely, the quota has regular effects on the permit price, whether measured in the wage or a consumption good.*

Effects of a Tax in Specialized SOE Equilibrium Under tax regulation, the pollution tax is determined by the government. If the tax is imposed in terms of the wage, then $r/w = \tau_w$ is exogenously given. If the economy specializes in manufacturing, from (26a) and (26b), we obtain

$$\frac{d\ln X_M}{d\ln\tau_w} = \frac{d\ln X_M}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = -\sigma_M\left(\theta_{ZM}-\varepsilon_M\right),$$

$$\frac{d\ln Z}{d\ln\tau_w} = \left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = -\sigma_M.$$

When the tax is imposed in terms of good j with $r/p_j = \tau_{p_j}$, we have

$$\frac{d\ln X_M}{d\ln\tau_{p_j}} = \frac{d\ln X_M}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = -\frac{\sigma_M\left(\theta_{ZM}-\varepsilon_M\right)}{\sigma_M\varepsilon_j+\theta_{Lj}},$$

$$\frac{d\ln Z}{d\ln\tau_{p_j}} = \left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = -\frac{\sigma_M}{\sigma_M\varepsilon_j+\theta_{Lj}}.$$

If, instead, the economy specializes in agriculture, from (27a) and (27b),

$$\frac{d\ln X_A}{d\ln\tau_w} = \frac{d\ln X_A}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = -\sigma_A\left(\theta_{ZA}-\varepsilon_A\right),$$

$$\frac{d\ln Z}{d\ln\tau_w} = \left(\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q}\right)^{-1} = -\sigma_A.$$

Similarly, when the tax is imposed in terms of good j,

$$\frac{d\ln X_A}{d\ln\tau_{p_j}} = \frac{d\ln X_A}{d\ln Q}\left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = -\frac{\sigma_A\left(\theta_{ZA}-\varepsilon_A\right)}{\sigma_A\varepsilon_j+\theta_{Lj}},$$

$$\frac{d\ln Z}{d\ln\tau_{p_j}} = \left(\frac{d\ln\left(\frac{r}{p_j}\right)}{d\ln Q}\right)^{-1} = -\frac{\sigma_A}{\sigma_A\varepsilon_j+\theta_{Lj}}.$$

Proposition 7. *If the SOE specializes completely, the pollution tax has regular effects, whether imposed in terms of the wage or a consumption good.*

4.3 The Whole Picture

The specialization pattern is not independent of environmental regulation. An SOE may pass through both diversified and specialized equilibria as the stringency of regulations changes. To characterize the free trade equilibrium, we first need to determine the conditions under which the economy specializes. For this purpose, it is convenient to begin with quota regulation. Define

$$\kappa_j\left(\frac{r}{w}\right) \equiv \frac{e_j(r,w)}{a_j(r,w)} = \frac{e_j\left(\frac{r}{w},1\right)}{a_j\left(\frac{r}{w},1\right)}, \quad \kappa \equiv \frac{Q}{L},$$

where Q is the quota determined by the government.

Assume, without loss of generality, that manufacturing is the pollution-intensive sector, that is, $\kappa_M(r/w) > \kappa_A(r/w)$. The necessary and sufficient condition for both goods to be produced is then

$$\kappa_M(r/w) > \kappa > \kappa_A(r/w).$$

Otherwise, if $\kappa = \kappa_M(r/w)$, the economy specializes in manufacturing ($X_A = 0$); if $\kappa = \kappa_A(r/w)$, it specializes in agriculture ($X_M = 0$).

Suppose the SOE is initially diversified. Given the world relative price p_M/p_A and the quota Q, we can derive r/w from (19). From (22c),

$$\frac{d\ln\kappa_j\left(\frac{r}{w}\right)}{d\ln Q} = \frac{d\ln\kappa_j\left(\frac{r}{w}\right)}{d\ln\left(\frac{r}{w}\right)}\frac{d\ln\left(\frac{r}{w}\right)}{d\ln Q} = \frac{\sigma_j\left(\varepsilon_M - \varepsilon_A\right)}{\Delta_\theta}, \tag{28}$$

where $d\ln\kappa_j\left(\frac{r}{w}\right)/d\ln\left(\frac{r}{w}\right) = -\sigma_j$ is used. By (28), if manufacturing is less sensitive to pollution ($\varepsilon_M - \varepsilon_A < 0$), then $\kappa_j(r/w)$ decreases with Q, while $\kappa = Q/L$ increases with Q. This implies that a range (Q_l, Q_h) exists where the economy remains diversified; for $Q \leq Q_l$, it specializes in agriculture, and for $Q \geq Q_h$, in manufacturing.[7]

By contrast, if manufacturing is more sensitive ($\varepsilon_M - \varepsilon_A > 0$), both $\kappa_j(r/w)$ and κ increase with Q. In this case, specialization does not necessarily arise, or multiple diversified intervals may exist. A similar argument applies when agriculture is the pollution-intensive sector.

Proposition 8. *Under quota regulation, if the pollution-intensive good is less sensitive to pollution, as the quota increases, the SOE first specializes in the labor-intensive good, then becomes diversified, and finally specializes in the pollution-intensive good.*

By Corollary 3, if the pollution-intensive good is less sensitive, a diversified equilibrium under tax regulation is unstable. By Proposition 8, this implies that tax regulation cannot achieve the environmental outcomes attainable under quota regulation in the interval (Q_l, Q_h). In this sense, taxes are not equivalent to quotas. Conversely, if the pollution-intensive good is more sensitive, quotas and taxes (in wage units) are negatively related and the equilibrium is stable; in this sense, the two instruments are equivalent.

Figure 1 illustrates the nonequivalence case in which manufacturing is pollution-intensive but less sensitive to pollution. The figure shows how specialization and the permit price (in wage units) vary with the quota. For a pollution tax $\tau_w \in [(r/w)_l, (r/w)_h]$, three equilibria may arise with three levels of total pollution discharge: Z_1, Z_2, and Z_3. Here, Z_1 and Z_3 correspond to specialization equilibria in agriculture and manufacturing, respectively, whereas Z_2 corresponds to a diversified equilibrium. By Propositions 3 and 5, the diversified equilibrium is unstable, so any small shock leads the economy to one of the specialized equilibria, (τ_w, Z_1) or (τ_w, Z_3).

[7] We implicitly assume $Q_h < \gamma L$ for simplicity. This ensures that the quota is binding when the economy specializes in agriculture or remains diversified, and binding over part of the range when it specializes in manufacturing.

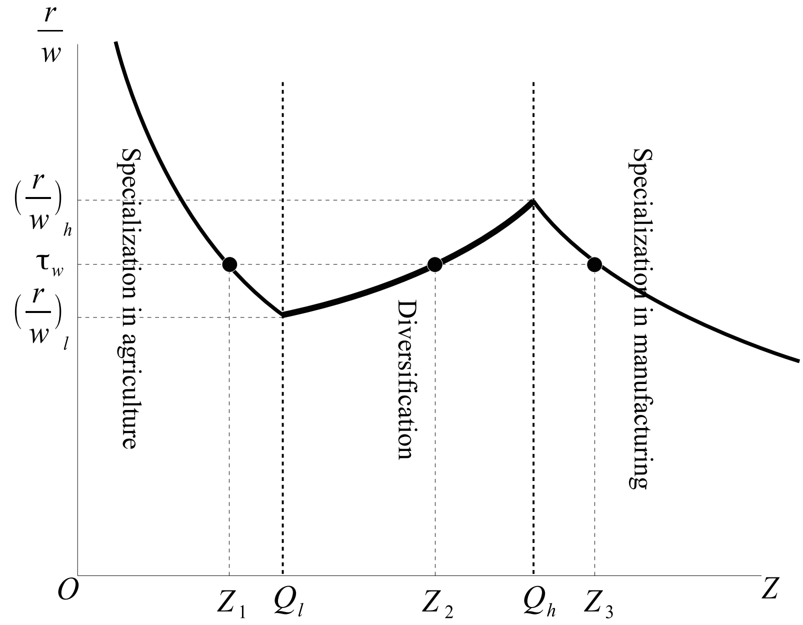

Figure 1: Nonequivalence between quotas and taxes ($\theta_{ZM} > \theta_{ZA}$ and $\varepsilon_M < \varepsilon_A$)

5 Conclusion

This study revisited the comparison between emission taxes and quotas in a two-sector general equilibrium model where pollution both accompanies production and lowers sectoral productivity. Even in the absence of uncertainty or implementation costs, the instruments are not generally equivalent. A quota directly fixes aggregate emissions, whereas a tax shifts a relative price whose effects depend on the structure of production and on the numeraire in which the tax is imposed. In some circumstances, environmental targets that can be reached by a quota cannot be achieved by any tax.

In an open economy, the comparison changes further. Trade can overturn autarky results and, as the quota is relaxed, push the economy between specialization and diversification. These regime changes alter the marginal effects of policy and the stability of equilibria, so that results derived in autarky may not carry over under free trade.

Another key insight is that the choice of numeraire matters. A wage-denominated tax influences behavior mainly through substitution between labor and emissions, whereas a tax expressed in a consumption good also acts through the productivity channel. The latter is therefore more likely to deliver *regular* effects (higher taxes reduce emissions) and to support the stability of an equilibrium. Quotas are robust instruments when implementability is the priority. Taxes can be effective, but the policymaker must specify the numeraire and recognize that different numeraires may produce opposite outcomes.

Future research could incorporate dynamic pollution stocks, international spillovers, distortionary revenue recycling, or imperfect competition. These may amplify or mitigate the nonequivalence reported here, but the key message remains: because taxes are relative prices, the choice of numeraire is consequential, and trade can fundamentally reshape the policy comparison.

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Journal of International Economic Studies (2026), No.40, 23–54
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Vietnam's Position in Semiconductor Global Value Chains: A Network Analysis

Jie Liu[a] and Sung Jin Kang[b]

Abstract

This study investigates Vietnam's position in the global value chains (GVCs) of semiconductors using bilateral trade data from the UN Comtrade database for the period 2000–2022, combined with Louvain Community Detection (LCD) and various network analytical indicators. Centrality measures suggest that Vietnam has become increasingly integrated into the global semiconductor trade network, characterized by an expanding set of trade partners and a dual role as both a major importer and supplier. Increases in closeness and betweenness centrality indicate enhanced network accessibility and intermediary capacity, whereas higher eigenvector centrality reflects stronger linkages with key economies, including South Korea, Japan, and the United States. The LCD results further reveal a structural transformation in Vietnam's trade configuration, shifting from broader, less concentrated clusters to more regionally embedded communities. This evolution positions Vietnam more closely within East and Southeast Asian production networks and provides insights into its deepening participation in regional and GVCs.

Keywords: semiconductor industry; global value chains; Network Centrality; community detection.

JEL Codes: **D85; C33; F14.**

a Center for Digital Economy and Smart Society, Guangzhou College of Commerce; School of Economics, Guangzhou College of Commerce, Guangzhou, People's Republic of China, jieliu@gcc.edu.cn.

b Corresponding author: Department of Economics, Graduate School of Energy and Environment (KU-KIST Green School), Program in Urban Regeneration, Korea University, Seoul, Republic of Korea, Tel: (+82) 01052915262, Fax: 02-3290-2225, E-mail: sjkang@korea.ac.kr

Acknowledgement

This research was conducted without any financial support from public, commercial, or non-profit funding agencies.

1. Introduction

Over the past decades, trade agreements such as the WTO Trade Facilitation Agreement have significantly enhanced global value chain (GVC) integration by promoting the freer movement of goods and services across borders (Flentø & Ponte, 2017). GVCs are complex networks involving diverse actors, including corporations, farmers, and workers, who engage in activities spanning the entire lifecycle of a product or service, from design and production to distribution and recycling.

Many studies have analyzed the international fragmentation of GVCs using data on foreign investment flows between firms and their affiliates. In Vietnam, participation in GVCs has been pivotal to economic and social development, contributing to labor market expansion through value creation, higher-quality employment, and the transfer of technological and managerial capabilities (Taglioni & Winkler, 2016). Vietnam's specialization in final assembly and finishing has reinforced its position as an "Asian manufacturing powerhouse" (JLL, 2024), supported by proactive government policies such as trade agreements, foreign direct investment (FDI) incentives, and initiatives to integrate domestic firms into GVCs.

While GVCs have expanded Vietnam's access to international markets, they have also exposed the country to significant risk and uncertainty. Vietnam continues to face persistent challenges in its deepening integration into GVCs, including low domestic value addition, limited participation of local suppliers, a shortage of skilled labor, and sluggish productivity growth, all of which constrain its ability to fully benefit from GVC participation. Moreover, the country's reliance on foreign intermediates and technologies, combined with weak domestic innovation capacity, has contributed to stagnant productivity and hindered long-term economic growth (Korwatanasakul & Hue, 2022).

Vietnam's semiconductor production remains underdeveloped, resulting in heavy dependence on imported components for electronics exports. Upstream activities are particularly weak, with chip design largely conducted overseas and critical inputs, such as electronic chips, sourced externally. Foreign multinational enterprises (MNEs) dominate downstream operations, whereas domestic firms struggle to expand globally because of limited experience, insufficient capital, and weak marketing capabilities. Although Vietnam has attracted MNEs from advanced economies in the high-tech sector, spillover effects and demand multipliers have fallen short of expectations. Weak linkages between MNEs and local firms limit opportunities for interaction, learning, and knowledge transfer, impeding the growth of competitive domestic enterprises (Truong, 2022).

This study investigates Vietnam's evolving position within semiconductor GVCs from 2000 to 2022 by applying Louvain Community Detection (LCD) and network centrality metrics. The results indicate that rising centrality scores reflect Vietnam's dual role as both an importer and exporter in the semiconductor industry. Improvements in closeness and betweenness centralities suggest enhanced accessibility and a growing intermediary role in global trade. Higher eigenvector centrality further underscores Vietnam's strengthening trade linkages with major economies, including South Korea, Japan, and the United States. The analysis also reveals a structural shift in Vietnam's GVC participation, marked by deeper integration into regionally concentrated trade networks across East and Southeast Asia.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 introduces our theoretical framework, data sources, and estimation strategies. Section 4 presents the empirical results. Section 5 concludes with the key findings and policy implications.

2. Literature Review

Trade within GVCs, commonly referred to as GVC trade (Baldwin, 2016), has transformed traditional goods trade by shifting the emphasis to trade in tasks (Grossman & Rossi-Hansberg, 2008). In this context, bilateral trade often reflects broader multilateral dynamics, as exports rely heavily on intermediate goods imported from third countries (Xing, 2021). International production fragmentation has attracted considerable academic attention (Fukao et al., 2003; Ando & Kimura, 2005; Hanson et al., 2005). Research at both the firm and industry levels continues to expand, underscoring the rising integration and specialization within GVCs, driven by expanding trade networks and growing economic interdependence (Marin, 2011; Johnson & Noguera, 2012).[1]

Vietnam's integration into the global economy has been instrumental in facilitating GVC participation. Accession to the WTO in 2007 enabled Vietnamese firms to expand their trade, attract capital, and strengthen their links with foreign partners. Active engagement in bilateral and multilateral free trade agreements (FTAs), including the ASEAN FTA (1996), the US–Vietnam Bilateral Trade Agreement (2001), and the South Korea FTA (2015), has accelerated regulatory reforms aimed at liberalizing business operations and streamlining administrative procedures (World Bank & MPI, 2016). These efforts have supported Vietnam's transition from a centrally planned economy to a market-oriented system, laying the groundwork for deeper GVC integration (Filatotchev et al., 2009).

Despite setbacks during the Cold War, Vietnam's semiconductor industry reemerged as a strategic priority. The establishment of Z181 in 1979 marked its initial entry into chip production, serving the Soviet and Eastern European markets (East Asia Forum, 2022). However, geopolitical disruptions and trade embargoes stalled early developments. In recent years, the Chinese government has actively promoted semiconductor capabilities. By 2022, FPT Semiconductor had made notable progress in chip design, indicating the rise of domestic initiatives. Concurrently, MNEs have expanded their operations in Vietnam, investing in assembly, testing, and packaging (ATP) and advancing the country's integration into the global semiconductor GVC.

Vietnam's strategic position in the global electronics and smartphone supply chains has significantly reinforced its role in downstream GVC activities. Between 2001 and 2019, the country advanced from the world's 47th to the 12th largest electronics exporter, largely due to supply chain shifts toward Southeast Asia. This progress was propelled by substantial investments in the

[1] Marin (2011) investigates how firms geographically separate production stages to exploit cross-country differences in production costs, with Austrian and German firms focusing on Eastern Europe to leverage factor price differentials. Similarly, Johnson and Noguera (2012) reveal the increasing complexity of multi-country vertical trading chains, highlighting the extensive vertical specialization that characterizes modern GVCs. Together, these studies illustrate the deepening integration and specialization within GVCs, driven by expanded trade networks and sophisticated economic interdependence.

semiconductor and electronics sectors. In addition, Vietnam benefits from a demographic advantage, with a working-age population exceeding 50 percent (ASEAN, 2021) and a labor force that is both cost-effective and technically skilled. These factors play critical roles in attracting FDI to the country's high-tech industries.

Deeper integration into semiconductor GVCs presents an opportunity to enhance domestic capabilities and reduce reliance on foreign inputs. Participation also contributes to technological upgrades and skill development. Export-oriented firms, particularly those linked to advanced economies, have demonstrated gains in worker skills and process innovation, highlighting the value of knowledge transfer through supply chain engagement (de Oliveira et al., 2021).

However, existing research lacks a longitudinal analysis of Vietnam's evolving role in GVCs, particularly within the semiconductor sector. Most studies have focused on electronics GVCs with an emphasis on assembly and processing. Although these areas are important, limited attention has been paid to Vietnam's role in semiconductor GVCs, which are essential components of electronics manufacturing. Furthermore, the literature has rarely examined Vietnam's integration into specific trade communities within the global semiconductor network. Applying network-based methodologies to analyze these communities is essential for assessing regional integration, identifying strategic partnerships, and understanding Vietnam's position in the global production system.

This study addresses these research gaps by analyzing Vietnam's role in semiconductor GVCs using network analysis and trade data. Drawing on bilateral trade data from UN Comtrade, which provides near-global coverage, and applying LCD with centrality measures, this study offers nuanced insights into Vietnam's evolving participation. Focusing on the period 2000–2022, the analysis enables a longitudinal assessment of Vietnam's growing significance within the semiconductor GVC, with emphasis on its changing position within specific trade communities.

3. Model

In network analysis, the relationships (edges) between variables (nodes) are graphically represented to illustrate structural connections. The strength of network analysis lies in its ability to estimate complex patterns of relationships, allowing the examination of network structures to reveal the core features of the system (Hevey, 2018). To identify trade communities within a semiconductor network, this study employs the LCD method, drawing on prior research (Vincent et al., 2008; Duan et al., 2009).

A trade community represents the regional or neighborhood structure of trade interactions, characterized by small-world properties. Formally, a graph (G) is represented as a matrix with elements corresponding to weighted edges and is defined as $G(V, E, W, F)$. Here, V denotes the set of nodes, where node indices $i, j \in (1, \dots, g)$. $E = \{< i, j > | i, j \in V\}$ denotes the edge set, where $< i, j >$ is an ordered pair of nodes. $W = \{w_{ij} \in R | i, j \in V \; and < i, j > \in E\}$ denotes the set of weights assigned to edges, and F is a mapping function that assigns weights to edges, defined as $F: E \rightarrow W$.

Let us assume the directed weighted matrix W as follows.

$$W = \begin{bmatrix} w_{11} & \cdots & w_{1g} \\ \vdots & \ddots & \vdots \\ w_{g1} & \cdots & w_{gg} \end{bmatrix}$$

where w_{ij} represents exports from country i to country j (or imports from country j country i).

Equation (1) defines the weighted in-degree and weighted out-degree of node i, which represent the total import and export flows of a specific country with the rest of the world.

$$wd_i^{in} = \sum_{j=1}^{g} w_{ji}, wd_i^{out} = \sum_{j=1}^{g} w_{ij}, \; j \neq i \; \#(1)$$

In the first step, we evaluate the global modularity Q of G using Equation (2). We denote the community (partition) indices by p and q and assume that there are k communities, that is, p, q=1,2,…k.

$$Q = \frac{1}{A} \sum_{p=1}^{k} \sum_{i,j \in p} \left(w_{ij} - \frac{wd_i^{in} wd_j^{out}}{A} \right) \#(2)$$

where $A = \sum_{i=1}^{g} \sum_{j=1}^{g} w_{ij}$ denotes the sum of all edge weights in G, representing the total export (or import) volume of all countries.

Here, the global modularity Q can be decomposed into the sum of the local modularity $D(p)$, as shown in Equation (3).

$$Q = \sum_{p=1}^{k} [\frac{1}{A} \sum_{i,j \in p} \left(w_{ij} - \frac{wd_i^{in} wd_j^{out}}{A} \right)] = \sum_{p=1}^{k} D(p) \, \#(3)$$

The original global modularity Q_1 before merging communities p and q, can be obtained by decomposing Q in Equation (3).

$$Q_1 = \sum_{p'=1,\ p' \neq p,q}^{k} D(p') + D(p) + D(q) \, \#(4)$$

The new global modularity Q_2 after merging communities p and q, is expressed in Equation (5).

$$Q_2 = \sum_{p'=1,\ p' \neq p,q}^{k} D(p') + D(p \cup q) \, \#(5)$$

The resulting increase in global modularity can be calculated using Equation (6).

$$\Delta Q = Q_2 - Q_1 = D(p \cup q) - D(p) - D(q) \#(6)$$

The change in global modularity value ΔQ between the merged Q (communities *p* and *q*) and the original Q (community *p*) is computed. The original community is then placed into the new merged community that results in the greatest increase in modularity. If no increase is possible, the original community remains unchanged. In the second step, this process is applied repeatedly and sequentially to all communities until no further increase in modularity occurs, indicating that a local maximum has been reached and ending the process.

In addition to the weighted degree centrality and community detection introduced above, unweighted degree centrality, closeness centrality, and betweenness centrality also reflect the characteristics of nodes in the network.

Unweighted degree centralities (d) include in-degree and out-degree centralities, which refer to the extent to which two nodes are graphically adjacent (connected). In-degree (d_i^{in}) represents the number of edges directed to country i's node, and out-degree (d_i^{out}) represents the number of edges originating from country i's node. Higher degrees indicate a more central position because the node has many direct connections with other countries. A higher in-degree indicates that a country imports semiconductors from other countries, suggesting that it is a significant consumer or assembler of semiconductor products. Similarly, a higher out-degree indicates that the country exports semiconductors to numerous other countries, indicating that it is a major producer or supplier. The in-degree (d_i^{in}) and out-degree (d_i^{out}) of country i's node can be calculated using Equation (7).

$$d_i^{in} = \sum_{j=1}^{g} t_{ij}\,, d_i^{out} = \sum_{j=1}^{g} t_{ij}\,, i \neq j \#(7)$$

where $t_{i,j}$ represents ties from country i's node to country j's node in the directed network of this study, and ties from country i's node to country j's node are considered exports from country i to country j.

The influence of a node on the flow of information in a network is measured by betweenness centrality. Nodes with high betweenness centrality serve as critical connectors between different parts of the network. In social networks, such nodes often effectively disseminate information because of their strategic positions within the network. The betweenness centrality score b_i for country i's node, normalized by dividing by the maximum possible betweenness centrality in a network of the same size, is given by Equation (8).

$$b_i = \frac{1}{(g-1)(g-2)} \cdot \sum_{j=1}^{g} \sum_{s=1}^{g} \frac{\rho_{sj}(i)}{\rho_{sj}}, s \neq i \neq j \#(8)$$

where ρ_{sj} is the total number of shortest paths from node s to node j, and $\rho_{sj}(i)$ is the number of those paths that pass through node i. In the first part, $(g-1)(g-2)$ represents the maximum possible betweenness centrality in a network of the same size, while the second part, $\sum_{j=1}^{g} \sum_{s=1}^{g} \frac{\rho_{sj}(i)}{\rho_{sj}}$, represents the standard betweenness centrality.

Closeness centrality measures how close a node is to every other node in the network and provides insight into its potential to efficiently access or influence the entire network. A higher closeness centrality score indicates that the node is closer to all other nodes in terms of path length, meaning that the transfer of information or resources from that node to others in the network are more efficient. Nodes with high closeness centrality can quickly spread information to all other nodes. The closeness centrality score c_i for country i's node, normalized by multiplying by the normalization factor, is given by Equation (9).

$$c_i = \frac{g-1}{\sum_{j=1}^{g} p_{ij}} \cdot \frac{g-1}{g-2} \#(9)$$

where p_{ij} is the shortest path distance between nodes i and j. The first part, $\frac{g-1}{\sum_{j=1}^{g} p_{ij}}$, represents the standard closeness centrality. The second part, $\frac{g-2}{g-1}$, is the normalization factor, which adjusts the value so that the maximum possible closeness centrality is 1 in a network of g nodes.

Eigenvector centrality measures the influence of a node within a network. A high eigenvector score indicates that a node is connected to many nodes with high scores. The eigenvector centrality score ev_i for country i's node, normalized by dividing by the square root of the sum of the squares of all eigenvector centrality scores, is given by Equation (8).

$$ev_i = \frac{1}{\sqrt{\sum_{j=1}^{g} ev_j^2}} \cdot \frac{1}{\lambda} \sum_{j=1}^{g} t_{ij} ev_j \, , i \neq j \#(8)$$

where λ is a constant, as in Equation (8), and $t_{i,j}$ represents ties from country i's node to country j's node. In the first part, $\sqrt{\sum_{j=1}^{g} ev_j^2}$ represents the square root of the sum of the squares of all eigenvector centrality scores, while the second part, $\frac{1}{\lambda}\sum_{j=1}^{g} t_{ij} ev_j$, represents the standard eigenvector centrality.

4. Data and Empirical Results

This section analyzes trends in global commodity and semiconductor trade from 1992 to 2022 (Figure 1), alongside Vietnam’s semiconductor trade across different stages of the value chain (Figures 2–7). Figures 8 and 9 present the network analysis results for Vietnam’s top 20 semiconductor import and export partners in 2022, respectively. Table 1 summarizes Vietnam’s centrality indicators in the global semiconductor trade network from 2000 to 2022. Using LCD, this study visualizes Vietnam’s position within the global semiconductor trade community in 2002, 2012, and 2022 (Figures 10–12). Additionally, Figures 13–20 depict Vietnam’s role at each stage of the semiconductor GVCs in 2002 and 2022, providing a comprehensive view of the country’s evolving participation.

The analysis relies on the UN Comtrade database, which contains over 1.1 billion records from 1962 to 2022. Commodity data were reported using updated classification systems, including HS 2002, HS 2007, and SITC Revision 3. Following OECD (2019), the semiconductor industry is categorized into four segments: raw materials, inputs, equipment, and final outputs.

Figure 1 presents global trade trends for all commodities (left axis) and semiconductors (right axis), measured as total exports and imports. From 1992 to 2008, global commodity trade rose from approximately 4.8 trillion USD to 31.0 trillion USD, driven by liberalization and globalization. Semiconductor trade grew in parallel, from 0.1 trillion USD to 0.8 trillion USD. However, the 2008 financial crisis triggered a sharp decline, with commodity trade contracting to 23.8 trillion USD and semiconductor trade falling to 0.7 trillion USD in 2009. Recovery followed in 2010, with steady growth until 2014. Minor declines in 2015 and 2016 were linked to global economic adjustments and geopolitical tensions. Semiconductor trade rebounded during this period but dropped by 0.1 trillion USD in 2017, largely due to US investigations into China’s semiconductor sector.

Between 2017 and 2019, global commodity trade regained momentum, peaking in 2018, before experiencing a modest decline in 2019. The outbreak of COVID-19 in 2020 caused major disruptions, and by 2022, global trade volumes had fallen to 28.4 trillion USD, indicating a slow and uneven recovery.

Semiconductor trade followed a similar trajectory, with declines from 2017 to 2019 driven by geopolitical tensions and supply chain disruptions. However, rising demand for electronic products during the pandemic supported a rebound, with trade volumes reaching 0.8 trillion USD in 2022.

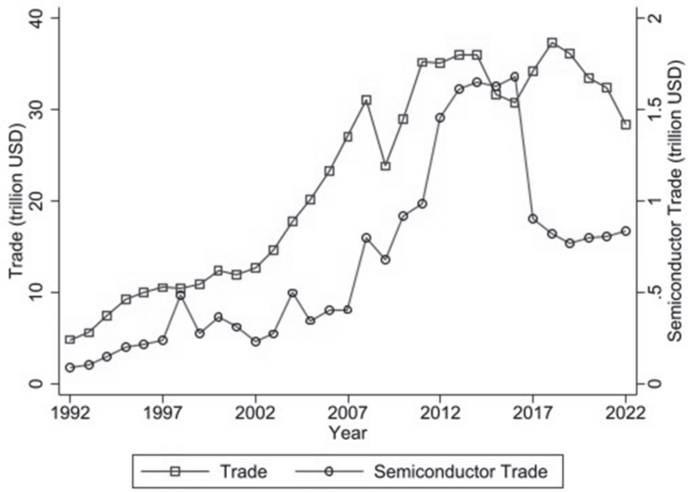


Figure 1. World Trade and Semiconductor Trade Trends (in trillion USD).

As Figure 2 shows, Vietnam's semiconductor imports have grown substantially since 2000. Notably, imports from Japan and South Korea increased from 0.02 billion USD and 0.01 billion USD, respectively, to 0.76 billion USD and 0.38 billion USD in 2022, highlighting Vietnam's heavy reliance on Japanese inputs. In contrast, imports from the US and the European Union (EU) remained relatively modest, reaching 0.05 billion USD and 0.09 billion USD, respectively, by 2022.

Semiconductor exports also grew steadily, albeit with some fluctuations (Figure 3). Exports to South Korea rose from near zero in 2000 to 0.45 billion USD in 2022, and exports to the US increased from 0.00 billion USD to 0.38 billion USD. By comparison, exports to Japan and the EU remained smaller, rising to 0.31 billion USD and 0.10 billion USD, respectively.

These patterns reflect Vietnam's increasing dependence on advanced economies and East Asian partners for semiconductor trade, reinforcing its role as a processor and assembler within global supply chains. Strengthening domestic production capacity is essential to reduce import dependence, improve the trade balance, and enhance Vietnam's competitiveness in the semiconductor sector.

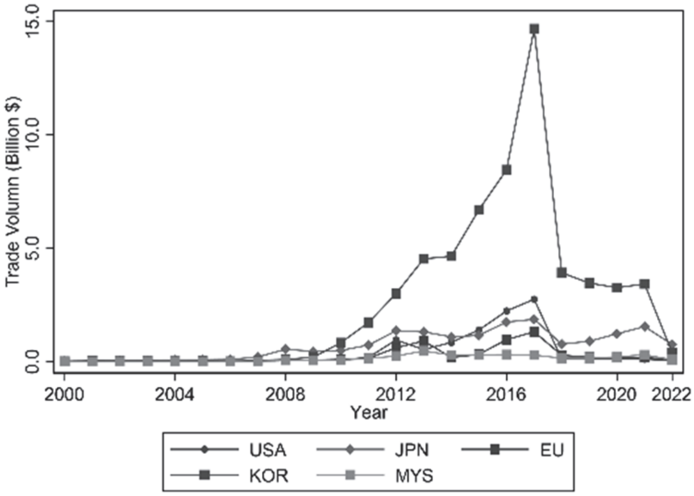


Figure 2. Vietnam's Semiconductor Imports Trend (in billion USD)

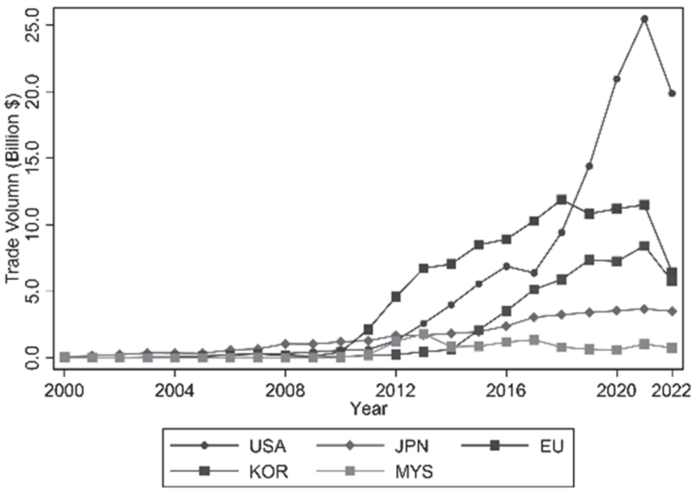


Figure 3. Vietnam's Semiconductor Exports Trend (in billion USD)

Figures 4 to 7 illustrate Vietnam's trade patterns across different stages of the semiconductor GVC. As shown in Figure 4, imports of semiconductor raw materials grew substantially from 0.04 million USD in 2001 to 1.30 billion USD in 2022, driven by the expansion of domestic manufacturing. Exports of raw materials also increased, from 0.03 million USD in 2001 to 0.38 billion USD in 2022, indicating gradual progress in processing and re-exporting. However, the persistent gap between imports and exports reflects Vietnam's continued dependence on foreign sources for critical inputs such as silicon wafers, despite ongoing efforts to build domestic production capacity.

Trade in semiconductor inputs, which refers to the processed intermediate goods used in chip manufacturing, has also expanded significantly. As shown in Figure 5, imports reached 0.63 billion USD in 2022, reflecting deeper integration into the global semiconductor supply chain. Although exports rose to 0.16 billion USD, they grew at a slower pace, highlighting Vietnam's role as a consumer and processor rather than a major supplier of semiconductor inputs.

To enhance competitiveness and reduce reliance on imports, Vietnam must prioritize the development of domestic production capabilities and promote technology transfer. The strategic import of advanced tools, such as optical and electron microscopy instruments, lenses, filters, and precision measurement equipment, is essential. These instruments are critical for improving precision, ensuring quality control, and advancing the technological capacity of semiconductor manufacturing. Building domestic expertise in these areas is vital for achieving long-term sustainability and strengthening Vietnam's position in the global semiconductor industry.

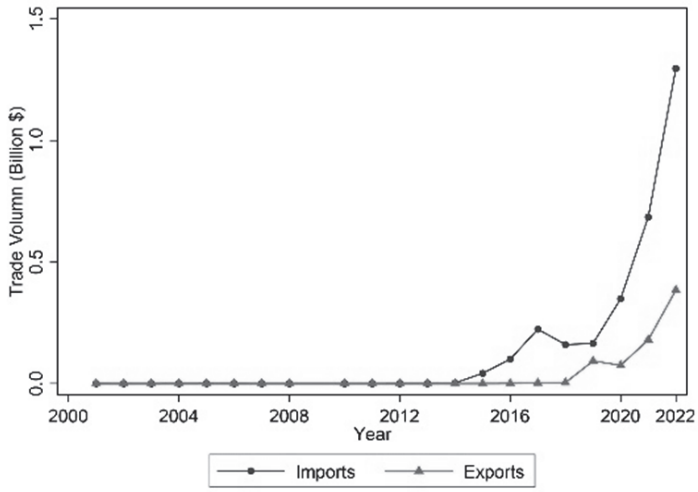


Figure 4. Semiconductor Raw Materials

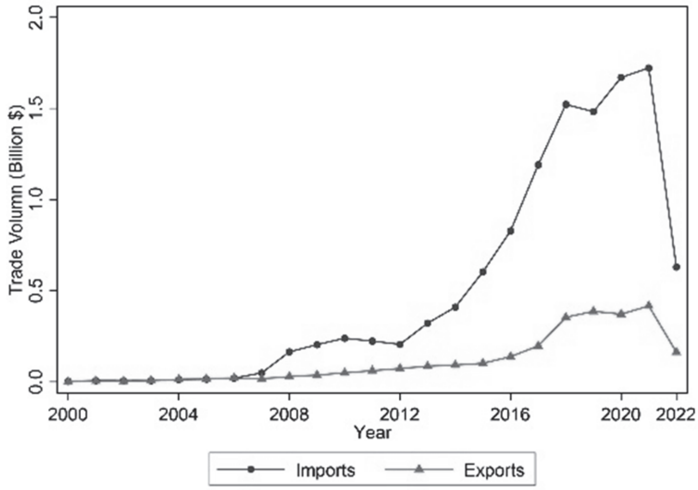


Figure 5. Semiconductor Inputs

Equipment such as cooling fans, heat exchange units, filtering systems, and purifying machinery is essential for maintaining stable operating conditions and clean environments in semiconductor manufacturing. As shown in Figure 6, Vietnam's imports of semiconductor equipment rose sharply from 1.42 billion USD in 2000 to 24.39 billion USD in 2022, reflecting the growing demand for advanced production machinery. Exports followed a similar trend, increasing from 0.10 billion USD to 15.63 billion USD over the same period. This surge in imports and exports highlights Vietnam's expanding role in the global semiconductor equipment supply chain, supported by substantial foreign investment and deeper integration into international production networks.

Vietnam's imports of semiconductor outputs also increased significantly, rising from 0.12 billion USD in 2000 to 1.35 billion USD in 2022 (Figure 7). During the same period, exports grew from 0.02 billion USD to 0.87 billion USD, indicating improvements in the country's capacity to produce and export final semiconductor goods. However, the persistently high import volumes suggest that Vietnam remains a net importer of semiconductor outputs. This trade imbalance underscores the need to strengthen domestic production capabilities and promote greater value addition in the semiconductor sector.

Trade in semiconductors plays a vital role in shaping Vietnam's electronics exports. These outputs, including integrated circuits, processors, memory chips, and micro-assemblies, are essential for improving the functionality and performance of modern electronic devices. Passive components such as capacitors, resistors, printed circuits, and storage solutions form the foundational infrastructure required to produce reliable and efficient electronics. Strengthening Vietnam's capacity to manufacture and export these key components is critical for enhancing its competitiveness in the global electronics supply chain.

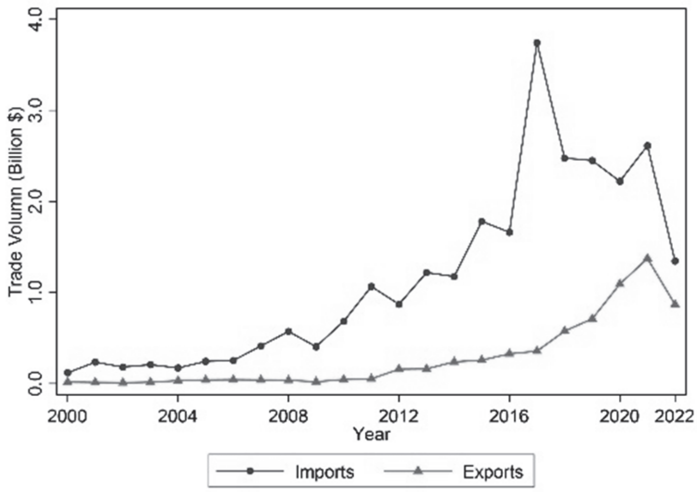


Figure 6. Semiconductor Equipment

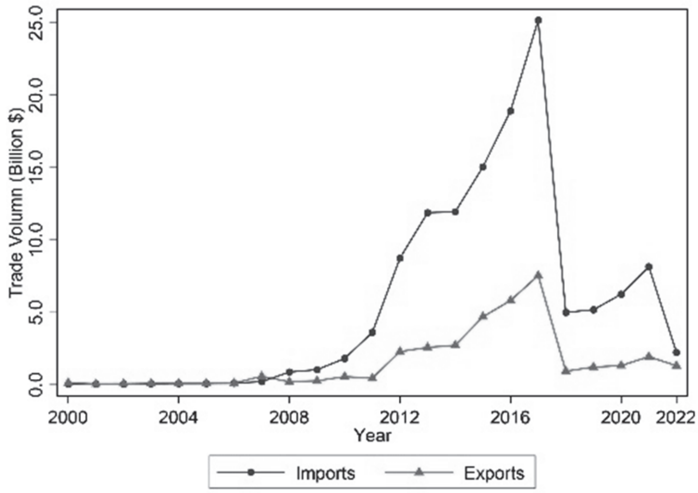
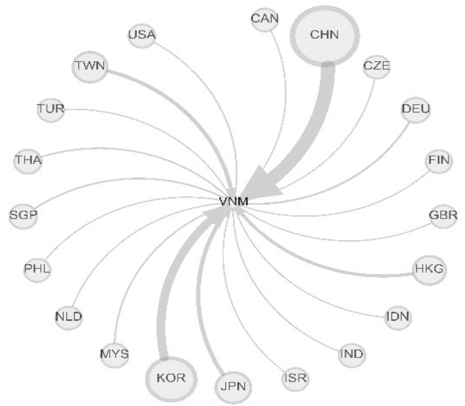


Figure 7. Semiconductor Outputs

Figures 8 and 9 present Vietnam's top 20 semiconductor trading partners in 2022, including the United States, Mainland China, South Korea, Taiwan (Province of China), and other major economies. Global production networks of MNEs have played a key role in strengthening Vietnam's trade ties with these countries, particularly through component exchanges between parent firms and subsidiaries (IT Brief Asia, 2022). For instance, Intel expanded its manufacturing operations across Vietnam, Malaysia, India, and Taiwan (Province of China). Similarly, South Korean firms such as Samsung Electronics, Hanmi Semiconductor, Hana Micron, and LG have established production facilities in Vietnam, reinforcing supply chain linkages and deepening Vietnam's integration into the global semiconductor industry.

In recent years, Vietnam has attracted substantial FDI from leading semiconductor-producing countries, particularly South Korea and the United States. This investment has supported the development of facilities that import raw materials and export finished products, thereby accelerating Vietnam's growth across all stages of the value chain.

Notably, the American electronic design automation firm Synopsys shifted its investment and engineering training operations from Mainland China to Vietnam. In 2021, Amkor Technology, a US-based provider of packaging and testing services, signed an agreement to invest 1.6 billion USD in a new manufacturing plant in Bac Ninh Province. Intel committed an additional 475 million USD to expand its assembly and testing operations in Vietnam, focusing on core processor production. Domestic firms are gradually advancing in semiconductor manufacturing. For example, FPT introduced a line of low-end chips for various applications, reflecting Vietnam's growing capabilities and expanding role in semiconductor GVCs (East Asia Forum, 2022).



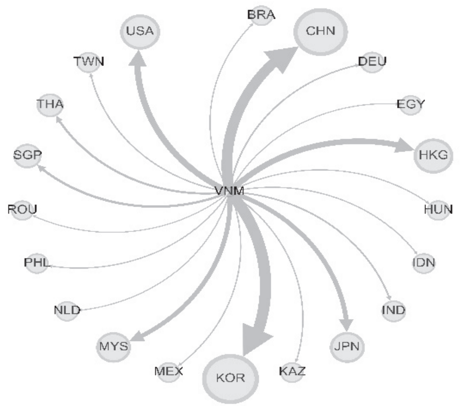


Figure 8. Vietnam's Top 20 Import Partners, 2022 **Figure 9. Vietnam's Top 20 Export Partners, 2022**

Note: The nodes, except for Vietnam, represent Vietnam's import/export partners. Larger nodes represent more important importing/exporting countries, and thicker edges represent higher import/export flows.

To assess Vietnam's position in the bilateral semiconductor trade network, this study examined its connectivity, trade volume, and influence using network centrality measures. The indicators derived from Equations (1), (7), (8), (9), and (10) are summarized in Table 1. The analysis covers the period from 2000 to 2022 and focuses on degree, weighted degree, closeness, betweenness, and eigenvector centralities. This approach provides a comprehensive view of Vietnam's evolving integration into global semiconductor trade networks.

Vietnam's in- and out-degree centralities (Columns 2 and 3 in Table 1) increased steadily over the study period, reflecting an expanding network of trade partners. In-degree centrality rose from 36 in 2000 to 63 in 2022, while out-degree centrality increased from 16 to 71. Throughout this period, the weighted in-degree consistently exceeded the weighted out-degree, indicating Vietnam's growing role as a major importer of semiconductors.

Although Vietnam's overall semiconductor trade volume has expanded considerably, notable fluctuations have occurred on the import side. These variations reflect both deeper integration into the global semiconductor value chain and the inherent volatility of international trade networks.

The weighted in-degree centrality, representing import volume, rose from 0.17 billion USD in 2000 to 5.54 billion USD in 2022, while the weighted out-degree, representing export volume, increased from 0.16 billion USD to 2.73 billion USD over the same period (Table 1, Columns 4 and 5). These trends indicate Vietnam's dual role as both a consumer and a supplier within the semiconductor supply chain, as well as its growing intermediary function connecting upstream and downstream actors in the GVC.

Closeness centrality (Column 6) increased from 0.526 to 0.688, reflecting improved accessibility and network positioning. Betweenness centrality (Column 7) rose from 0.001 to 0.053, signifying a larger role in bridging indirectly connected economies. Eigenvector centrality (Column 8) grew from 0.472 to 0.647, indicating stronger ties with influential partners such as South Korea and Japan. Together, these trends highlight Vietnam's deeper integration into the global semiconductor network, driven by its participation in regional value chains and growing connections with leading exporters.

Centrality indicators provide key insights into Vietnam's evolving role in the global semiconductor trade network. First, the sharp increase in weighted degree centrality between 2012 and 2017 reflects deeper integration into global supply chains and rising trade in semiconductor components. This trend reversed in 2018, as United States–Mainland China trade tensions disrupted supply chains and reduced trade volumes.

Second, closeness, betweenness, and eigenvector centrality—which measure network influence—are less affected by trade volume fluctuations. Closeness centrality reflects improved proximity to other economies, while betweenness centrality indicates Vietnam's role in linking indirectly connected partners. However, Vietnam's influence remains concentrated among a few key economies—particularly South Korea, Japan, and the United States—rather than broadly distributed.

Third, the eigenvector centrality pattern aligns with Vietnam's ties to major trade hubs. Strong connections with well-connected economies such as South Korea and Japan contributed to stable and gradual growth in this measure, suggesting that Vietnam's rising network position is primarily shaped by its relationships with leading semiconductor exporters.

Despite increased trade volumes, Vietnam's structural position in the global semiconductor network remains largely unchanged, as it continues to serve primarily as a manufacturing and assembly hub for electronic goods. Rising imports, coupled with modest export growth in semiconductor equipment and outputs (Figures 6 and 7), underscore the ongoing reliance on external inputs to support domestic production. Limited changes in raw material trade further indicate that Vietnam has not yet become a major hub or intermediary in silicon wafer processing. While total trade expanded, Vietnam's trade partnerships remained relatively stable, constraining the diversification of its intermediary role. Strengthening domestic production and broadening trade beyond traditional partners are essential for deeper integration and greater influence in the semiconductor value chain.

The decline in weighted degree centrality in 2018 highlights the impact of United States–China trade tensions on Vietnam's semiconductor trade. These disruptions affected global supply chains, including those in Vietnam, and reduced trade volumes. A concurrent slowdown in global demand for electronic products likely exacerbated this decline, reinforcing Vietnam's dependence on its assembler role. This trend underscores Vietnam's vulnerability and the need to enhance domestic capabilities to mitigate external shocks.

Table 1. Vietnam's Centrality Indicators in the Semiconductor Trade Network.

Year	In-degree	Out-degree	Weighted In-degree ($BN)	Weighted Out-degree ($BN)	Closeness	Betweenness	Eigenvector
2000	36	16	0.168	0.157	0.526	0.001	0.476
2001	39	47	0.293	0.077	0.583	0.014	0.472
2002	37	31	0.245	0.076	0.551	0.003	0.429
2003	46	28	0.285	0.137	0.545	0.01	0.522
2004	41	30	0.274	0.139	0.548	0.005	0.463
2005	47	38	0.300	0.133	0.563	0.005	0.532
2006	46	45	0.354	0.140	0.575	0.004	0.491
2007	52	59	0.624	0.611	0.601	0.016	0.529

2008	51	57	1.617	0.274	0.598	0.01	0.514
2009	53	46	1.652	0.333	0.576	0.015	0.53
2010	52	54	2.742	0.656	0.591	0.019	0.514
2011	59	49	4.910	0.569	0.582	0.007	0.567
2012	61	74	9.829	2.522	0.639	0.024	0.551
2013	61	83	13.428	2.831	0.661	0.047	0.551
2014	67	92	13.542	3.063	0.69	0.037	0.603
2015	66	92	17.478	5.057	0.687	0.033	0.599
2016	65	96	21.518	6.289	0.702	0.038	0.594
2017	68	105	30.348	8.105	0.731	0.149	0.632
2018	69	83	9.160	1.875	0.671	0.045	0.636
2019	69	85	9.285	2.413	0.696	0.027	0.653
2020	68	75	10.496	2.862	0.692	0.055	0.689
2021	63	75	13.180	3.914	0.673	0.082	0.628
2022	63	71	5.514	2.733	0.688	0.053	0.647

Because the LCD method does not capture year-over-year variations, this study analyzes the global semiconductor trade network at 10-year intervals. In 2002 (Figure 10), four trade communities were identified: 118 nodes in the quadrangle, 9 in the round, 20 in the triangle, and 23 in the pentagonal communities. As Baldwin and Lopez-Gonzalez (2015) noted, supply chain trade remains primarily regional, with production concentrated in hubs such as Factory Asia, Factory North America, and Factory Europe.

In 2002, the largest network nodes were Germany, Taiwan (a Province of China), the United States, and Singapore. For Vietnam and Japan, trade linkages with the United States and other members of the triangular community created important economic opportunities. However, Vietnam's electronics and semiconductor sector was still in its early stages, centered on low-end assembly and production. Consequently, Vietnam relied heavily on semiconductor imports from key economies, particularly Japan and the United States, to support the development of its emerging manufacturing base.

By 2012, Vietnam's semiconductor trade network had expanded to include 62 import partners and 75 export partners (Figure 11), accompanied by a sharp increase in trade volume. Imports (weighted in-degree) reached 9.8 billion USD, whereas exports (weighted out-degree) rose to 2.51 billion USD.

In 2012, the global semiconductor network comprised three trade communities: 32 nodes in the quadrangle, 20 in the round, and 120 in the triangle. Their respective trade volumes were 64.9 billion, 241.6 billion, and 74.8 billion USD. Although the triangular community had the most members, its trade volume was substantially lower than that of the round community, indicating disparities in trade intensity across regions. Germany and the United States were the most prominent nodes in the triangular and quadrangular communities, respectively, reflecting their central positions in the global supply chain.

Vietnam’s growing number of trade partners and rising trade volumes demonstrate its increasing integration into semiconductor GVCs. However, trade remained concentrated within specific regional clusters, suggesting that further diversification is required to strengthen its position in the broader network.

By 2022, Vietnam maintained trade relations with 63 import and 71 export partners (Figure 12). Imports remained high at 5.5 billion USD, whereas exports declined to 2.7 billion USD. South Korea, Vietnam’s main trading partner, imported 2.0 billion USD in semiconductor components from Vietnam and exported 3.5 billion USD to the country. Major partners such as the United States., Germany, South Korea, and Japan maintained relatively balanced trade flows, reflecting a more mature and selective trade environment.

The assembly, packaging, and testing (APT) stage, which requires less capital and more labor than front-end fabrication, is undergoing a transformation with the rise of advanced packaging technologies. By 2019, back-end activities accounted for 13 percent of the semiconductor industry’s capital expenditure and contributed 6 percent of the total value added. These operations remain concentrated in Taiwan (a Province of China) and Mainland China, with emerging hubs in Southeast Asia, particularly Malaysia, Vietnam, and the Philippines. Vietnam has expanded its APT capacity by joining other countries that host multiple fabrication facilities within the same trade network.

Figure 10. Semiconductor Network in 2002

Figure 11. Semiconductor Network in 2012

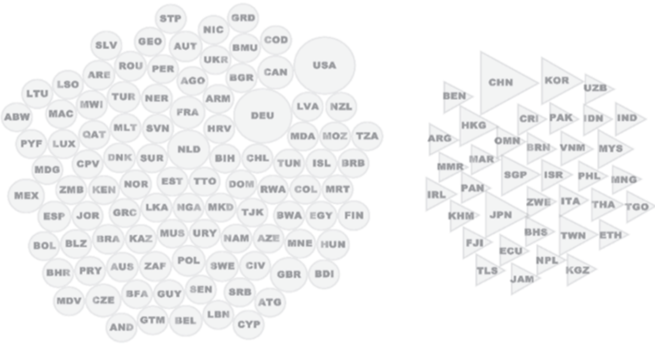


Figure 12. Semiconductor Network in 2022

The LCD analysis of semiconductor raw materials revealed structural consolidation in the trade network, with eight communities reduced to four by 2022 from 2002 (Figures 13 and 14). Japan and the United States were the central nodes in 2002, whereas by 2022, Japan and Taiwan (a Province of China) assumed dominant positions, reflecting shifts in regional sourcing and supply chain control.

Vietnam transitioned from a heterogeneous trade community in 2002, characterized by diverse geopolitical affiliations, to a regionally concentrated cluster by 2022, centered around China (mainland) and Hong Kong SAR. This shift indicates Vietnam's deeper integration into East and Southeast Asia's semiconductor raw-material network and its increasing alignment with regional production hubs. The realignment reflects not only evolving trade preferences but also Vietnam's growing strategic relevance within Asia's semiconductor supply base.

South Korea, Vietnam's primary supplier of semiconductor raw materials, exported 3.5 billion USD worth of materials to Vietnam by 2022. This trade is driven by Korea's import of high-purity silicon wafers from leading producers such as Shin-Etsu Chemical and SUMCO in Japan, GlobalWafers in Taiwan (Province of China), and Siltronic in Germany. Korea processes these wafers and exports them to Vietnam, where they support ATP operations and mid- to low-end chip manufacturing. This arrangement enhances Korea's role in the global supply chain by adding value to imported raw materials while meeting Vietnam's production needs.

To strengthen its role in semiconductor GVCs by 2030, Vietnam plans to build a small-scale fabrication plant and ten ATP factories (The Investor, 2024). By 2024, major MNEs, including Intel, Amkor Technology, and Hana Micron, had established ATP operations in the country. Intel operates its largest back-end facility in Vietnam, Amkor is constructing a 200,000-square-meter plant, and Hana Micron is scaling up its production. Additional firms such as Qualcomm, Texas Instruments, NXP Semiconductors, SK Hynix, and Hayward Quartz Technology are also expanding their investments, reflecting growing global confidence in Vietnam's semiconductor ecosystem.

Vietnam aims to establish at least 100 semiconductor design companies by 2030, with annual revenue targets of 25 billion USD for semiconductors and 225 billion USD for electronics (The Investor, 2024). Between 2030 and 2040, the country plans to expand domestic capabilities and attract FDI, targeting 200 design firms, two fabrication plants (fabs), and 15 ATP facilities. By 2050, Vietnam envisions a mature ecosystem with 300 design companies, three fabs, 20 ATP factories, and full R&D capabilities in semiconductors.

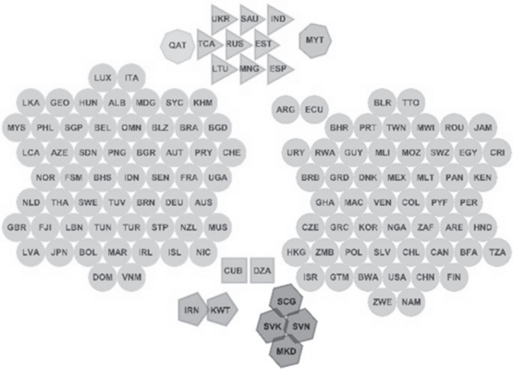


Figure 13. Semiconductor Raw Material Networks in 2002

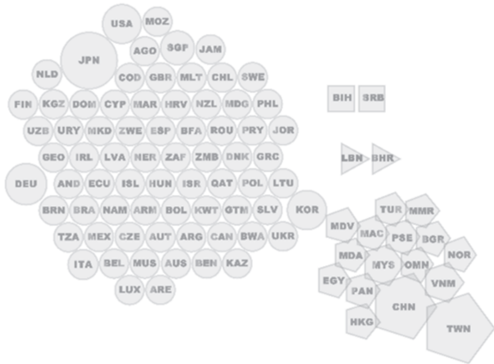


Figure 14. Semiconductor Raw Material Networks in 2022

As illustrated in Figures 15 and 16, the semiconductor input network comprised five distinct communities in 2002, which consolidated into two communities by 2022. In 2002, Japan and the United States were the dominant nodes, reflecting their global leadership in semiconductor trade. By 2022, the United States and China (mainland) had assumed central positions, indicating significant network consolidation.

In 2002, Vietnam belonged to a blue triangular community (Figure 15), consisting of countries with limited integration into GVCs and similar economic structures. By 2022 (Figure 16), Vietnam was aligned with China (mainland), Taiwan (Province of China), and other East and Southeast Asian economies within a regionally integrated network. This transition reflects Vietnam's growing participation in semiconductor supply chains and its enhanced technological capabilities.

South Korea, Vietnam's principal partner for semiconductor inputs, imported 453.2 million USD worth of inputs from Vietnam in 2022. Conversely, Hong Kong SAR, Vietnam's largest input supplier, exported 1 billion USD to Vietnam that year.

Key semiconductor inputs, such as optical lenses, filters, and electron microscope components, are processed at Vietnamese facilities operated by Samsung Electronics, LG Display, Amkor Technology, and local subcontractors. These components support the equipment requirements of Korean firms for wafer inspection, high-precision optics, and testing systems.

The Hong Kong SAR–Vietnam trade relationship highlights Hong Kong SAR's role as a critical intermediary in the semiconductor supply chain. Although not a major producer, Hong Kong SAR connects Vietnam to global markets through its advanced logistics infrastructure, efficient trade channels, and robust financial systems. This intermediary function enhances Vietnam's network centrality and facilitates its integration into regional and international semiconductor trade flows.

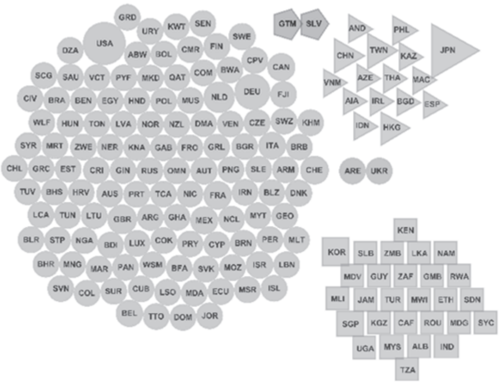


Figure 15. Semiconductor Input Networks in 2002

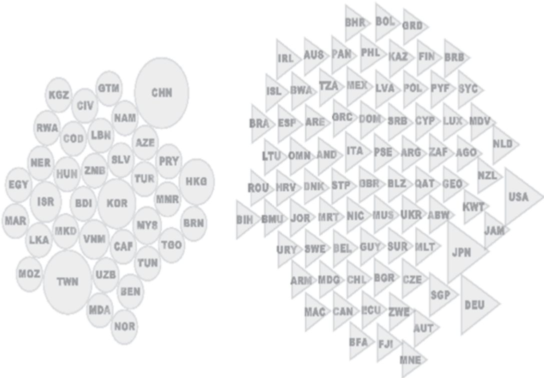


Figure 16. Semiconductor Input Networks in 2022

Analysis of the semiconductor equipment network (Figures 17 and 18) shows a shift from four distinct communities in 2002 to two by 2022. In 2002, the United States, Germany, and Italy were the leading nodes (Figure 17), reflecting their dominance in global semiconductor equipment trade. By 2022, the United States and Taiwan (Province of China) became the largest nodes, indicating structural consolidation and a shift in trade dynamics within the industry.

Vietnam, initially part of a green quadrangular community in 2002, belonged to a diverse and loosely connected network. By 2022, it transitioned to a green square community (Figure 18), aligning more closely with regional manufacturing hubs such as China (mainland), Malaysia, and South Korea. This shift reflects Vietnam's growing integration into Asia's semiconductor equipment supply chain and its expanding role as a regional assembly and export platform.

In 2022, Hong Kong SAR imported semiconductor equipment worth 454.9 million USD from Vietnam, making it Vietnam's top export destination. China (mainland) remained the largest import source, with exports worth 6.1 billion USD. Hong Kong SAR's role as an intermediary facilitates Vietnam's access to global markets through advanced logistics, efficient trade systems, and robust financial infrastructure, enhancing its connectivity and positioning within the global semiconductor equipment network.

Figure 17. Semiconductor Equipment Networks in 2002

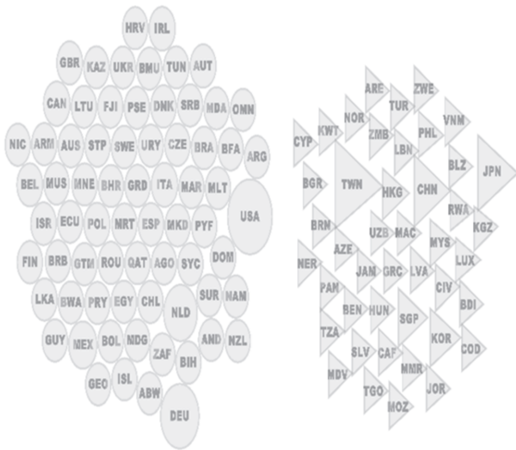


Figure 18. Semiconductor Equipment Networks in 2022

Figures 19 and 20 illustrate the evolution of the final semiconductor output network, with five trade communities identified in 2002 and three in 2022. In 2002, the United States, Singapore, Japan, and Germany were the predominant nodes (Figure 19). By 2022, China (mainland), the United States, and Germany had emerged as central actors, reflecting shifts in trade structures and technological capabilities. Vietnam has also become a significant player, with semiconductor output exports reaching 24.4 billion USD and imports totaling 20.9 billion USD in 2022. These developments highlight the reconfiguration of global manufacturing networks and Vietnam's strategic role in the semiconductor value chain.

Between 2002 and 2022, Vietnam deepened its trade ties with East and Southeast Asian economies, including China (mainland), South Korea, and Japan. By 2022, its trade network had expanded to include developing countries such as Bangladesh and Myanmar (Figure 20), signaling Vietnam's transition from a peripheral participant to a regional hub in semiconductor output trade.

In 2022, China (mainland) was Vietnam's largest export partner for semiconductor outputs, with imports worth 220.2 million USD, while Japan was the largest import partner, with exports worth 1.4 billion USD. Japan's chip exports are driven by Vietnam's growing role in global electronics manufacturing and the demand for both advanced and basic components. Japanese firms supply the integrated circuits, memory, processors, and passive components used in Vietnam's electronics and semiconductor packaging sectors, including operations by Samsung, LG, and Foxconn. The presence of Panasonic and Toshiba, alongside the Japan–Vietnam Free Trade Agreement, further supports this trade.

Vietnam processes and packages chips imported from Japan, which are then re-exported to China (mainland) for integration into final goods. Lower production costs and preferential terms under the ASEAN–China FTA reinforce Vietnam's position as a key intermediate supplier. These chips are further upgraded and assembled in China (mainland), supporting their export competitiveness in sectors such as smartphones, home appliances, and automotive electronics.

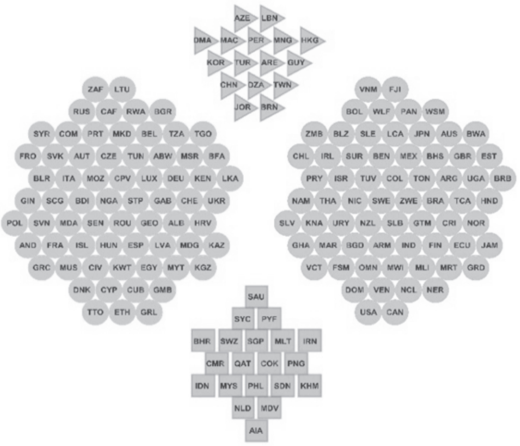


Figure 19. Semiconductor Output Networks in 2002

Figure 20. Semiconductor Output Networks in 2022

Between 2002 and 2022, Vietnam shifted from participating in broad, less regionally concentrated trade networks to joining more regionally integrated communities closely aligned with China (mainland), South Korea, and Taiwan (Province of China). This transition reflects Vietnam's deepening role in East and Southeast Asian semiconductor supply chains. Over the past two decades, Vietnam has evolved from an emerging participant to a key regional hub for raw semiconductor materials and equipment, highlighting its rapid industrialization and increasing global economic significance.

5. Conclusion

Using LCD and network centrality measures, this study analyzed Vietnam's position in semiconductor GVCs from 2000 to 2022, based on bilateral trade data from UN Comtrade. The key findings are as follows.

First, Vietnam's semiconductor imports have grown significantly, particularly from Japan and South Korea, reflecting its dependence on advanced economies for raw materials and components. Exports to South Korea and the United States have also increased, indicating Vietnam's growing participation in global semiconductor trade.

Second, network indicators reveal deeper integration into the global semiconductor trade network. Vietnam has expanded its trade portfolio and assumed a dual role as both importer and supplier. Increases in closeness and betweenness centrality indicate improved trade accessibility and Vietnam's intermediary function, while rising eigenvector centrality reflects strengthened ties with key economies such as South Korea, Japan, and the United States. LCD analysis shows Vietnam's transition from loosely connected networks to tighter regional alignment with East and Southeast Asia, particularly China (mainland), South Korea, and Taiwan (Province of China).

However, structural challenges remain. Trade imbalances across all stages of the value chain highlight continued reliance on external inputs. To enhance domestic capacity, Vietnam should implement targeted policies, including fiscal incentives for local manufacturers, increased R&D funding, and stronger collaboration with educational institutions to cultivate a skilled semiconductor workforce.

Vietnam's role remains concentrated in downstream activities, with limited advancement in upstream production, such as chip design and fabrication. To address this gap, long-term incentives should attract FDI in advanced manufacturing, while partnerships between domestic firms and global leaders can facilitate technology transfer and upstream capability development.

Finally, although Vietnam's integration into regional trade networks has progressed, trade remains concentrated among a few key partners. To reduce dependence and enhance resilience, Vietnam should pursue greater trade diversification, support SME participation in global supply chains, and leverage ASEAN frameworks to promote regional semiconductor cooperation. These measures will strengthen Vietnam's position in the global semiconductor industry and support sustainable upgrades within the GVC.

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Journal of International Economic Studies (2026), No.40, 55–70
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Dynamic Effects of FDI on Exports and GDP in ASEAN Countries

Tuan Khai Vu
Faculty of Economics, Hosei University

Abstract

The economic development experience of ASEAN countries over the past half century offers a compelling setting for analyzing the dynamic interrelationships between inward foreign direct investment (FDI), exports, and GDP. This paper examines the dynamic effects of FDI on exports and GDP in six ASEAN countries. To do so, I employ a sign-restricted structural vector autoregression (VAR), in which FDI shocks are identified as a type of short-run aggregate demand shock. I also calculate the FDI multiplier to quantify the effects of FDI. The main findings are as follows. First, a positive FDI shock increases GDP in both the short and long run in most ASEAN countries, indicating that FDI also affects the supply side of the economy. Second, the FDI shock also raises exports, although the magnitude and timing of the response differ across countries. Third, the FDI multiplier—a measure of the cumulative effect of FDI shocks on output—increases over time, with ASEAN-average estimates of 2.2 at the one-year horizon and 12.0 at the fifteen-year horizon. Finally, the FDI multiplier differs significantly across countries—ranging from 3.3 to 20.2 at the fifteen-year horizon—and is negatively correlated with the FDI-to-GDP ratio, which implies diminishing returns to FDI.

Keywords: FDI, aggregate demand shock, supply-side effect, multiplier, diminishing returns to FDI, sign-restricted VAR, ASEAN economies.

JEL Classification Codes: **F21, F41, F43.**

1. Introduction

This paper examines the effects of inward foreign direct investment (hereafter, FDI) on exports and GDP in ASEAN countries. While the literature on the effects of FDI is voluminous, studies that focus exclusively on ASEAN countries and employ long-term time series data remain limited. In addition, the *dynamic* and *quantitative* aspects of the effects of FDI have not received sufficient attention. This paper seeks to fill these gaps.

This research is motivated by the economic development experience of ASEAN countries, which suggests strong interdependencies among FDI, exports, and GDP in these countries. First, over the past half century, exports and FDI in many ASEAN countries have increased steadily, playing a crucial role in the economic growth of these countries (the next section provides detailed evidence showing that these countries have enjoyed strong economic growth and have been highly open to trade and FDI when compared to the world average). Furthermore, recognizing this importance, governments in ASEAN have adopted proactive policies to promote exports and attract FDI, which in turn reinforced the interdependence among FDI, exports, and GDP.

Second, over the past several decades, production and trade networks have emerged within East Asia, in which ASEAN is an integral part. These networks have become indispensable to understanding the economic dynamism in East Asia. They are characterized by a sophisticated division of production, in which multinational firms play a central role by strategically fragmenting production processes and locating production sites across different countries. This, in turn, has fostered active flows of FDI and exports within the region. Vu (2018, 2025) demonstrates that intraregional trade in intermediate goods within these networks is closely linked to business cycle fluctuations and macroeconomic interdependence among East Asian economies.

Against this background, ASEAN countries can be viewed as a compelling case study of an economic phenomenon in which FDI, exports, and GDP interact in a dynamic way. This paper aims to shed light on this phenomenon, focusing on the role of FDI. Specifically, it addresses the following questions: What are the effects of FDI on exports and GDP at the macroeconomic level? How do these effects differ across countries and over time? What factors underlie these differences?

This paper employs the analytical framework of a structural vector autoregression (VAR), a time-series econometric model well suited for capturing the dynamic interrelationships among economic variables. FDI shocks—the exogenous component of FDI—are identified as a type of short-run aggregate demand shock using the sign restriction scheme à la Uhlig (2005). This framework allows me to examine how FDI shocks affect exports and GDP.

While this paper focuses on understanding the role of FDI in ASEAN countries, it also contributes to the broader literature on the effects of FDI in two main ways. First, it proposes a new framework—the aforementioned sign-restricted VAR—which is appropriate for analyzing the effects of FDI on macroeconomic variables such as GDP and exports. The VAR approach has an important advantage over the single-equation approach—including the panel-data models often used in the FDI and trade literature[1] —in that it can capture the dynamic interdependencies between FDI, exports, and GDP, as noted above. This point is especially relevant at the macro level, where variables are often jointly determined. Existing VAR-based studies typically rely on recursive structures, where at least one of the variables (such as FDI, exports, or GDP) is assumed not to be contemporaneously affected by the others. [2] This assumption is not only too restrictive and often inconsistent with economic theory but it may also lead to implausible relationships among variables. By contrast, the sign-restricted VAR employed in this study allows for contemporaneous interdependence among variables, thereby addressing these limitations.

Second, this paper provides detailed quantitative results on the effects of FDI on exports and GDP. This point has received insufficient attention so far, as existing studies largely focus on whether FDI affects GDP and/or exports,[3] neglecting the question of “by how much.” To quantify the effects of FDI, I use the concept of the *multiplier*, which is often used to measure the effects of fiscal policy in public finance. To the best of my knowledge, this is the first study that applies the multiplier concept into the FDI literature. In addition to calculating FDI multipliers for ASEAN countries, I also examine the cross-country differences in these multipliers and discuss the underlying factors.

The remainder of the paper is organized as follows. Section 2 provides an overview of trends in economic growth, exports, and FDI in ASEAN countries over the past fifty years. Section 3

1 For an example related to ASEAN countries, see Hsiao and Hsiao (2006). For surveys of the FDI literature in general, see de Mello (2007) and Demena and Bergeijk (2017).

2 See, e.g., Taguchi and Pham (2019), who study the effects of FDI at the provincial level in Vietnam.

3 Examples relevant to ASEAN countries include Hsiao and Hsiao (2006) and Roy and Mandal (2012), who examine causalities between GDP, exports, and FDI using the Granger causality test.

describes the empirical framework of a sign-restricted VAR. Section 4 presents estimation results and provides a detailed analysis of the effects of FDI on exports and GDP. Section 5 concludes with key findings and directions for future research.

2. Trends in Economic Growth, Exports, and FDI in ASEAN Countries

This section provides an overview of trends in economic growth, exports, and FDI since 1970 in six ASEAN member states: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. For convenience, this group will hereafter be referred to as the ASEAN-6. A summary of the data is presented in Table 1.

Table 1: Economic Growth, Exports, and FDI in ASEAN Countries and the World

		1970-1995	1996-2009	2010-2024	1970-2024
Economic growth (annual rate, %)	Indonesia	6.6	3.7	4.7	5.4
	Malaysia	7.6	4.6	4.6	6.0
	Philippines	3.6	4.2	5.3	4.2
	Singapore	8.6	5.2	4.4	6.6
	Thailand	7.7	3.1	2.6	5.1
	Vietnam	6.3	6.7	6.1	6.4
	ASEAN-6	6.5	4.6	4.6	5.1
	World	3.3	3.2	3.0	3.2
Export growth (annual rate, %)	Indonesia	7.5	5.3	5.4	6.4
	Malaysia	10.5	5.3	3.6	7.3
	Philippines	8.2	5.0	6.4	6.9
	Singapore	12.2	7.5	5.5	9.2
	Thailand	12.4	6.5	3.2	8.4
	Vietnam	18.8	16.2	10.5	14.3
	ASEAN-6	12.4	7.6	5.7	8.2
	World	5.7	5.2	3.7	5.0
Inward FDI flows (% of GDP)	Indonesia	1.2	0.6	2.0	1.3
	Malaysia	4.0	3.4	3.4	3.7
	Philippines	0.7	1.5	2.0	1.3
	Singapore	8.4	16.0	24.3	14.7
	Thailand	1.0	3.4	2.0	1.9
	Vietnam	3.6	5.8	4.6	4.7
	ASEAN-6	2.1	4.3	5.3	3.5
	World	0.6	3.0	2.3	1.7
Inward FDI stock (% of GDP)	Indonesia	7.7	14.4	22.7	14.8
	Malaysia	24.0	41.3	44.7	36.3
	Philippines	6.4	13.1	21.4	13.5
	Singapore	64.3	139.9	324.1	174.5
	Thailand	7.0	27.6	50.8	28.0
	Vietnam	8.2	43.4	45.3	34.4
	ASEAN-6	15.2	40.4	71.0	41.7
	World	8.4	22.6	38.7	22.9

Note: Data for Vietnam start from the 1980s. Source: Author's calculations based on WDI and UNCTAD data.

ASEAN countries experienced relatively strong and stable economic growth during 1970–1995, with the ASEAN-6 recording an average annual growth rate of 6.5%. Growth in these countries, except for Vietnam and the Philippines, slowed during 1996-2009, a period that encompassed two major crises: the 1997–1998 Asian currency crisis and the 2008 global financial crisis. In the more recent period, 2010–2024, Indonesia managed to regain growth momentum and the Philippines experienced accelerated growth, while the other countries did not fully recover. Over the entire period 1970–2024, the ASEAN-6 achieved an average annual growth rate of 5.1%, surpassing the world average of 3.2% for the same period.

Regarding exports, the ASEAN-6 also recorded consistently higher growth rates than the world average. For example, during 1970–2024, their average annual real export growth rate was 8.2%, compared with the world average of 5.0%. Moreover, in all ASEAN countries, exports have grown faster than GDP over the past several decades. One key factor behind this trend is the rapid expansion of trade in intermediate goods, particularly within the East Asian production networks (see Vu, 2025 for more details). Consequently, ASEAN countries exhibit high trade openness. For example, the average export-to-GDP ratio for the ASEAN-6 during 1970–2024 was 54.5%, well above the world average of 22.6%. It is worth noting that this ratio varied widely across countries, ranging from 26.0% in Indonesia and 45.7% in Thailand to as high as 176.1% in Singapore. [4]

Export growth also differed substantially across countries. During 1970–2024, the annual growth rate was highest in Vietnam (14.3%), followed by Singapore (9.2%), and lowest in Indonesia (6.4%). Over time, export growth has followed a clear decelerating trend, with the average annual rate for the ASEAN-6 falling from 12.4% during 1970–1995 to 7.6% during 1996–2009, and further to 5.7% during 2010–2024.

Now let us turn to FDI. The ASEAN-6 has been more open to FDI compared to the world average, as indicated by its FDI-inflows-to-GDP ratio of 3.5% compared with 1.7% globally over 1970–2024. A similar pattern emerges for FDI stock-to-GDP ratios, which averaged 41.7% in the ASEAN-6 versus 22.9% worldwide.

Openness to FDI, however, has varied widely across countries. During 1970–2024, Singapore and Vietnam recorded the highest FDI inflows-to-GDP ratios, at 14.7% and 4.7%, respectively, while Indonesia and the Philippines posted the lowest, both at 1.3%. These differences are reflected in their FDI stock-to-GDP ratios as well: 174.5% in Singapore and 34.4% in Vietnam, compared with 14.8% and 13.5% in Indonesia and the Philippines, respectively.

Openness to FDI also changed markedly over time. For the ASEAN-6 as a whole, the FDI inflows-to-GDP ratio followed a steady upward trajectory, rising from 2.1% during 1970–1995 to 4.3% during 1996–2009, and further to 5.7% during 2010–2024. At the individual country level, however, divergent patterns emerged. For example, in Indonesia, the ratio declined from 1.2% in 1970–1995 to 0.6% in 1996–2009 before rebounding to 2.0% in 2010–2024. In Thailand, by contrast, it increased from 1.0% to 3.4% between the first two subperiods, then fell to 2.0% in the most recent period.

3. Empirical Framework

This section describes the framework of a structural VAR identified by sign restrictions, which is capable of identifying FDI shocks and analyzing their dynamic effects on macroeconomic variables of an economy.

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4 These figures are not reported in Table 1 but were calculated by the author using the same source, the WDI database.

A Sign-Restricted VAR

Consider the following reduced-form VAR:

$$y_t = B_0 + B_1 y_{t-1} + \cdots + B_p y_{t-p} + u_t. \tag{1}$$

Here t denotes time. $y_t \equiv (Y_t, P_t, FDI_t, EXP_t)'$ is a column vector containing four endogenous variables: output (Y), the price level (P), FDI, and exports (EXP). B_i (i=0,…,p) are coefficient matrices, with B_0 of size 4×1, B_i (i=1,…,p) of size 4×4, and p the lag length. u_t is a column vector of the same size as y_t, containing the error terms.

The error terms are assumed to be linear combinations of the structural shocks contained in a column vector ϵ_t, which is of the same size as u_t. Therefore, the relationship between u_t and ϵ_t can be expressed as $u_t = S\epsilon_t$, where S is a square matrix of size 4×4. The structural shocks in ϵ_t are assumed to have zero mean and unit variance, to be mutually uncorrelated contemporaneously and at all leads and lags, and to be uncorrelated with their own leads and lags.

The reduced-form VAR in (1) can be estimated using OLS to obtain estimates of B_i, u_t and its covariance matrix Σ. Therefore, if we know S, then from the reduced-form (1) and $u_t = S\epsilon_t$, we can uncover the structural form of the VAR as follows:

$$S^{-1} y_t = \tilde{B}_0 + \tilde{B}_1 y_{t-1} + \cdots + \tilde{B}_p y_{t-p} + \epsilon_t, \tag{2}$$

where $\tilde{B}_i = S^{-1} B_i$. The structural form of the VAR, once uncovered, allows us to analyze the effects of structural shocks—including the FDI shock that is of primary interest in this paper—on the economic variables in y_t.

It follows from the assumptions made above on ϵ_t that $\Sigma = SS'$. However, this relation is not sufficient to identify a unique S because there are many candidates for S that satisfy it. Therefore, additional restrictions are needed. In this paper, I adopt the scheme proposed by Uhlig (2005) to impose sign restrictions on the impulse response functions (IRFs) of the endogenous variables to structural shocks based on economic theory. A noteworthy feature of this scheme is that it is capable of identifying a part of the matrix S, rather than the whole matrix itself, to study the effects of the structural shock(s) that are of interest here. Without loss of generality, I assume that the FDI shock is the first element of ϵ_t. Thus, identifying this shock amounts to identifying the first column of S.

For details on the sign restriction scheme, the reader is referred to Uhlig (2005) and Vu (2015); here, I briefly outline the procedure used to identify the FDI shock. In this scheme, random draws of B_i (i=0,…,p) and Σ are respectively generated from the normal distributions and Wishart distribution, which are obtained from the estimation of the reduced-form model (1). In addition, random draws of orthonormal matrices D are also generated, which are then used to generate candidate matrices S ~ for S using the formula: $\tilde{S} = CD$, where C is the Cholesky decomposition of Σ. Note that, by construction, $\tilde{S}\tilde{S}' = CDD'C' = CC' = \Sigma$, which guarantees that $\tilde{S}$ is a candidate for S.

For each draw of (B_i, Σ, $\tilde{S}$), the IRFs to the FDI shock are computed, and only the draw under which the signs of the IRFs are consistent with the implications of widely accepted economic theory—details of which are provided below—is retained. A random draw that satisfies the sign restrictions is called a valid draw. Under a valid draw, the matrix S and hence the structural model (2) are identified.

By repeating the process of generating random draws and checking the signs of the IRFs with the sign restrictions imposed as described above, a set of valid draws is obtained, from which statistics such as the median and error bands of the IRFs can be calculated. If the number of valid draws is sufficiently large (e.g., several thousand), the statistics obtained through this numerical procedure closely approximate those that would be obtained from the entire sets of B_i and Σ that satisfy the sign restrictions imposed.

The Sign Restrictions Imposed

Let us now describe the sign restrictions imposed on the VAR model to identify FDI shocks. The key idea is to identify FDI shocks as a type of aggregate demand (AD) shock in the short run, based on the aggregate demand–aggregate supply (AD–AS) framework. This is grounded in the following reasoning: FDI, as a form of real investment, [5] involves a “time to build”—a lag between the initiation of the investment and its completion, when production begins. Once production starts, investment affects the aggregate supply side of the economy by increasing production capacity, which occurs typically over the medium to long run. During the building phase—such as constructing plants or acquiring machinery and equipment—investment mainly entails the purchase of goods and services for the project, thereby affecting primarily the aggregate demand side. Accordingly, FDI shocks can be regarded as AD shocks in the short run.

Based on this reasoning, I impose the sign restrictions on the IRFs to an FDI shock shown in Table 2. A (positive) FDI shock is defined as one that induces positive responses of FDI, GDP, and the price level in the first period following the shock. Among these responses, the response of FDI is a necessary condition for identifying an FDI shock (i.e., an exogenous change originating from FDI), while the responses of GDP and the price level further characterize the FDI shock as an AD shock.

In addition to FDI shocks, I also identify AS shocks to examine how FDI responds to exogenous changes in GDP. A (positive) AS shock is defined as one that is orthogonal to the FDI shock and induces a positive response of GDP and a negative response of the price level in the first period when it occurs. The contrasting signs of GDP and the price level responses, as shown in Table 2, are sufficient to distinguish the two types of structural shocks.

It worth mentioning that, although these sign restrictions are derived from the AD–AS model, they are also consistent with standard New Keynesian dynamic stochastic general equilibrium (DSGE) models and are widely accepted in macroeconomics.

Table 2: Sign Restrictions Imposed on the VAR to Identify Structural Shocks

	AS shock	FDI shock
GDP (Y)	>0	>0
Price level (P)	<0	>0
FDI		>0
Exports (EXP)		

Note: The sign restrictions are imposed on the first period in which the shock occurs. Blank entries indicate that no sign restriction is imposed.

5 In official statistics, such as the balance of payments system, FDI is defined as the acquisition of 10% or more of the total equity of a foreign enterprise, and it is classified into mergers and acquisitions (M&A) of existing firms and greenfield investment, which involves establishing new firms. In reality, FDI typically includes both types of investment. In the case of FDI inflows to developing countries such as the ASEAN countries studied in this paper, it is highly likely that real investment will occur. This is because greenfield investment accounts for a dominant share of FDI in these economies, and even M&A projects are often accompanied by some form of real investment.

4. Empirical Results

In this section, I present the estimation results and analysis of the effects of FDI using the sign-restricted VAR model described in the previous section.

Data and Estimation of the VAR Model

This study uses annual data for the six ASEAN countries, as described in Section 2. The data are sourced from the World Bank's *World Development Indicators (WDI)* database. For each country, I use the longest available sample period: 1989–2021 for Vietnam and 1970–2024 for the other five countries.

Among the four variables of the VAR model, real (i.e., constant-price) data are used for GDP and exports, while data for the price level are taken from the GDP deflator. These three variables are transformed into natural logarithms and multiplied by 100 prior to estimation. This transformation facilitates the interpretation of the results, as the IRFs can then be interpreted as percentage changes in each variable.

Regarding FDI, since the data on FDI inflows are negative for some countries and years, a natural logarithm transformation cannot be applied. Therefore, I use the ratio of FDI inflows to GDP, expressed as a percentage, as a proxy for FDI. This approach is justified because, as the data show, FDI inflows are much more volatile than GDP, so most of the variation in the ratio of FDI inflows to GDP reflects fluctuations in FDI inflows themselves.

I estimate a VAR model separately for each of the six ASEAN countries. For each country, the lag length of the VAR is set to two based on the Akaike Information Criterion (AIC).

Estimation Results and Analysis

I now examine the estimation results, which are shown in Figure 1. I begin with the effects of a FDI shock. By construction, this shock raises FDI as well as GDP and the price level in the first year. The effects on GDP persists over the medium and long run, approximately five to fifteen years, in most countries. The effects on exports are also positive, but their patterns differ across countries. In Thailand, exports increase quickly and persistently, while in Malaysia and Singapore they increase only in the first one or two years before becoming statistically insignificant. In Indonesia and the Philippines, it takes about three to four years for the FDI shock to generate significant and positive effects on exports, while in Vietnam the lag is even longer, at around eight years.

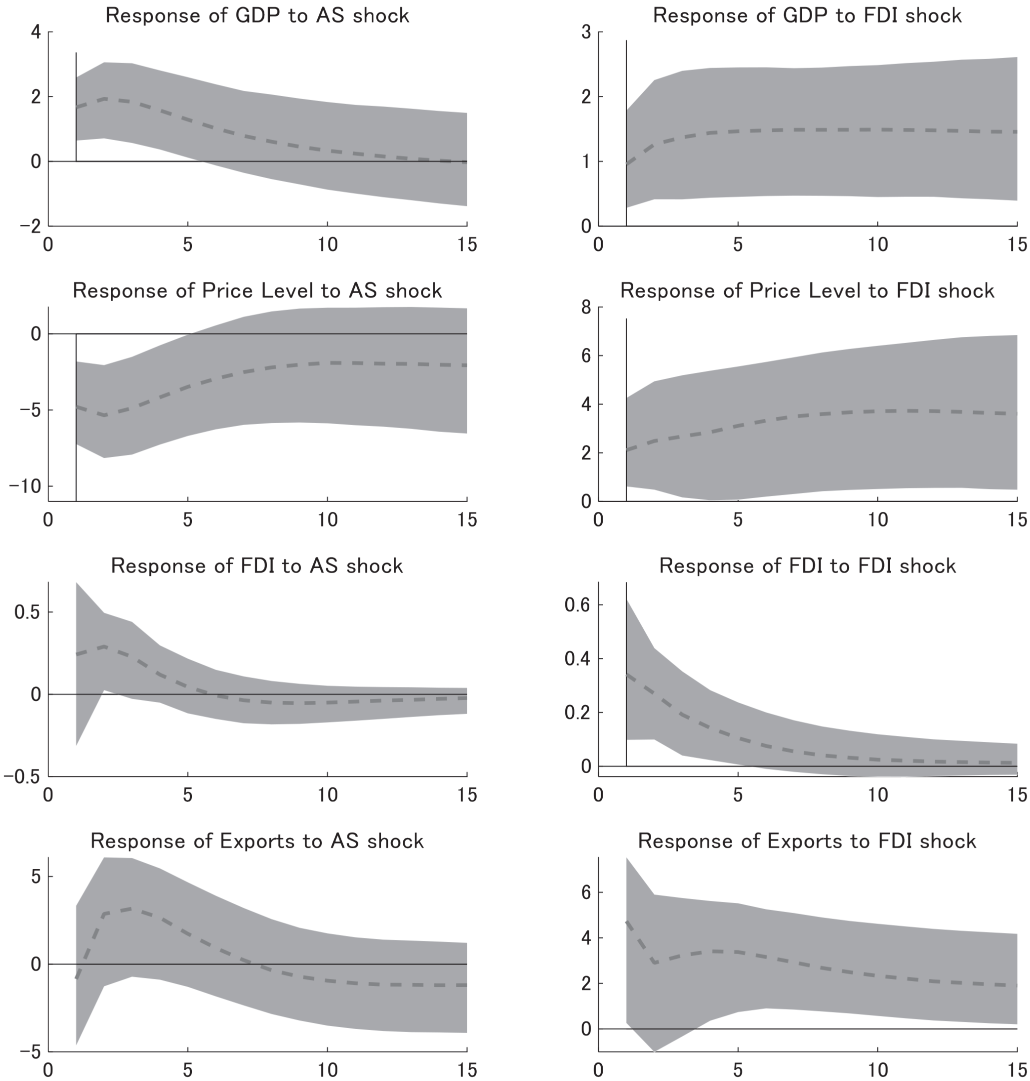
These results indicate that the relationships between FDI, GDP, and exports are highly dynamic. Consequently, static single-equation models—often estimated using panel data—which consider only contemporaneous relationships among variables, are insufficient or even inappropriate for capturing such dynamics. This underscores the advantage of the VAR approach adopted in this study.

Let us now turn to the effects of an AS shock. This shock, by construction, raises GDP while lowering the price level in the first year. In all countries, the effects on GDP persist beyond that period. In Malaysia and the Philippines, these effects remain significant even at the ten-year horizon. The AS shock leads to an increase in exports in the Philippines, while its effects on exports in the other countries are not statistically significant.

One issue of particular interest with the AS shock is how FDI responds to it. Figure 1 shows that, in all countries and across most horizons, the responses of FDI to the AS shock are generally insignificant. This indicates that this study finds no statistical evidence of an endogenous FDI response to economic growth, as captured by changes in output.

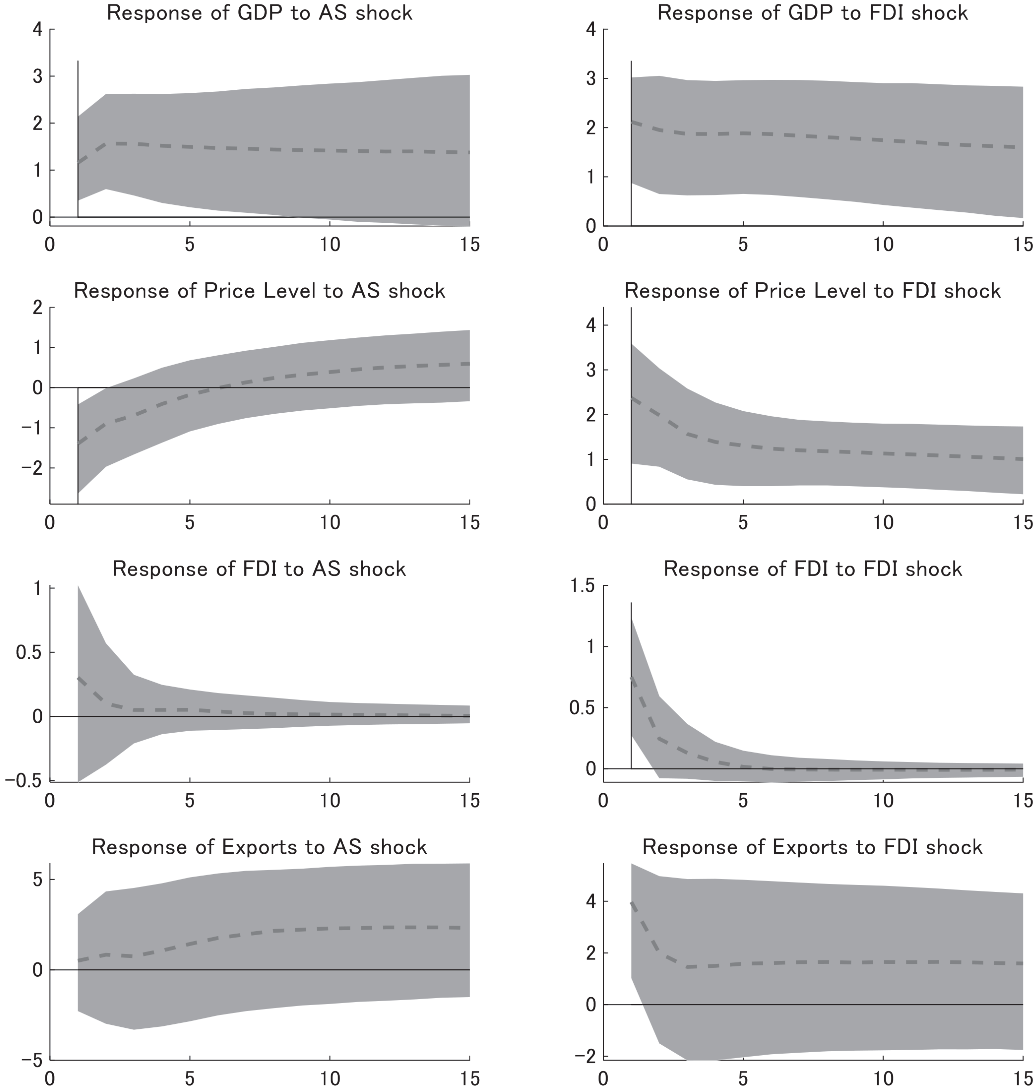
Figure 1: Responses of Economic Variables to Structural Shocks in ASEAN Countries

Indonesia



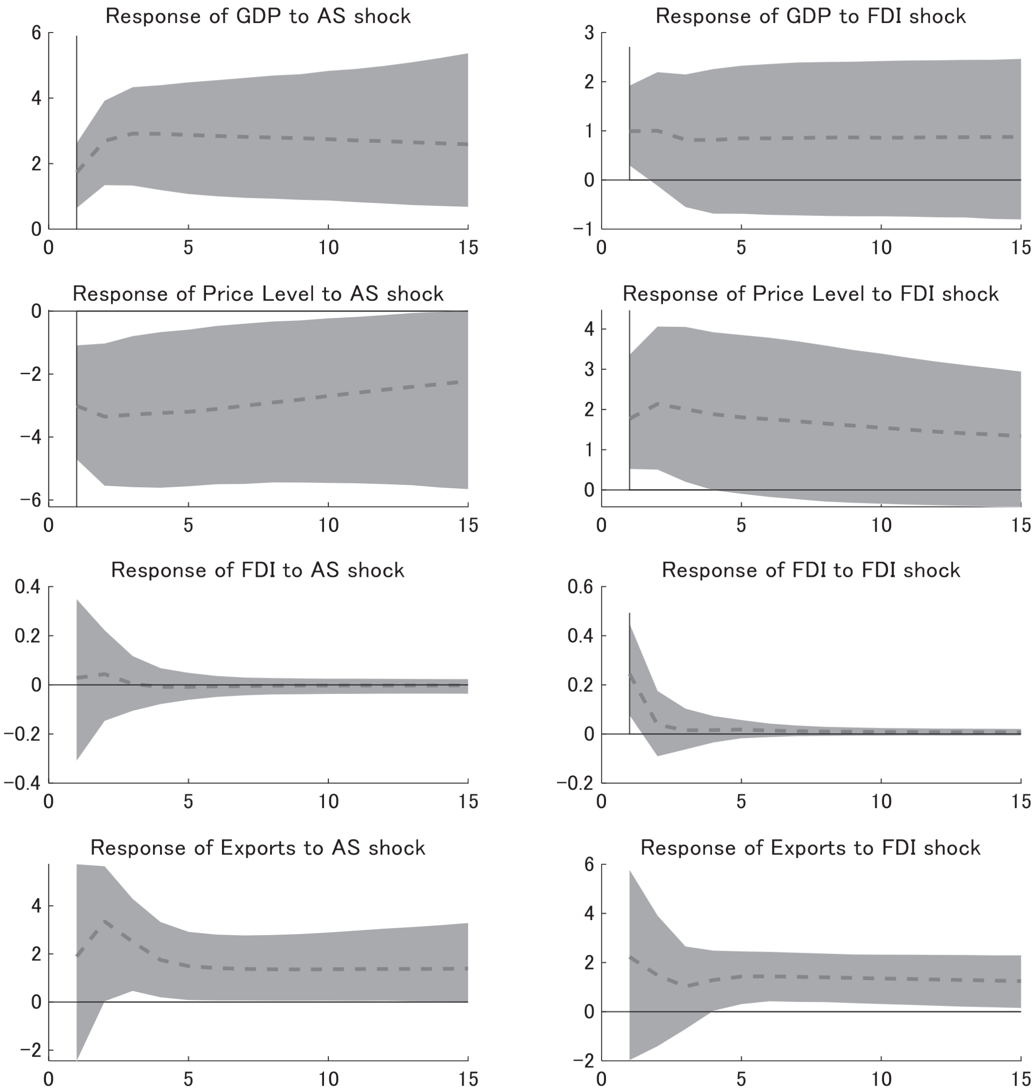
Note: In each panel, the horizontal axis represents years, with the shock occurring in the first year. The vertical axis shows percentage changes in the respective variable. The dashed line indicates the point estimates, while the shaded area represents the 68% error bands. A vertical bar, when present, marks the period in which the sign restrictions are imposed on the IRFs. Source: Author's calculations using the methodology and data described in Sections 3 and 4.

Malaysia



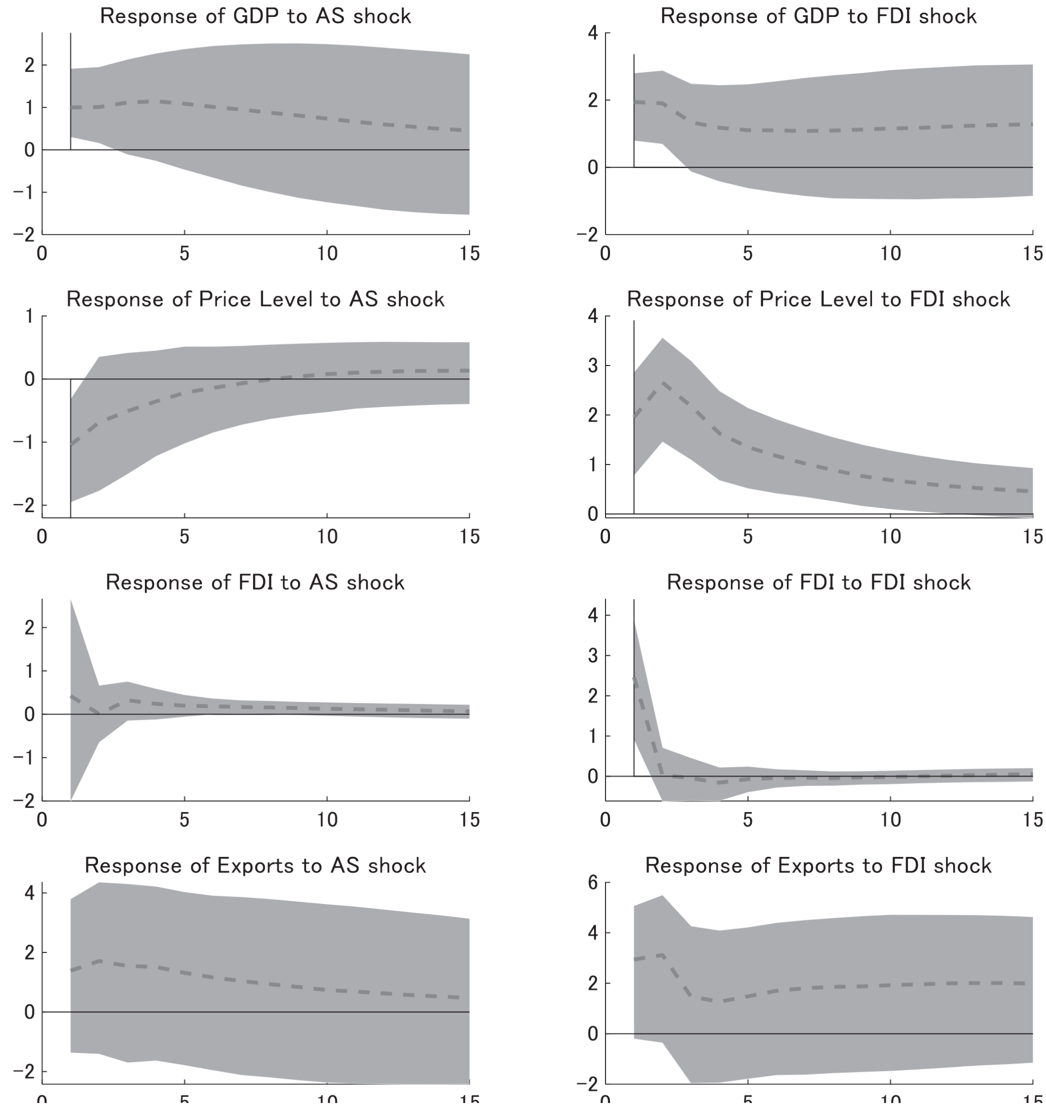
Note: In each panel, the horizontal axis represents years, with the shock occurring in the first year. The vertical axis shows percentage changes in the respective variable. The dashed line indicates the point estimates, while the shaded area represents the 68% error bands. A vertical bar, when present, marks the period in which the sign restrictions are imposed on the IRFs. Source: Author's calculations using the methodology and data described in Sections 3 and 4.

Philippines



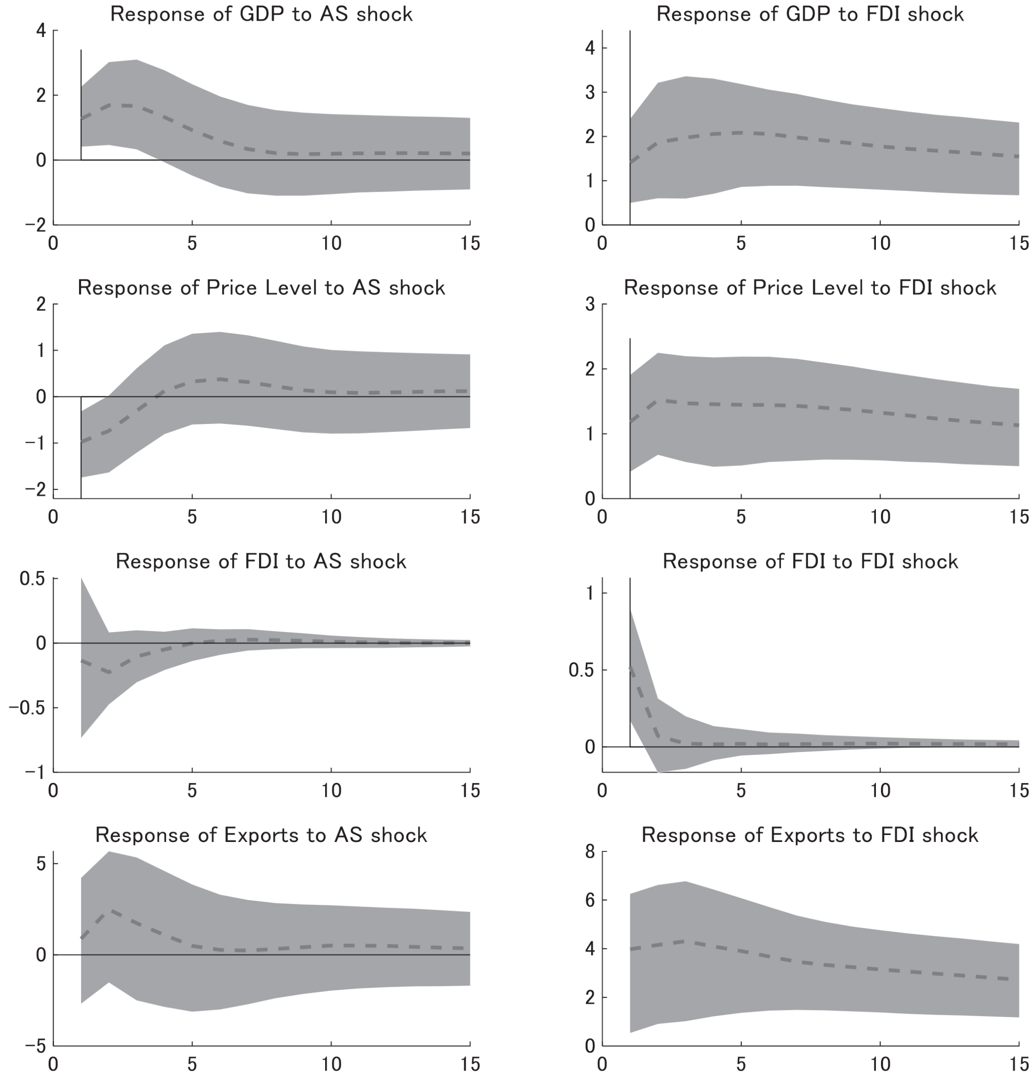
Note: In each panel, the horizontal axis represents years, with the shock occurring in the first year. The vertical axis shows percentage changes in the respective variable. The dashed line indicates the point estimates, while the shaded area represents the 68% error bands. A vertical bar, when present, marks the period in which the sign restrictions are imposed on the IRFs. Source: Author's calculations using the methodology and data described in Sections 3 and 4.

Singapore



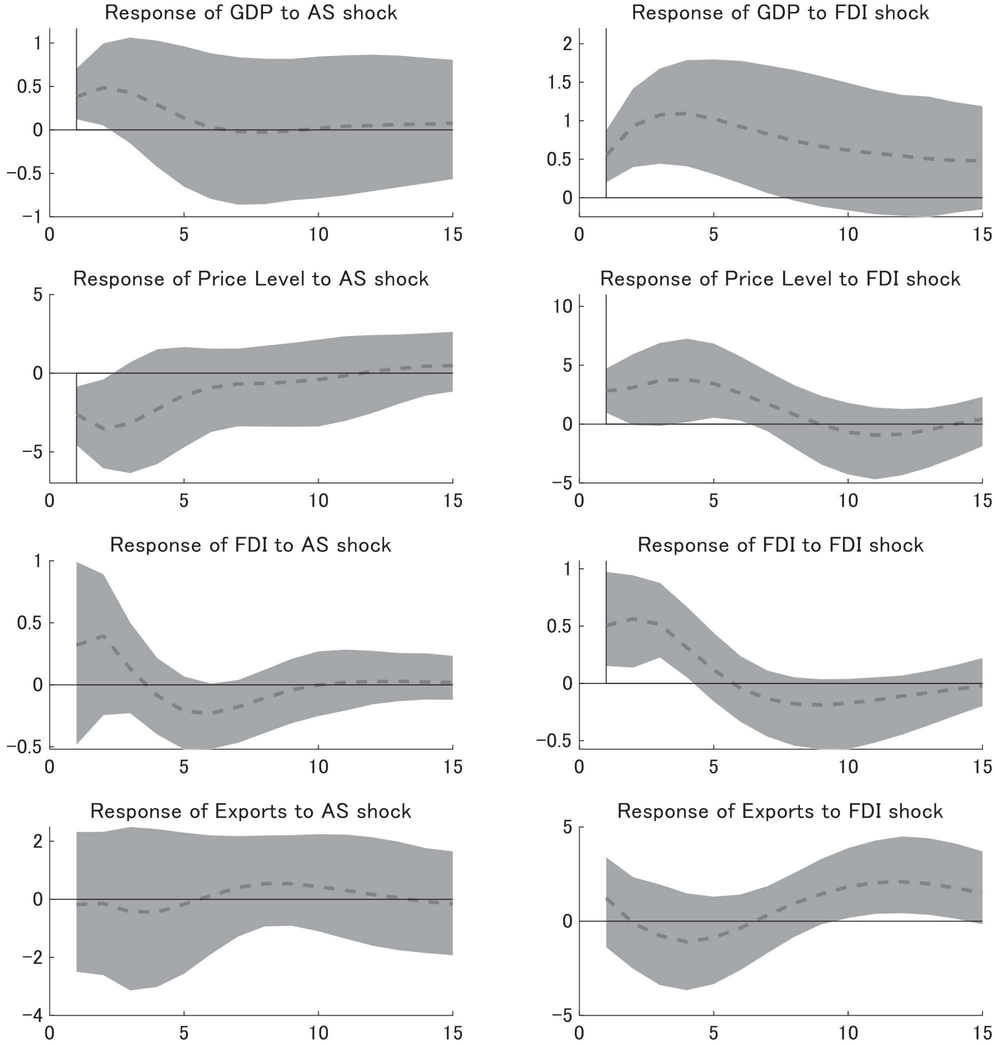
Note: In each panel, the horizontal axis represents years, with the shock occurring in the first year. The vertical axis shows percentage changes in the respective variable. The dashed line indicates the point estimates, while the shaded area represents the 68% error bands. A vertical bar, when present, marks the period in which the sign restrictions are imposed on the IRFs. Source: Author's calculations using the methodology and data described in Sections 3 and 4.

Thailand



Note: In each panel, the horizontal axis represents years, with the shock occurring in the first year. The vertical axis shows percentage changes in the respective variable. The dashed line indicates the point estimates, while the shaded area represents the 68% error bands. A vertical bar, when present, marks the period in which the sign restrictions are imposed on the IRFs. Source: Author's calculations using the methodology and data described in Sections 3 and 4.

Vietnam



Note: In each panel, the horizontal axis represents years, with the shock occurring in the first year. The vertical axis shows percentage changes in the respective variable. The dashed line indicates the point estimates, while the shaded area represents the 68% error bands. A vertical bar, when present, marks the period in which the sign restrictions are imposed on the IRFs. Source: Author's calculations using the methodology and data described in Sections 3 and 4.

FDI multipliers

To further deepen our understanding of the effects of FDI, I perform a quantitative assessment by estimating the *FDI multiplier*, an idea inspired by the fiscal policy multiplier used in public finance to measure the impacts of fiscal policy. Simply put, the FDI multiplier indicates the increase in GDP in dollar terms associated with a one-dollar increase in FDI. More specifically, within the VAR framework in this paper, the present-value FDI multiplier at the k-year horizon is calculated as follows: [6]

$$m_k = \frac{\sum_{j=0}^{k}(1+r)^{-j}(y_j/100)}{\sum_{j=0}^{k}(1+r)^{-j}\{(fdi_j/100)[(y_j/100)+1]+(\overline{fdi}/100)(y_j/100)\}}$$

where y_j and fdi_j are the IRFs of GDP and FDI (as defined above) to the FDI shock at horizon j, [7] $\overline{fdi}$ is the sample average of FDI, and r is the real interest rate.[8]

Table 3 reports the median estimates of the FDI multiplier. Two key findings emerge. First, in all countries, the FDI multipliers increase steadily over time, from the short to the medium and long run. For instance, they rise from 2.8 to 5.5 and then to 10.7 in Indonesia, and from 2.5 to 10.0 and then to 16.5 in Thailand, as the horizon extends from one to five and fifteen years. The corresponding averages for the ASEAN-6 are 2.3, 6.6, and 12.0, respectively. This pattern suggests that FDI not only exerts short-run aggregate demand effects but also medium- to long-run aggregate supply effects.

Second, the FDI multipliers differ markedly across countries. At the fifteen-year horizon, they range from 3.3 to 20.2. The Philippines and Thailand exhibit relatively high multipliers of 16.5 and 20.2, respectively, while Vietnam and Singapore record much lower values of 5.7 and 3.3. One plausible explanation for these cross-country differences lies in the varying degrees of linkages and spillovers from FDI to the domestic economy. This explanation is supported by the additional observation form Table 3: the gap between the multipliers of Vietnam and Singapore and those of the Philippines and Thailand widens over the medium to long run, suggesting that the aggregate supply effects of FDI in Vietnam and Singapore are relatively limited.

A complementary explanation relates to differences in FDI intensity. As discussed in Section 2, Vietnam and Singapore have received relatively large FDI inflows, which may have exposed them to the law of diminishing returns: as FDI inflows increase, the additional contribution of FDI to GDP declines. This hypothesis is tested using data from Tables 1 and 3. Table 4 reports the regression results of the fifteen-year FDI multiplier on the ratios of FDI inflows and FDI stock to GDP. Although the sample size is small, the estimated coefficients on the FDI variables are negative, consistent with the diminishing-returns hypothesis. Moreover, the coefficient on the FDI inflows-to-GDP ratio is statistically significant at the 10% level.

6 For a related concept, see Mountford and Uhlig (2009), who calculate the present-value government spending multiplier.

7 The IRFs used here to calculate the FDI multiplier are those reported in Figure 1.

8 Data for the real interest rate are also sourced from the WDI database.

Table 3: FDI Multiplier

Horizon	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
1	2.8	2.5	4.3	0.7	2.5	1.0
2	3.5	3.3	7.9	1.2	4.8	1.3
3	4.2	4.1	10.8	1.6	6.8	1.4
4	4.9	5.0	12.8	1.9	8.6	1.7
5	5.5	5.8	14.4	2.1	10.0	2.0
6	6.2	6.6	16.1	2.3	11.3	2.3
7	6.8	7.2	17.6	2.5	12.3	2.7
8	7.4	7.8	18.9	2.6	13.1	3.2
9	7.9	8.4	20.1	2.8	13.8	3.6
10	8.5	8.8	21.1	2.9	14.4	4.1
11	9.0	9.3	22.1	3.0	14.9	4.6
12	9.4	9.6	22.9	3.1	15.4	5.0
13	9.9	10.0	23.7	3.2	15.8	5.3
14	10.3	10.3	24.5	3.3	16.1	5.5
15	10.7	10.6	25.1	3.3	16.5	5.7

Source: Author's estimations using the VAR model and data described in Sections 3 and 4.

Table 4: OLS Estimation of the Relationship Between FDI and the FDI Multiplier

Dependent variable: FDI multiplier (15-year)					
	Coef.	Ste.	t-value	p-value	Adj. R2
Const.	15.43	2.72	5.67	0.00	0.44
FDI flows (% of GDP)	-0.93	0.42	-2.23	0.09	
Const.	14.67	2.91	5.04	0.01	0.31
FDI stock (% of GDP)	-0.07	0.04	-1.80	0.15	

Source: Author's estimation using data from Tables 1 and 3.

5. Concluding Remarks

This paper examines the effects of FDI on exports and GDP in ASEAN countries, whose economic development experience over the past half century offers a compelling case for analyzing the dynamic relationships between the three variables. To capture these relationships, I employ a sign-restricted structural VAR framework, in which FDI shocks are identified as a type of short-run AD shock.

The main findings can be summarized as follows. First, a positive FDI shock increases GDP in both the short and long run in most ASEAN countries included in the sample. The long run effect of the FDI shock on output suggests that FDI also affects the supply side of the economy through mechanisms such as capital accumulation, positive technological spillovers, and the promotion of competition. Second, the FDI shock also raises exports, although the magnitude and timing of the response vary across countries: in some, the effect is immediate and persistent, while in others it is either short-lived or delayed. Third, the FDI multiplier—a measure of the cumulative effect of FDI shocks on output—increases over time, with ASEAN-average estimates of 2.2 at the one-year horizon and 12.0 at the fifteen-year horizon. Finally, the FDI multiplier varies significantly across countries—ranging between 3.3 to 20.2 at the fifteen-year horizon—and is negatively correlated with the FDI-to-GDP ratio, suggesting that the effects of FDI on output are subject to diminishing returns.

While this paper identifies the stock of FDI as an important factor underlying cross-country differences in the effects of FDI, it is certainly not the only determinant. Other factors—such as the strength of linkages between the FDI sector and the domestic economy—are also likely to play a significant role. A thorough investigations of these additional determinants remains an important avenue for future research.

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Journal of International Economic Studies (2026), No.40, 71–92
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Why Nations Prosper?

Chandra Natadipurba
Lembaga Riset Veritas, Bandung, Indonesia

Abstract

The main idea of this paper is that Synechi causes prosperity. I define "Synechi" as "a situation where a political leader or a group of political leaders implement and reinforce a series of free-market policies continuously without substantial reversal for at least 20 years." To support this, I employ several methods: First, *the difference-in-difference method*, using West Germany, South Korea, and Botswana as the treatment group, and East Germany, North Korea, and Zimbabwe as the control group, to simulate a "natural experiment." Second, *direct Method of Agreement* using data from 34 countries. I utilize data from the Maddison Project Database on long-run GDP per capita published in early 2018, along with other relevant data sources. This approach is novel because previous papers have only shown a correlation between free-market policies and prosperity, whereas I attempt to establish a causal relationship through these rigorous methods.

Keywords: Free market, Synechi, Prosperity, Difference-in-difference, Maddison

***JEL classification:* O10, O11, O20, O21, P00**

Chandra Natadipurba is the Director of Veritas Research Company, Bandung, Indonesia (bonaveritas.com), and the sole author of this paper. He is deeply grateful for the invaluable inputs provided by the journal editor and reviewers over five years of rewriting and revision.

1. Introduction

This paper challenges widely accepted explanations for national prosperity—such as democracy, geography, culture, and institutions—arguing that these theories fail to account for key anomalies. In their place, it introduces a novel, falsifiable concept: **Synechi**, defined as "a situation where a political leader or a group of political leaders implement and reinforce a series of free-market policies continuously without substantial reversal for at least 20 years."

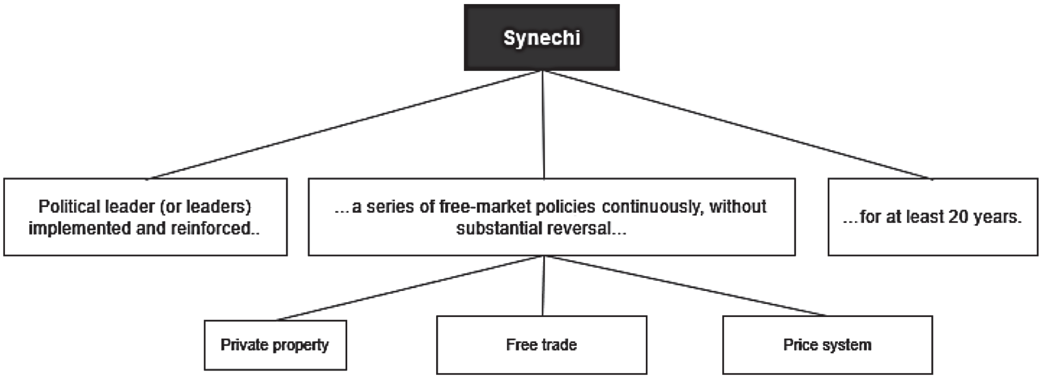
The paper makes three key contributions: (1) it is among the first to apply both difference-in-difference and method of agreement approaches to causally demonstrate that long-term policy consistency drives prosperity; (2) it introduces Synechi as a new, precise framework; and (3) it offers a clear, testable narrative to explain why some nations succeed while others stagnate.

The remainder of this paper is organized as follows: Section 2 defines key concepts and methods. Sections 3 and 4 explain data methodology, critique existing explanations, and argue for a new thesis. Section 5 outlines the empirical strategy, discusses findings, and Section 6 concludes.

2. SYNECHI: DEFINITION AND MECHANISM

My answer to the question of 'why nations prosper' is "Synechi". I coined this term as "a situation where a political leader or a group of political leaders implement and reinforce a series of free-market policies continuously without substantial reversal for at least 20 years." Synechi, derived from the Ancient Greek word συνέχεια (sunékheia) meaning "continuity," signifies the sustained implementation of these policies over time. It is formed by combining σύν (sún, "with, together") and ἔχειν (ékhein, "hold"). The pronunciation of Synechi is /sɪˈnɛk.i/ or /sɪn.ɛˈk.i/. Figure 1 describes this definition hierarchically.

Figure 1: Elaboration of Synechi definition



2.1. WHY SYNECHI CAUSES PROSPERITY

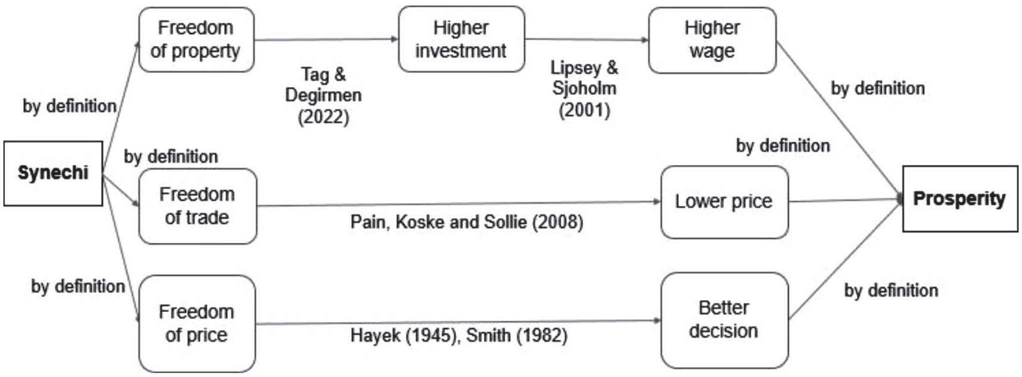
Synechi causes prosperity because it enables individuals to work and trade freely—activities that are the fundamental means of creating wealth. As people mature, they come to understand that wealth is achieved through effort (work) or through voluntary exchange (trade). Freedom is the only system that removes barriers to these activities, and the free market—defined as the combination of private property, free trade, and a price system—maximizes the potential for individuals and societies to generate wealth.

The free market fosters prosperity through three main mechanisms. First, private property rights ensure that individuals can keep the rewards of their labor, incentivizing productivity. Second, free trade allows for voluntary, mutually beneficial exchange and specialization, which boosts efficiency and output. Third, the price system acts as a decentralized information tool, signaling relative scarcity and value. When prices are free to adjust, they guide optimal decision-making, minimize waste, and direct resources where they are most productive.

Altogether, these mechanisms make the free market a dynamic system that expands economic opportunity and efficiently allocates resources. By sustaining this environment over time, Synechi ensures that the benefits of individual freedom and market coordination compound—leading to sustained national prosperity.

Figure 2 shows how this mechanism operates in detail:

Figure 2: The Mechanism of How Synechi Causes prosperity



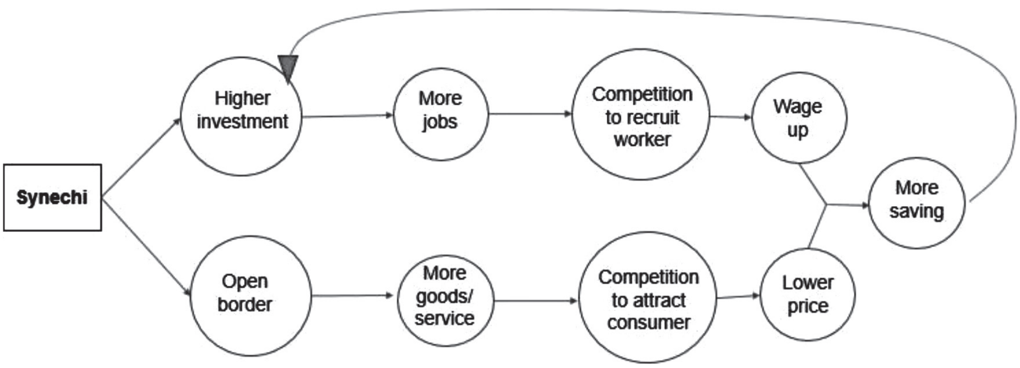
Empirical evidence strongly supports the causality between Synechi and prosperity. Tag & Degirmen (2022), analyzing data from 127 countries over 19 years, found that foreign direct investment (FDI) increases significantly in countries that uphold the rule of law, promote trade freedom, and reduce regulatory barriers. Complementing this, Lipsey & Sjöholm (2001) showed that in Indonesia, factories with foreign investment paid 12% higher wages to blue-collar workers and 20% more to white-collar workers, highlighting how freedom of property rights attracts investment and raises incomes.

Pain, Koske, and Sollie (2008) revealed that globalization and the freedom of price formation—through exposure to lower-priced imports—forces domestic producers to cut excessive price markups, benefiting consumers.

This aligns with Hayek's (1945) foundational argument that decentralized price signals are essential for rational economic coordination. Vernon Smith's (1982) experimental evidence confirmed that even in volatile environments, market-based pricing outperforms centralized control, enabling better decisions.

Together, these findings show that freedom of property leads to higher wages, freedom of trade lowers prices, and freedom of price improves decision-making. This synergy fuels a virtuous cycle: lower prices and higher wages lead to increased savings, which boost investment, expand businesses, and create more jobs—generating long-term improvements in income and well-being for the entire population, as figure 3 shows below.

Figure 3: The Feedback Mechanism of How Synechi Causes Prosperity



2.2. THE IMPLEMENTATION OF A FREE MARKET SYSTEM

The implementation of a free-market system can occur through two primary methods: active and passive. Active implementation involves deliberate reform by political leaders who shift from a non-market system (such as communism) to a market-oriented one—as exemplified by China's transformation beginning in 1978. In contrast, passive implementation occurs when leaders simply refrain from intervention, allowing natural market forces to emerge organically, as seen historically in the early development of the United States, Canada, Australia, and New Zealand.

In the context of Synechi, the phrase "a series of free-market policies without any substantial reversal" refers to a long-term, consistent commitment to policies that foster a functioning market economy. This includes both enacting and sustaining pro-market reforms over an extended period—typically at least 20 years—to allow institutions and behaviors to stabilize, adapt, and produce lasting economic gains.

2.3. THE ILLUSTRATIVE EXAMPLE OF SYNECHI

The case of China serves as a clear illustration of Synechi. After 1978, China launched a series of uninterrupted reforms aimed at market liberalization, private sector growth, and global economic integration. Despite its authoritarian political system, China's consistent economic liberalization without significant policy reversals over several decades led to dramatic economic expansion and its emergence as a global economic power—highlighting the transformative potential of sustained free-market implementation. Table 1 gives a detailed illustration.

Table 1: Illustration of A Series of Free Market Policies

No	Year	Free-market policy	Classification
1	1978	Fifth National Congress "Ten years'development plan". Third Plenum of the 11th party Congress Switch to the reform: "Socialism modernization"	Leader's highest general political decision
2	1979	Joint Venture Law	Private property policy
3	1979	• Establishment of Special Export Zone. • Abolishment of central foreign trade management System	• Free trade policy. • Open Policy (trade & investment)
4	1980	Reorganization of Special Export Zone to Special Economic Zone (SEZ)	• Private property policy • Free trade policy
5	1983	Decision about the reform of People's Bank of China (PBC). Defined transition to the central bank.	• Private property policy • Price system policy
6	1984	Decision of opening 14 coastal cities	• Private property policy • Free trade policy
7	1985	Dismantle of People's Commune (Agriculture policy; Private Property)	Private property policy
8	1985	• State Monopoly Purchasing system abolished in most fields. • Domestic free market trade was permitted for most goods.	Price system policy
9	1986	Foreign Capital Enterprise Law	Private property policy

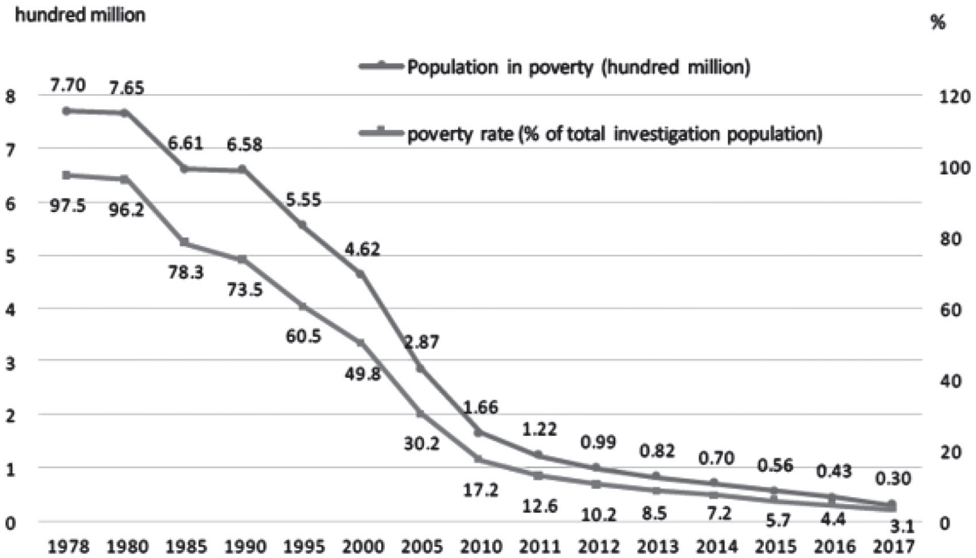
10	1987	Transition from enterprise income tax system to contract responsibility system. Bankruptcy Law	Private property policy
11	1989	The Fourth Plenum of the 13th Party Congress "Keep the Opening" Policy	Leader's highest general political decision
12	1991	Establishment of Shenzhen security exchange market	• Private property policy • Price system policy
13	1992	Spring Tour of Deng Xiaoping Re- acceleration of Reform The 14th Party Congress "Socialist Market Economy"	Leader's highest general political decision
14	1993	The Company Law was adopted for the first time by the National People's Congress Standing Committee	Leader's highest general political decision
15	1994	• China abolished the official rate of exchange of their currency • The Foreign Trade Law was adopted for the first time by the National People's Congress Standing Committee	• Free price • Free trade policy
16	1998	China launched a 3 year plan to reform and restructure State-owned Enterprises (SOEs) which led to widespread job losses but paved the way for China's economy to boom in the coming years.	Private property policy
		milestone of Synechi (20 years since 1978)	
17	2001	China became a member of the World Trade Organization (WTO)	Free trade

This table is adapted and summarized from Shimomura's work (1994)

Let's see the story behind table 1. China began its transition to a free-market economy under Deng Xiaoping in 1978, gradually implementing the pillars of economic freedom: free pricing, free trade, and private property rights. Throughout the 1980s, these reforms were steadily installed. A pivotal political commitment in 1989 reinforced China's direction, and by 1998, the country had achieved 20 years of uninterrupted pro-market reforms—qualifying as a case of Synechi. Although minor setbacks occurred in 2009 and 2017, the core market-oriented momentum remained intact. Had China not pursued Synechi, its 2016 income per capita would have remained at $4,206, potentially stuck in the middle-income trap. Instead, it experienced an extraordinary transformation. Between 1978 and 2018, China lifted 740 million people out of poverty—the largest and fastest poverty reduction in human history. This transition was catalyzed by Deng's leadership following Mao Zedong's death, marking a decisive shift from central planning to market liberalization.

Figure 4 which was provided by Garnaut, Ross & Song, Ligang (2012) shows that poverty rate of China decreased spectacularly during 1978 – 2018. While China's path was gradual, other countries like Singapore, South Korea, and Taiwan reached prosperity more rapidly through swift policy shifts. In contrast, countries such as Serbia and Chile took longer, and others like the Czech Republic still benefited despite experiencing some reversals. The lesson is clear: early and sustained adoption of free-market policies is critical, and the pace and continuity of these reforms significantly influence long-term national outcomes.

Figure 4: The Decline of Poverty in China



Source: Garnaut, Ross & Song, Ligang (2012)

2.4. THE 20-YEAR TIME HORIZON: A BEHAVIORAL-ECONOMIC RATIONALE

But why is a 20-year period of uninterrupted implementation required for a system to be considered Synechi? I initially identified this threshold as an empirical regularity while examining historical data from both formerly poor nations that have since become wealthy and those that remain poor. Then I realized why this happens. The 20-year duration required to qualify a system as Synechi is based on both empirical observation and a behavioral-economic rationale. The underlying mechanism is twofold: (1) a typical human needs around 20 years from birth to mature and enter the labor force as a productive agent; and (2) transformational economic change, such as a shift from a command economy to a market-based one, requires intergenerational adaptation. Families, institutions, and individuals must internalize new incentives, values, and skillsets—processes that unfold over extended time horizons.

A thought experiment highlights the difference: a child born in the morning after communism collapses in previous night is educated to compete in a free market and becomes a contributor to national wealth. In contrast, a child born under communism is socialized into political loyalty and privilege-seeking, not value creation. This contrast explains how different economic systems shape human capital and social mobility.

Moreover, Synechi's timeline reflects broader systemic transitions: institutions shift from rent-seeking to rule enforcement; entrepreneurs need time to emerge and scale; and cultural habits must pivot from dependency to trade. It is analogous to an airplane that must gather sufficient speed in *a certain amount of time* on the runway before achieving lift-off. In conclusion, Synechi is not a utopian ideal—it is a time-consistency theory of prosperity, rooted in human behavior. It holds regardless of political regime; what matters is whether leaders—democratic or authoritarian—consistently uphold free-market reforms for at least 20 years.

Political leaders play a vital role in this process, regardless of whether they are democratically elected, monarchs, or authoritarian figures. Their ability to implement and maintain free-market policies is what drives economic outcomes. Jones and Olken (2005) show that leaders significantly impact national economies. However, the type of leader or the origin of free-market policies—whether inherited, forced, or intentionally created—is less important than the consistent implementation of these policies. In summary, Synechi emphasizes the importance of sustained free-market policies, regardless of how or by whom these policies are implemented.

3. DATA METHODOLOGY

This section defines key terms used in the paper, particularly prosperity, which is measured by a country's real GDP per capita—specifically, exceeding USD 12,275 in 2011 Geary-Khamis dollars (exception will be stated), as recorded in the version of Bolt et al. (2018) entitled Maddison Project Database (2018 version). Although the World Bank uses GNI, GDP is used here due to its strong correlation with GNI (Farris et al (2017)) and broader data availability.

The 2018 version of the Maddison Database is intentionally selected to exclude the global distortions caused by the COVID-19 pandemic, allowing for a clearer, pre-pandemic analysis. The study also makes a critical distinction between sustainable prosperity and temporary wealth from natural resource windfalls, such as oil. Countries like Venezuela and Libya, despite vast resource wealth, have not achieved stable prosperity, underscoring the volatility and unsustainability of resource-dependent growth. Thus, this study excludes countries highly dependent on oil, emphasizing that long-term prosperity is not driven by natural resources, but by more stable, systemic economic factors.

4. CRITIQUE OF EXISTING THEORIES

In this section, I will briefly recap several previous theories that attempt to explain why nations prosper, although this recap will not be exhaustive. Subsequently, I will discuss why these existing explanations are unsatisfactory. Specifically, their shortcomings may stem from either (1) the inability of these theories to account for all relevant facts, or (2) their susceptibility to the fallacy of "reverse causality." This section will lay the groundwork for identifying the research gap that this study aims to address. The need for present study arises from emerging contradictions between established facts and existing theories.

Thomas Kuhn (1962), in "The Structure of Scientific Revolutions," argued that crises in knowledge occur when existing knowledge fails to explain anomalies and observed facts. For instance, the theory proposed by Acemoglu, Johnson, and Robinson regarding the importance of good institutions cannot fully explain why China has achieved prosperity despite not being a democratic country. This example highlights a crisis in our understanding. Therefore in this section, I will address contradictions between known facts and previous theories. By the end of this section, readers will likely agree that a new theory is needed to comprehensively explain why nations prosper, taking into account all available evidence. Table 2 shows previous theories review.

Table 2: Previous Theories Review

No	Theory and Paper	Contradictory fact and evidences
1	Level of Democracy (Barro, 1996, 1997): High democracy causes prosperity.	China (low democracy, high prosperity) and India (high democracy, low prosperity) disprove this.
2	Absolute Latitude (Sala-i-Martin, 1997a, 1997b): High latitude causes prosperity.	Singapore (low latitude, high prosperity) and North Korea (high latitude, low prosperity) disprove this.
3	Disease Ecology (McCarthy, Wolf, and Wu, 2000): Low disease prevalence causes prosperity.	Suriname (high malaria, high prosperity) and China (low malaria, low prosperity) disprove this.
4	Landlocked/Coastline (Easterly and Levine, 2001; Bloom and Sachs, 2001): Coastline causes prosperity.	Switzerland (no coastline, high prosperity) and North Korea (coastline, low prosperity) disprove this.
5	Arable Land (Masters and Sachs, 2001): High arable land causes prosperity.	Singapore (low arable land, high prosperity) and Bangladesh (high arable land, low prosperity) disprove this.
6	Constraints on Executive/Expropriation Risk (Acemoglu, Johnson, and Robinson, 2001): High constraints/low expropriation risk cause prosperity.	China (low constraints, high prosperity) and India (high constraints, low prosperity) disprove this. Jamaica (low expropriation risk, low prosperity) also contradicts this theory.
7	Religious Belief (Barro and McCleary, 2003): Low religiosity causes prosperity.	United States (high religiosity, high prosperity) and Cuba (low religiosity, low prosperity) disprove this.
8	Social Capital (Rupasingha, Goetz, and Freshwater, 2000): High social capital causes prosperity.	Bahamas (low social capital, high prosperity) and Kyrgyzstan (high social capital, low prosperity) disprove this.
9	Luck (Easterly et al., 1993): Luck as a factor.	Luck is unfalsifiable and untestable, making it a meaningless variable.
10	Culture (Landes, 2000): Culture causes prosperity.	Hofstede's (2001) cultural dimensions show cultural differences alone do not explain prosperity variations.
11	Education Enrollment (Marquez-Ramos and Mourelle, 2019): Higher education contributes to prosperity.	Pritchett (2001) shows prosperity may lead to higher enrollment, indicating reverse causality.
12	Urbanization (Nguyen and Nguyen, 2018): Urbanization positively impacts growth.	He and Sim (2015) suggest reverse causality, as growth drives urbanization in China's decentralized fiscal system
13	Industrialization (Murphy, Shleifer, and Vishny, 1989): Industrialization causes prosperity.	Barone and Mocetti (2016) show that Venice and Genoa achieved wealth through trade and finance before industrialization, showing reverse causality.

Additional Notes:

- Doucouliagos and Ulubaşoğlu (2008) conducted a meta-analysis of 483 estimates from 84 studies on democracy and growth, finding no direct impact of democracy on growth. Most studies (74%) failed to find a significant positive relationship.
- Meta-analyses for other factors (luck, social capital, religion, arable land, coastline, disease, latitude) are unavailable.
- Many theories fall prey to reverse causality, where prosperity influences the variable rather than the other way around.

In sum, all previous explanations fail to pass the test. Their explanations are either inaccurate, incomplete, or incoherent. In John Stuart Mill's (1882) guidance for conveying causality, he said that "All known causes of a complex set of events are subtracted. What is leftover is said to be the cause." In Conan Doyle's (1890) words, "When you have eliminated all which is impossible, then whatever remains, however improbable, must be the truth." What remains is Synechi, as I will elaborate further.

5. EMPIRICAL ANALYSIS AND DISCUSSION

5.1. DIFFERENCE-IN-DIFFERENCE ANALYSIS

This study employs the Difference-in-Difference (DiD) method to evaluate the impact of Synechi by comparing economic performance before and after its adoption with that of similar countries that did not adopt it. Inspired by the approach in *Natural Experiments in History* by Diamond and Robinson (2010), the study uses "twin country" comparisons—pairs of nations that are nearly identical in culture, geography, and early development, but differ in economic systems.

Three country pairs fit the criteria: West vs. East Germany, South vs. North Korea, and Botswana vs. Zimbabwe. Prior to implementing Synechi, these nations were remarkably similar, making the adoption of free-market continuity the decisive factor behind their economic divergence.

The findings strongly challenge the idea that long-term prosperity is determined by inherent traits such as geography, culture, or climate. Instead, the results point to Synechi—continuous free-market policy without reversal—as the pivotal factor explaining why some nations became prosperous while their twins stagnated.

The econometrics model of DiD is as follows:

$$GDP_{it} = \beta_0 + \beta_1 PRESENCE_i + \beta_2 TIMEt + \beta_3 PRESENCE_i \cdot TIMEt + \varepsilon_{it}$$

This will be called as model 1. With this model, data are calculated to produce β_0, β_1,β_2, and β_3.

(1) GDPit is the proxy to prosperity that is real gross domestic per capita of country *i* in period *t* (before and after Synechi)
(2) PRESENCEi is whether Synechi is implemented in country *i*, 1 if present (those are West Germany, South Korea and Botswana) and 0 if not present (those are East Germany, North Korea and Zimbabwe)
(3) TIMEt is the period, for West Germany 1 (from year 1952 to 1989) and 0 (for year 1950 and 1951), for South Korea 1 (from year 1964 to 2016) and 0 (for year 1950 to 1963), for Botswana 1 (from year 1967 to 2015) and 0 (for year 1950 to 1966).
(4) ε_{it} is the error term.

The study uses GDP per capita as a proxy for prosperity and employs a Difference-in-Difference (DiD) methodology to assess the impact of Synechi, using its adoption year as the key independent variable—1952 for West Germany, 1964 for South Korea, and 1967 for Botswana. Each country pair is modeled individually, and a fourth combined regression includes all three, assuming that differences in start years are negligible.

DiD is chosen because it inherently controls for unobserved, time-invariant confounders and minimizes omitted variable bias, leveraging longitudinal data to compare treated and untreated groups over time. The critical assumption is parallel trends—that in the absence of Synechi, the treated and control countries would have followed similar economic paths. Therefore DiD framework is robust and suitable for isolating the causal effect of sustained free-market policy (Synechi) on prosperity.

Table 3 shows that the calculations yield the following results:

Table 3: Result of Difference-in-difference calculation (Model 1)

	West and East Germany	South and North Korea	Botswana and Zimbabwe	All combined dataset
Constant	4,191.22	617.36***	547.41***	1,472***
	(4,100.10)	(225.04)	(207.87)	(62.33)
PRESENCE	5,119.25	302.07	541.76*	614.9***
	(5,798.41)	(318.25)	(293.97)	(212.8)
TIME	4,054.33	187.64	54.59	1732***
	(4,206.61)	(279.12)	(274.13)	(50.55)
PRESENCE*TIME	11,060.00*	2,014.66***	2,557.41***	11,855***
	(5,949.05)	(394.74)	(387.68)	(230.1)
Observations	80	132	134	346
R-squared	0.677	0.641	0.726	0.532

Robust standard errors (robust against heteroskedasticity and clustering) in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculation based on the Maddison Project Database (Bolt et al., 2018). Data for West Germany and East Germany are from Merkel (1991) and have been converted to real 2011 USD using historical exchange rates and CPI data to ensure consistency with the rest of the dataset

Implementing Synechi led to significantly higher GDP per capita: West Germany outperformed its counterpart by $11,060, South Korea by $2,014, and Botswana by $2,557 (all in 2011 USD). In the combined dataset, Synechi countries outperformed by 11,855. All results are statistically significant between 90% to 99% confidence level.

What is the Synechi story behind this result?

(1) West Germany and East Germany

Ludwig Erhard, who served as West Germany's Minister of Economics (1949–1963) and later as Chancellor (1963–1966), is widely regarded as the architect of West Germany's Synechi transformation. In contrast, East Germany, under Chancellor Otto Grotewohl, adhered to a rigid communist economic model.

Erhard (1958) initiated Synechi by abolishing price controls through a series of currency reforms beginning in 1948 and completed by 1952. These reforms lifted price restrictions across critical sectors such as manufacturing, coal, iron, steel, food, rent, and transportation. Tax incentives introduced in 1949 encouraged saving, while West Germany's entry into the European Payments Union in 1950 and the creation of the Coal and Steel Community in 1951 marked key steps in trade liberalization. The 1951 Law to Promote Export further incentivized businesses by allowing tax-free reserves. Collectively, these policies laid the foundation for what became known as the West German economic miracle—a powerful demonstration of Synechi's transformative impact.

(2) South Korea and North Korea

In South Korea, Park Chung Hee initiated Synechi through trade liberalization reforms during 1964–1965, expanding the list of importable goods from 500 to 1,500 and shifting from a restrictive positive-list system to a more open negative-list framework.

According to Frank, Kim, and Westphal (1975), these reforms catalyzed dramatic improvements across South Korea's economy between 1964 and 1966. Meanwhile, North Korea—under Kim Il-sung—formally embraced the Juche ideology in 1973. This system emphasized self-reliance and socialist planning, leading to central control over all economic activity. Unlike the South, the North saw stagnation, reinforcing the stark contrast in outcomes between Synechi and its absence.

(3) Botswana and Zimbabwe

Botswana's success was driven by its early post-independence leaders: Seretse Khama and Quett Masire. Masire (2007), who served as both finance minister and later president, played a key role in shaping a market-oriented economy. Evidence of their commitment to Synechi includes the 1967 diamond concession granted to De Beers, the world's largest diamond company. This partnership marked Botswana's early integration with global markets and its embrace of private investment under stable, pro-market rules.

In contrast, Zimbabwe under Robert Mugabe followed a Marxist-leaning economic model. One of his most damaging policies was the land reform of 2000, which forcibly seized agricultural land and livestock from white citizens and redistributed them to black citizens. Although the policy had egalitarian intentions, its execution destroyed the incentives for investment, property maintenance, and long-term economic planning. The threat of state expropriation created a climate of fear and economic deterioration—an anti-Synechi outcome driven by political ideology over market logic.

5.2. DIRECT METHOD OF AGREEMENT ANALYSIS

The direct method of agreement extends prior reasoning, using broader empirical evidence to show how Synechi causes prosperity. Below I'll provide stylized facts about all high-income European and "Western European Influences" countries.

I use the term "Western European Influences" for nations who adopting Western European political/economic systems, regardless of race or ethnicity. For example, Japanese and Hong Kong residents are included in this criteria, not for their Mongoloid descent or specific custom or artistic traditions, but for their adopted systems. The inclusion of Japan and Hong Kong as Western European Influences extends beyond Angus Maddison's (2001) traditional definition. Japan adopted a free-market system following the Ansei Treaty and Hong Kong adopted its model under 150 years of British governance. Great Britain, not China, declared Hong Kong a free port on June 7, 1841, by Captain Charles Elliot, who was crucial in establishing it as a British colony.

John Stuart Mill (1882) in his book *A System of Logic, Ratiocinative and Inductive* introduced *The Direct Method of Agreement* to convey causality by identifying factors present when a phenomenon occurs. Essentially, in direct method of agreement, a scholar looks for factors that are present when a phenomenon occurs. This method directly compares observed outcomes with theoretical predictions, seeking consistent patterns between Synechi adoption and high-income status. My conclusion, using this method, is that all current high-income countries implemented Synechi, supporting its critical role in achieving and sustaining prosperity.

Tables 4, 5, and 6 illustrate the economic development of various affluent countries, detailing their progress from the initiation of Synechi policies to their status in 2016. These tables present key data points, including the year each nation began its Synechi phase, the GDP per capita at that starting point, the year high-income status was achieved, the corresponding GDP per capita in that initial high-income year, the duration from Synechi's start to achieving high-income status, and their GDP per capita in 2016. Specifically, Tables 4, 5, and 6 also indicate whether each country subsequently shifted to anti-free-market policies after Synechi, with all nations listed in Table 4 (Western European countries) showing "Never" for such a shift.

Table 4: Western European Country GDP Per Capita in Starting Synechi and in 2016

Nations/ Leader who initiate Synechi (Source)	Year of completed Synechi status	GDP per capita in years starting Synechi	Year of achieving high-income status	GDP per capita in first- year high-income status	Years of running Synechi until achieving high-income status	GDP per capita in 2016	Generally ever switch to anti free-market policy after Synechi?
Austria/Franz Joseph I (Bairoch, 1989)	1866	1,925	1969	12,671	103	45,010	Never
Belgium/ Leopold II (Abbeloos, 2008)	1857	2,767	1966	12,548	109	39,733	Never
Denmark/ Frederick VII (Mathias and Pollard,1989)	1857	2,306	1961	12,785	104	45,141	Never
Finland/ Lars Gabriel von Haartman (Hjerppe, 1989)	1860	1,038	1969	13,251	109	38,335	Never
France/ Napoleon III (Becuwe, 2021)	1860	2,404	1964	12,492	104	38,758	Never
Italy/ Camillo Benso (James and O'Rourke, 2012)	1863	1,466	1969	12,317	106	34,989	Never
Netherlands/ Johan Rudolph Thorbecke (Lintsen et al, 2018)	1865	2,672	1964	12,886	99	49,254	Never
Sweden/ Johan August Gripenstedt (Sandberg, 2001)	1865	1,646	1962	12,806	97	44,371	Never
Switzerland/ Friedrich Frey-Herose (Bairoch, 1989)	1854	1,828	1956	12,825	102	61,844	Never
United Kingdom/ Robert Peel (Ronald and O'Rourke, 2003)	1846	2,859	1961	12,385	115	39,162	Never

Source: GDP per capita data from Bolt et al. (2018) Maddison Project Database; Synechi starting years and policy analysis based on author's calculations from historical documentation cited in references.

Table 5: Eastern European Country GDP Per Capita in Starting Synechi and in 2016

Nations/ Leader who initiate Synechi (Source)	Year of completed Synechi status	GDP per capita in years starting Synechi	Year of achieving high-income status	GDP per capita in first- year high-income status	Years of running Synechi until achieving high-income status	GDP per capita in 2016	Generally switch to anti free-market policy after Synechi?
Bulgaria/ Stefan Stembolov (Perry, 1993)	1887	2,002	2007	13,709	120	17,953	Yes
North Macedonia/ Franz Joseph I (Bairoch, 1989)	1887	2,002	2013	12,421	126	13,887	Yes
Croatia/Franz Joseph I (Bairoch, 1989)	1866	1,925	1974	12,374	108	21,625	Yes
Czech Republic/Franz Joseph I (Bairoch, 1989)	1866	1,925	1970	12,527	104	31,089	Yes
Slovak Republik/ Franz Joseph I (Bairoch, 1989)	1866	1,925	1985	14,361	119	26,713	Yes
Hungary/Franz Joseph I (Bairoch, 1989)	1866	1,925	1988	12,486	122	24,047	Yes
Poland/Franz Joseph I (Bairoch, 1989)	1866	1,925	1999	12,902	133	26,002	Yes
Serbia/Franz Joseph I (Bairoch, 1999)	1866	1,925	2011	12,463	145	14,001	Yes
Montenegro/Franz Joseph I (Bairoch, 1989)	1866	1,925	1980	14,223	114	18,244	Yes
Slovenia/Franz Joseph I (Bairoch, 1989)	1866	1,925	1971	12,586	105	28,761	Yes
Estonia/Tsar Alexander II (Moon, 2001)	1861	1,728	2001	12,534	140	26,173	Yes
Latvia/Tsar Alexander II (Moon, 2001)	1861	1,728	1982	12,360	121	23,362	Yes
Lithuania/Tsar Alexander II (Moon, 2001)	1861	1,728	1988	12,738	127	26,182	Yes

Source: GDP per capita data from Bolt et al. (2018) Maddison Project Database; Synechi starting years and policy analysis based on author's calculations from historical documentation cited in references.

Note: • Croatia, Czech-Slovak Republic, Hungary, Poland, Serbia, Montenegro, and Slovenia were used to be part of the former Empire of Austro-Hungary. Estonia, Latvia, and Lithuania had been part of the Russian Empire since the end of the 18th century, but after the Russian Revolution of 1917 they became independent states.

Tables 4 and 5 highlight significant economic growth in Western and Eastern European nations over decades, demonstrating consistent policy environments and substantial GDP per capita increases from Synechi's start to 2016. Achieving high-income status took 92 to 115 years, reflecting long-term economic strategies. Eastern Europe, initially capitalist, shifted to communism post-WWII under Soviet influence, disrupting growth; after communism's 1990 collapse, they reverted to free markets, rebuilding price systems and private property, though free trade persisted.

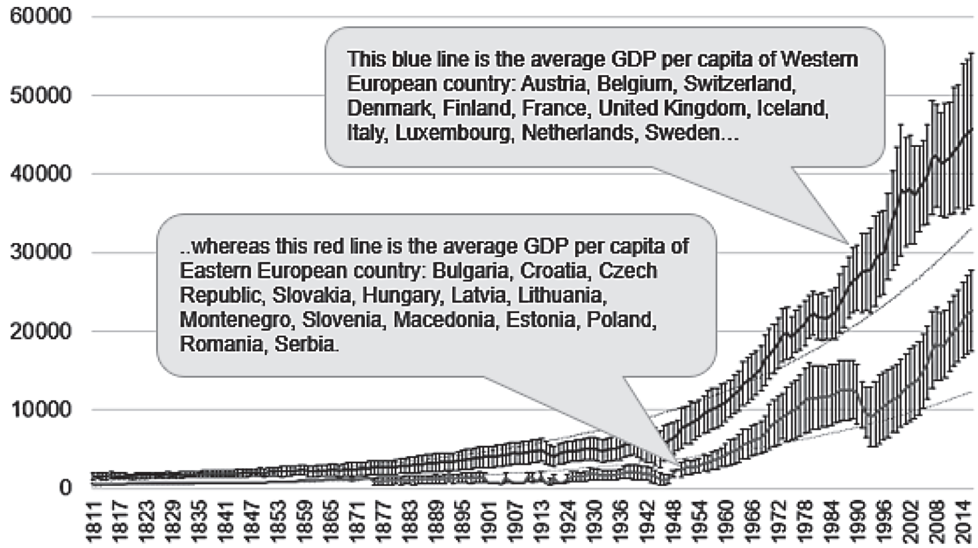
Table 6: Western European Influences Country GDP Per Capita in Starting Synechi and in 2016

Nations/Leader who initiate Synechi (Source)	Year of completed Synechi status	GDP per capita in years starting Synechi	Year of achieving high-income status	GDP per capita in first- year high-income status	Years of running Synechi until achieving high-income status	GDP per capita in 2016	Generally ever switch to anti free-market policy after Synechi?
Australia/Robert Gouger (Steer, 2017)	1831	1,150	1941	12,857	110	44,783	Never
Canada/John A. Macdonald (Firestone, 1960)	1866	2,894	1944	12,482	78	42,969	Never
New Zealand/ Henry Sewell (Alvarez et al, 2011)	1860	3,058	1958	12,808	98	34,040	Never
United States/ Abraham Lincoln (Merry, 2009)	1862	3,459	1941	12,841	79	53,015	Never
Hong Kong/ Captain Charles Elliot (Shuyong, 1997)	1840	1,235	1976	12,867	136	47,043	Never
Japan/ Commodore Perry (Horie, 1937)	1854	910	1970	12,904	116	36,452	Never
Argentina/ Domingo Faustino Sarmiento (Balze,1995)	1870	2,514	1970	12,259	100	18,695	Yes
Brazil/Manuel Ferraz de Campos Sales (Pinheiro et al, 2004)	1898	639	2010	13,418	112	13,479	Yes
Chile/Manuel Monti (Mayo, 1981. Caputo and Saravia, 2018)	1854	1,037	2005	13,309	151	21,446	Yes
Mexico/Porfirio Díaz (Skidmore and Smith, 2005)	1894	1,326	2005	13,018	111	15,803	Yes
Uruguay/Lorenzo Latorre (Bonino-Gayoso et al, 2015)	1876	3,156	2008	13,194	132	19,896	Yes

Source: GDP per capita data from Bolt et al. (2018) Maddison Project Database; Synechi starting years and policy analysis based on author's calculations from historical documentation cited in references.

Table 6 examines Western European Influences (Australia, Canada, New Zealand, U.S., etc.), detailing their Synechi timelines, GDP per capita growth, and high-income status achievements. Most maintained post-Synechi free-market policies, achieving high-income status in 78 to 151 years.

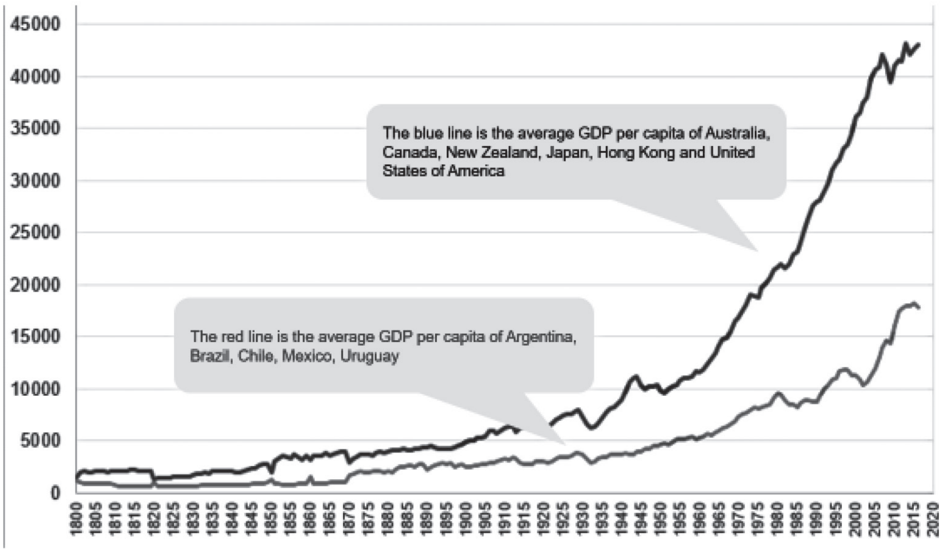
Figure 6: Comparison of Western Europe and Eastern Europe GDP per capita



Source: Author's calculation based on Bolt et al (2018)

Western and Eastern Europe implemented Synechi in the mid-19th century but diverged as Eastern Europe adopted communism (1945-1990), stalling growth, as Figure 6 shows. Figure 6 compares GDP per capita trends (1811-2014) between Western and Central/Eastern European countries; Western Europe consistently outperformed with significant post-WWII growth, while Central/Eastern Europe lagged. Similarly, Western European Influences like the U.S. and Brazil initially embraced free markets, but Brazil and others shifted away due to dependency theory, hindering progress; though both groups are now wealthy, Brazil and similar nations lag behind. Figure 7 illustrates this comparison:

Figure 7: GDP per Capita in Western European-Influenced Economies: Consistent vs. Inconsistent Free Market after Synechi



Source: Author's calculation based on Bolt et al (2018)

Figure 7 contrasts GDP per capita trends (1800-2020) for "blue line" nations (Australia, Canada, etc.) and "red line" nations (Argentina, Brazil, etc.). Post-1900, "blue line" countries experienced exponential growth, while "red line" countries showed slower, inconsistent growth reflecting economic challenges.

Western Europe, Eastern Europe, and Western European Influences were the first civilizations to achieve economic "take-off," reaching high-income status over a century. This progress, driven by free-market systems, significantly reduced poverty, improved life expectancy, basic needs access, and living standards.

5.3. FURTHER REGRESSION ANALYSIS

In addition to the previous analysis, I will conduct a regression analysis incorporating a dummy variable. Countries that consistently adhered to the free-market system will be assigned a dummy variable of 1 (NeverSwitch), and 0 otherwise. This will be referred to as model 2. Beside model 2, I will also test the effect of located in Europe (model 3 and 4) and substituting NeverSwitch with variable of years duration after implementation of Synechi until 2016 (model 5). Therefore, the models are as follow:

Model 2: $GDP_1 = \beta_0 + \beta_1 GDPSyn_i + \beta_2 NeverSwitch + \varepsilon_{it}$

Model 3: $GDP_1 = \beta_0 + \beta_1 GDPSyn_i + \beta_2 NeverSwitch + \beta_3 Europe + \varepsilon_{it}$

Model 4: $GDP_1 = \beta_0 + \beta_1 GDPSyn_i + \beta_2 NeverSwitch + \beta_3 Europe + \beta_3 Europe \times NeverSwitch + \varepsilon_{it}$

Model 5: $GDP_1 = \beta_0 + \beta_1 GDPSyn_i + \beta_2 Years + \varepsilon_{it}$

where

(1) ε_{it} is the error term

(2) GDP_1 is the real GDP per capita of country *i* in year 2016

(3) $GDPSyn_i$ is real GDP per capita of country *i* in year they started Synechi

(4) NeverSwitch is dummy variable, 0 = if the country *i* ever switch to non free market system after they started Synechi, 1 = never

(5) Europe is dummy variable, 0 = if the country is not Europe, 1 = Europe

(6) Europe x NeverSwitch is interaction between Europe and NeverSwitch

(7) Years is years duration between implemented Synechi and year 2016

By running regression of these models, I can check several hypothesis: (1) whether Never Switch into non free market system, or (2) located in Europe or (3) years duration between implemented Synechi and year 2016 that affect GDP per Capita in 2016. But, before discussing regression model, we would see the descriptive statistics. Table 7 shows the descriptive statistics of all countries in previous analysis as follow:

Table 7: Descriptive Statistics for 34 High-income Countries

	N	GDP per capita		Year of starting Synechi	
		in year 2016 (median)	in year starting Synechi (median)	median	standard deviation
Western European	10	41,372	2,116	1860	6.1
Eastern European	13	24,047	1,925	1866	6.5
Western European Influences who were consistent	6	43,900	1,660	1855	13.8
Western European Influences who were not consistent	5	18,695	1,326	1884	11.8

	N	Year of achieving high-income status		Years of running Synechi until achieving high-income status	
		median	standard deviation	median	standard deviation
Western European	10	1964	3.9	104	5.2
Eastern European	13	1988	14.9	121	14.8
Western European Influences who were consistent	6	1951	15.4	104	22.5
Western European Influences who were not consistent	5	2005	16.7	112	12.0

Source: GDP per capita data from Bolt et al. (2018) Maddison Project Database; Synechi starting years and policy analysis based on author's calculations from historical documentation cited in references.

Table 7 displays comparative statistics for 34 high-income countries, categorized by Western European, Eastern European, and Western European Influence, further distinguished by consistent free-market policy implementation. It includes median GDP per capita in 2016 and at Synechi's start, median policy initiation year, and standard deviation of those years.

Western European countries generally began Synechi earlier (median 1860) and achieved higher median 2016 GDP per capita; Eastern European nations showed more variation in policy start years and lower income outcomes. The table also indicates the time taken for each group to reach high-income status post-Synechi adoption.

Findings show Western European countries and consistent Western European Influences reached high-income status faster (median 104 years) than Eastern European or inconsistent counterparts. This supports that long-term consistency in free-market policy implementation significantly causes prosperity.

Table 8 shows the result from calculation which are generated by model 2, 3, 4 and 5.

Table 8: Calculation Result of Model 2, 3, 4 and 5

	Model 2	Model 3	Model 4	Model 5
Constant	19440.00*** (3423.29)	18936.70*** (3411.10)	16440.00*** (3933.60)	-66460.00*** (20300.00)
GDPSyn	1.12 (1.67)	1.30* (1.60)	1.16 (1.68)	4.03 (2.54)
NeverSwitch	21630.00*** (2219.03)	22406.10*** (2152.90)	24150.00*** (3742.50)	—
Europe	—	3996.97 (3129.00)	3996.97 (3129.00)	—
Europe x NeverSwitch	—	—	-2296.96 (4507.70)	—
Years	—	—	—	595.31*** (129.36)
Observations	34	34	34	34
R-squared	0.766	0.762	0.778	0.436

Robust standard errors (robust against heteroskedasticity and clustering) in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculation based on the Maddison Project Database (Bolt et al., 2018)

The regression analysis (Table 8) identified key factors influencing 2016 real GDP per capita (GDP1). The model included GDP at Synechi adoption (GDPSyni), a dummy for consistent free-market policy (NeverSwitch), a Europe dummy, a NeverSwitch × Europe interaction, and Synechi duration. These variables aimed to address potential omitted variable bias and test Synechi's impact robustness.

NeverSwitch was the most significant predictor of GDP1, with a statistically significant coefficient of 24,150, confirming higher income levels for countries maintaining consistent free-market policies. Initial GDP (GDPSyni) was not statistically significant, suggesting no direct effect of starting conditions on long-term outcomes. Neither being in Europe nor the NeverSwitch × Europe interaction showed significant impact, indicating Synechi's consistent effect across regions.

Synechi's duration positively correlated with higher GDP, though modestly ($595 per additional year), supporting longevity's contribution to prosperity. Models 2, 3 and 4 had strong explanatory power (R^2 between 0.76 and 0.79), while Model 5 (duration alone) had weaker fit ($R^2 = 0.436$), reinforcing NeverSwitch's centrality.

Overall, consistent adherence to free-market policies (Synechi) is the most decisive factor for long-term prosperity, rather than geography or starting income. This policy consistency impacts across regions, challenging assumptions of inherent European economic advantages and underscoring Synechi's universal importance for successful economic outcomes.

6. CONCLUSION

While the reasons why certain leaders adopt Synechi (and others do not) remain uncertain—possibly influenced by historical contingencies—the paper provides a powerful framework to explain divergent outcomes in national prosperity.

To conclude, the author rephrases Tolstoy's insight from *Anna Karenina: "Every poor country is poor in its own way, but prosperous countries resemble one another due to their ultimate cause: Synechi."*

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