

## A COMPARATIVE ANALYSIS OF GLOBAL MODELS AND POLICY FRAMEWORK PROPOSAL FOR SEMICONDUCTOR HUMAN RESOURCE DEVELOPMENT IN VIETNAM

### ANÁLISE COMPARATIVA DE MODELOS GLOBAIS E PROPOSTA DE ESTRUTURA POLÍTICA PARA O DESENVOLVIMENTO DE RECURSOS HUMANOS NA INDÚSTRIA DE SEMICONDUTORES NO VIETNÃ

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#### Abstract

This study conducts a comparative analysis of semiconductor human resource development models in four leading countries—the United States, Taiwan, South Korea, and China—to propose a policy framework for Vietnam. Employing a Comparative Institutional Analysis (CIA) approach, the research examines the institutional arrangements, funding mechanisms, and industry-academia linkages that have enabled these nations to build competitive semiconductor workforces. The findings reveal three critical policy gaps in Vietnam's current approach: institutional rigidity preventing competitive compensation for industry-experienced faculty, inadequate funding for essential Electronic Design Automation (EDA) infrastructure, and weak quadruple helix linkages among government, universities, research institutions, and industry. Based on these findings, the study proposes a hybrid policy framework combining Taiwan's institutional flexibility with the United States' shared infrastructure model, operationalized through the establishment of the Institute for Semiconductors and Advanced Materials (ISAM) at Vietnam National University, Hanoi. The proposed framework addresses the urgent need to develop 50,000 semiconductor engineers by 2030 as Vietnam positions itself within global semiconductor supply chain restructuring.

#### Resumo

*Este estudo realiza uma análise comparativa dos modelos de desenvolvimento de recursos humanos na indústria de semicondutores em quatro países líderes — Estados Unidos, Taiwan, Coreia do Sul e China — para propor uma estrutura política para o Vietnã. Empregando uma abordagem de Análise Institucional Comparativa (AIC), a pesquisa examina os arranjos institucionais, os mecanismos de financiamento e as ligações entre indústria e academia que permitiram a essas nações construir forças de trabalho competitivas na indústria de semicondutores. Os resultados revelam três lacunas políticas críticas na abordagem atual do Vietnã: rigidez institucional que impede a remuneração competitiva de docentes com experiência na indústria, financiamento inadequado para infraestrutura essencial de Automação de Projeto Eletrônico (EDA) e ligações frágeis na quádrupla hélice entre governo, universidades, instituições de pesquisa e indústria. Com base nesses resultados, o estudo propõe uma estrutura política híbrida que combina a flexibilidade institucional de Taiwan com o modelo de infraestrutura compartilhada dos Estados Unidos, operacionalizado por meio da criação do Instituto de Semicondutores e Materiais Avançados (ISAM) na Universidade Nacional do Vietnã, em Hanói. A estrutura proposta aborda a necessidade urgente de formar 50.000 engenheiros de semicondutores*



**Keywords:** Semiconductor Human Resources, Comparative Policy Analysis, Vietnam Higher Education, Industry-Academia Linkages, Chips Act, Talent Development.

*até 2030, à medida que o Vietnã se posiciona no contexto da reestruturação da cadeia de suprimentos global de semicondutores.*

**Palavras-chave:** Recursos Humanos em Semicondutores. Análise Comparativa de Políticas. Ensino Superior no Vietnã. Relações Indústria-Academia. Lei de Chips. Desenvolvimento de Talentos.

## 1 INTRODUCTION

The global semiconductor industry has emerged as the cornerstone of contemporary geopolitical competition, with integrated circuits serving as critical inputs for artificial intelligence, telecommunications, defense systems, and virtually all modern electronic devices. The ongoing restructuring of global semiconductor supply chains, accelerated by U.S.-China technological rivalry and post-pandemic supply disruptions, has created unprecedented opportunities for emerging economies to capture segments of this strategic industry. Vietnam, with its established electronics manufacturing base, young demographic structure, and strategic geographic position, has been identified as a potential beneficiary of this restructuring (World Bank, 2024).

However, realizing this potential requires addressing a fundamental constraint: human capital. The semiconductor industry demands highly specialized engineers across multiple domains—IC design, fabrication process engineering, packaging and testing, and equipment maintenance—each requiring years of advanced training and practical experience. Vietnam's current semiconductor workforce of approximately 5,000 engineers represents a fraction of the 50,000 professionals targeted by 2030 under the National Semiconductor Industry Development Strategy (Government of Vietnam, 2024). This tenfold expansion within six years presents an extraordinary policy challenge that cannot be addressed through incremental adjustments to existing higher education programs.

This study addresses the following research questions: (1) What institutional arrangements have enabled leading semiconductor nations to develop competitive human resources? (2) What are the critical policy gaps in Vietnam's current approach to semiconductor human resource development? (3) What policy framework would be most appropriate for Vietnam given its institutional context and development objectives?

The study contributes to the literature on higher education policy transfer and adaptation by examining how developing countries can learn from established models while accounting for local institutional constraints. It also provides practical policy recommendations for Vietnamese decision-makers as they navigate this critical development challenge.

## **2 THEORETICAL FRAMEWORK**

### **2.1 Human capital theory and high-technology industries**

Human capital theory, originating with Schultz (1961) and Becker (1964), provides the foundational rationale for public investment in education as a driver of economic growth. In high-technology industries such as semiconductors, human capital takes on particular significance due to the knowledge-intensive nature of production processes and the rapid pace of technological change. Unlike traditional manufacturing where physical capital and low-cost labor provide competitive advantages, semiconductor competitiveness derives primarily from the specialized knowledge embedded in the workforce (Macher & Mowery, 2008).

The semiconductor industry's human capital requirements exhibit several distinctive characteristics. First, the knowledge base is highly specialized and stratified, with different skill sets required for design, fabrication, packaging, and testing segments. Second, technological change is rapid and continuous, following patterns described by Moore's Law, requiring ongoing workforce reskilling. Third, tacit knowledge—experiential understanding that cannot be easily codified or transferred—plays a crucial role, particularly in fabrication process engineering (Brown & Linden, 2009). These characteristics suggest that effective human resource development requires sustained institutional investment rather than short-term training programs.

### **2.2 Triple helix and quadruple helix models**

The Triple Helix model (Etzkowitz & Leydesdorff, 1995) conceptualizes innovation systems as emerging from interactions among university, industry, and government actors. Each actor contributes distinct resources: universities provide

knowledge generation and talent development; industry offers market signals and practical application contexts; government supplies policy frameworks and public investment. The model emphasizes that these actors increasingly take on hybrid roles—universities engaging in commercialization, firms conducting basic research, governments fostering entrepreneurship.

For semiconductor human resource development, the Triple Helix framework highlights the importance of institutional arrangements that facilitate knowledge flows among these actors. However, the model has been critiqued for underemphasizing the role of civil society and public research institutes (Carayannis & Campbell, 2009). The Quadruple Helix extension incorporates these additional actors, which is particularly relevant in contexts like Vietnam where public research institutes play significant roles in the innovation system.

### **2.3 Policy transfer and institutional adaptation**

Policy transfer studies examine how policies, programs, and institutions developed in one context are adopted and adapted in others (Dolowitz & Marsh, 2000). The literature distinguishes between direct copying, emulation, hybridization, and inspiration as different modes of transfer (Stone, 2012). For developing countries seeking to build semiconductor capabilities, the challenge lies in identifying which elements of successful models can be transferred and which require local adaptation.

Institutional theory suggests that transferred policies must achieve both technical efficiency and social legitimacy within receiving contexts (Scott, 2014). Policies that work well in Taiwan's developmental state context may face implementation barriers in Vietnam's different institutional environment. This theoretical perspective guides our comparative analysis, focusing not only on policy content but also on the institutional conditions that enable or constrain implementation.

## **3 METHODOLOGY**

This study employs a Comparative Institutional Analysis (CIA) approach to examine semiconductor human resource development models across four countries and Vietnam's domestic institutions. The CIA framework, developed within the varieties of

capitalism literature (Hall & Soskice, 2001), examines how different institutional configurations produce different economic outcomes. We adapt this framework to focus specifically on human resource development institutions.

The comparative analysis covers four leading semiconductor nations selected based on their global market positions and diverse institutional approaches: the United States (market-led innovation system), Taiwan (developmental state with strong industry-academia linkages), South Korea (chaebol-centered development), and China (state-directed catch-up strategy). For each case, we examine three dimensions: (1) institutional arrangements for talent development, (2) funding mechanisms and resource allocation, and (3) industry-academia-government linkages.

Data sources include government policy documents, industry reports from organizations such as the Semiconductor Industry Association (SIA), SEMI, and VLSI Research, academic publications, and institutional statistics. For Vietnam, we supplement secondary sources with primary data from five leading institutions: Vietnam National University, Hanoi (VNU-HN); Hanoi University of Science and Technology (HUST); Vietnam National University, Ho Chi Minh City (VNU-HCM); University of Danang (UD); and the National Innovation Center (NIC).

## 4 RESULTS

### 4.1 Comparative analysis of international models

**United States:** The U.S. model combines market-driven talent development with strategic government intervention. The CHIPS and Science Act of 2022 allocated \$52.7 billion for semiconductor manufacturing and research, including \$13.2 billion specifically for workforce development through the National Semiconductor Technology Center (NSTC). The NSTC model is particularly instructive—it creates shared infrastructure (including expensive EDA tools) accessible to universities and startups, reducing barriers to entry for talent development programs. U.S. research universities maintain strong industry connections through mechanisms such as the Semiconductor Research Corporation (SRC), which coordinates pre-competitive research across firms and universities. However, the U.S. faces its own talent shortages, with SIA estimating a need for 67,000 additional workers by 2030.

**Taiwan:** Taiwan's semiconductor success is built on exceptional industry-academia coordination. The Industrial Technology Research Institute (ITRI) has served as a crucial intermediary, spinning off TSMC and UMC while continuously developing talent pipelines. National universities such as National Taiwan University (NTU), National Chiao Tung University (NCTU), and National Tsing Hua University (NTHU) operate specialized IC design programs with direct industry involvement in curriculum development, internships, and faculty recruitment. Taiwan produces approximately 10,000 IC design graduates annually, supported by government programs that subsidize industry practitioners teaching at universities. The model demonstrates how institutional flexibility—allowing competitive compensation, industry secondments, and rapid curriculum updates—can bridge academic and industrial requirements.

**South Korea:** South Korea's model is characterized by chaebol-centered development, with Samsung and SK Hynix playing dominant roles in talent development. These conglomerates operate extensive in-house training programs and maintain close relationships with elite universities such as KAIST, Seoul National University, and Pohang University of Science and Technology (POSTECH). The government's role has been to support this ecosystem through targeted funding for semiconductor education programs and research infrastructure. South Korea announced plans to invest \$450 billion in semiconductor development through 2047, including significant workforce development components. The model demonstrates the effectiveness of concentrated corporate investment but raises questions about transferability to contexts without comparable industrial champions.

**China:** China's approach reflects state-directed catch-up dynamics, mobilizing massive resources to address talent gaps. The "Big Fund" (National IC Industry Investment Fund) has channeled over \$50 billion into semiconductor development since 2014. For human resources, China has established specialized institutions such as the National Integrated Circuit Industry-Education Integration Innovation Platform and significantly expanded enrollment in IC-related programs at leading universities. The country has also aggressively recruited overseas talent through programs like the Thousand Talents Plan. Despite these efforts, China faces persistent talent shortages estimated at 200,000 engineers, and U.S. export controls have constrained access to advanced technologies and experienced personnel. The Chinese case illustrates both the possibilities and limitations of state-directed approaches.



**Table 1***Comparative Analysis of National Semiconductor HR Development Models*

Dimension	United States	Taiwan	South Korea	China
<b>Primary Model</b>	Market-led with strategic intervention	Developmental state coordination	Chaebol-centered development	State-directed catch-up
<b>Key Institution</b>	NSTC, SRC, Research Universities	ITRI, NTU/NCTU/NTHU	Samsung/SK Hynix, KAIST, SNU	Big Fund, Tsinghua/Peking/Fudan
<b>Funding Mechanism</b>	CHIPS Act \$52.7B, Industry consortia	Government programs, Industry co-investment	\$450B national plan, Chaebol investment	Big Fund \$50B+, Provincial funds
<b>Industry-Academia Linkage</b>	SRC coordinates pre-competitive research	Industry faculty, Subsidized practitioner teaching	Corporate training programs, Elite university pipeline	Industry-Education Integration Platform
<b>Annual Graduate Output</b>	~5,000 (shortage of 67,000 by 2030)	~10,000 IC design specialists	~8,000 semiconductor engineers	~20,000 (shortage of 200,000)
<b>Key Strength</b>	Research excellence, Shared infrastructure	Institutional flexibility, Strong coordination	Concentrated investment, Industry leadership	Scale of mobilization, State resources

Source: Compiled by authors from SIA (2024), SEMI (2024), government documents

#### 4.1 Assessment of Vietnam's current approaches

Vietnam's semiconductor human resource development is currently distributed across several institutions, each with distinct approaches and constraints. Our analysis of five leading institutions reveals both emerging capabilities and significant limitations.

**Vietnam National University, Hanoi (VNU-HN)** operates semiconductor-related programs through multiple member universities, including the University of Engineering and Technology (UET), University of Science (HUS), and University of Technology (UT). VNU-HN's strength lies in its multidisciplinary structure, enabling integration of physics, materials science, electrical engineering, and computer science. The university has established partnerships with international institutions and industry players, though these remain limited in scope. Current enrollment in directly relevant programs totals approximately 500 students annually.

**Hanoi University of Science and Technology (HUST)** has established the School of Electrical and Electronic Engineering with programs in IC design and embedded systems. HUST benefits from strong engineering traditions and industry connections, particularly with Samsung Vietnam. The institution operates limited EDA tool licenses through academic programs with Cadence and Synopsys. Annual enrollment in semiconductor-related programs is approximately 300 students.

**Vietnam National University, Ho Chi Minh City (VNU-HCM)** houses semiconductor activities primarily in the University of Technology and University of Science. The institution benefits from proximity to the southern industrial zone and emerging semiconductor facilities. VNU-HCM has developed collaborations with international universities and is expanding IC design education through the Vietnam-Korea Institute of Science and Technology. Current capacity is approximately 400 students annually.

**University of Danang (UD)** represents the central region's primary institution for semiconductor education. While smaller in scale than the national universities, UD has developed targeted programs in electronics and computer engineering. The institution serves as a regional hub, potentially supporting emerging semiconductor facilities in the central corridor. Current annual enrollment is approximately 200 students.

**National Innovation Center (NIC)** operates as a government-supported platform for innovation and technology development. NIC has developed semiconductor-focused initiatives including training programs and industry connections. While not a degree-granting institution, NIC plays a coordination role in connecting universities with industry partners and international resources.

## 4.2 Identification of critical policy gaps

Our comparative analysis reveals three critical policy gaps that constrain Vietnam's semiconductor human resource development:

**Gap 1: Institutional Rigidity in Faculty Compensation and Recruitment.** Vietnamese public universities operate within civil service salary structures that cannot compete with industry compensation. A senior semiconductor engineer at a foreign-invested firm in Vietnam earns \$10,000-20,000 monthly, while a university professor's salary is approximately \$1,000-2,000. This disparity makes it virtually impossible to recruit industry-experienced practitioners as faculty—precisely the profile most needed for practical semiconductor education. In contrast, Taiwan's model allows universities to offer competitive compensation through flexible funding mechanisms and industry secondments. The institutional rigidity in Vietnam reflects broader public sector management constraints that extend beyond education policy.

### **Gap 2: Inadequate Infrastructure Funding, Particularly for EDA Tools.**

Electronic Design Automation tools from vendors such as Cadence, Synopsys, and Siemens are essential for IC design education, yet license costs range from several hundred thousand to several million dollars annually for comprehensive packages. Individual Vietnamese institutions cannot afford these costs, and there is no national mechanism for shared access comparable to the U.S. NSTC model. The result is that students receive limited hands-on experience with industry-standard tools, reducing their employability and the quality of academic research. This infrastructure gap represents a market failure where the collective benefit of shared access exceeds the sum of what individual institutions can justify investing.

**Gap 3: Weak Quadruple Helix Linkages.** Despite Vietnam's growing semiconductor industry presence, systematic linkages among government, universities, research institutes, and industry remain underdeveloped. There is no equivalent to Taiwan's ITRI serving as an intermediary institution, no industry consortium comparable to the U.S. SRC coordinating pre-competitive research, and limited mechanisms for industry input into curriculum development. The existing partnerships tend to be bilateral and ad hoc rather than systemic. This gap reflects both the nascent stage of Vietnam's semiconductor industry and institutional barriers to collaboration.

## **5 DISCUSSION**

Based on our comparative analysis and identification of policy gaps, we propose a hybrid policy framework for Vietnam that combines elements from successful international models while accounting for local institutional constraints.

### **5.1 Hybrid policy framework design**

The proposed framework integrates three key elements:

**First, Institutional Autonomy (adapted from Taiwan):** We propose establishing specialized semiconductor education units with enhanced autonomy in personnel management, compensation, and curriculum development. These units would operate under special regulatory provisions allowing them to offer competitive salaries to industry practitioners, adjust enrollment based on industry demand signals, and rapidly

update curricula to reflect technological changes. This approach mirrors Taiwan's flexibility while working within Vietnam's broader institutional framework.

**Second, National Shared Infrastructure (adapted from the United States):**

We propose creating a National IC Design Technology Center (N-ICDTC) that provides shared access to EDA tools, design libraries, and computing resources for all participating universities. This center would negotiate national-level licenses with tool vendors, achieving economies of scale impossible for individual institutions. The model draws from the U.S. NSTC concept while being appropriately scaled for Vietnam's context.

**Third, Interdisciplinary Deployment (leveraging VNU-HN's structure):**

Vietnam National University, Hanoi's multidisciplinary structure provides a natural platform for integrating the diverse knowledge domains required for semiconductor development. By establishing a cross-cutting institute that draws on physics, chemistry, materials science, electrical engineering, and computer science from multiple member universities, VNU-HN can create comprehensive programs that individual departments cannot offer alone.

## **5.2 Operationalization: institute for semiconductors and advanced materials (ISAM)**

We propose operationalizing this framework through the establishment of the Institute for Semiconductors and Advanced Materials (ISAM) at Vietnam National University, Hanoi. ISAM would serve as a pilot institution demonstrating the viability of the hybrid model, with potential for replication at other national universities.

ISAM's organizational structure would include: (1) an Academic Division offering undergraduate and graduate programs in IC design, semiconductor process engineering, and advanced materials; (2) a Research Division conducting both fundamental and applied research across semiconductor domains; (3) an Industry Collaboration Division managing partnerships, internships, and technology transfer; and (4) the N-ICDTC providing shared infrastructure access.

The proposed investment plan totals 1,500 billion VND (approximately \$60 million) allocated as follows: 30% for EDA tools and IT infrastructure; 30% for analytical and prototyping equipment; 25% for core personnel and training programs; 10% for operations, intellectual property management, and research marketing; and 5% for

contingency and maintenance. This investment would be phased over five years, with government funding supplemented by industry contributions and international development assistance.

Governance would involve a multi-stakeholder board including representatives from government (Ministry of Education and Training, Ministry of Science and Technology), industry (both foreign-invested and domestic firms), and academia. This structure ensures that the institute remains responsive to policy objectives, industry needs, and academic standards.

## 6 CONCLUSIONS

This study has examined semiconductor human resource development models in four leading countries and assessed Vietnam's current approaches against these benchmarks. Our comparative analysis reveals that successful models share common elements—institutional flexibility, adequate infrastructure funding, and strong industry-academia linkages—while differing in their specific configurations based on national institutional contexts.

Vietnam's current approach suffers from three critical gaps: institutional rigidity preventing competitive faculty compensation, inadequate funding for essential EDA infrastructure, and weak quadruple helix linkages. Addressing these gaps requires policy innovation that goes beyond incremental adjustments to existing programs.

Based on our analysis, we offer five specific recommendations:

**Recommendation 1:** Establish ISAM at VNU-HN as a pilot institution with enhanced autonomy in personnel, compensation, and curriculum matters. This pilot can demonstrate the viability of institutional reforms before broader application.

**Recommendation 2:** Create the National IC Design Technology Center (N-ICDTC) to provide shared EDA tool access to participating universities. Negotiate national-level licenses to achieve cost efficiencies.

**Recommendation 3:** Develop mechanisms for industry practitioners to teach at universities without requiring permanent appointments. Programs could include visiting professorships, adjunct appointments, and industry secondments.

**Recommendation 4:** Establish a Semiconductor Education Consortium bringing together universities, research institutes, government agencies, and industry. The

consortium would coordinate curriculum development, share resources, and create structured internship programs.

**Recommendation 5:** Allocate dedicated funding for semiconductor human resource development within the National Semiconductor Industry Development Strategy. The 1,500 billion VND investment proposed for ISAM should be viewed as a down payment on the broader investments required to achieve 50,000 engineer target by 2030.

The global semiconductor industry restructuring presents a time-limited opportunity for Vietnam. Countries and firms are making strategic investments now that will shape supply chains for decades. Vietnam's success in capturing a meaningful role in this industry depends critically on its ability to develop the required human capital. The policy framework proposed in this study provides a pathway for addressing this challenge, drawing on international best practices while accounting for Vietnam's specific institutional context.

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### **Authors' Contribution**

All authors contributed equally to the development of this article.

### **Data availability**

All datasets relevant to this study's findings are fully available within the article.

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