Aging, Digitization, Automation, Migration, Trade Costs, and Productivity: A U.S. Case Study

APEC Economy Case Study Paper

Prepared for APEC Project EC_201_2024A
"The Effects of Structural Reform on Digitalization, Productivity and Labor Migration on APEC Economies in the Age of Ageing Population"

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2026

Abstract. The United States faces demographic, technological, and policy-induced constraints that together suppress long-term productivity growth. Manufacturing labor productivity has been essentially flat for two decades. Tariffs at their highest level in 80 years raise costs on intermediate and capital goods, while immigration enforcement has sharply contracted the available workforce. Growth accounting confirms that the labor contribution to U.S. GDP growth has contracted by more than one percentage point per year relative to the prior decade, while capital deepening lags peer economies by a factor of four. The United States appears unique among major APEC economies in having simultaneously constrained key adjustment margins — trade openness, immigration, and automation investment. Peer economies offer workable alternatives on each dimension.

JEL: F13, F16, J11, J61, O33, O47
Keywords: automation, tariffs, immigration, productivity, APEC, manufacturing

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This paper was prepared as a U.S. economy case study for APEC Project EC_201_2024A, proposed by Japan and co-sponsored by Canada, Malaysia, Singapore, Chinese Taipei, Thailand, and the United States, with funding from the APEC Support Fund. I am grateful to Tomoo Kikuchi (Waseda University) for his leadership as Project Overseer, and to Kensuke Yanagida and The Japan Institute of International Affairs (JIIA) for their excellent work organizing the workshop and publication. I also thank the co-sponsoring economies and workshop participants for valuable comments and discussion. The views expressed herein are those of the author and do not necessarily reflect the views of CSIS or any APEC member economy.

I. Introduction

A. Context Within APEC

This paper is an economy case study for the APEC series on structural reform and productivity growth, contributing to the evidence base established by the Enhanced APEC Agenda for Structural Reform (EAASR) and the Putrajaya Vision 2040. It examines how the United States — the largest APEC economy — is managing the intersection of demographic aging, automation, trade policy, and immigration.

B. Central Thesis

The U.S. economy faces exogenous challenges and self-imposed constraints that together suppress productivity growth. The exogenous challenges — an aging population, sub-replacement fertility, and declining research productivity — are shared across APEC economies. The self-imposed constraints — elevated tariffs, immigration restrictions, and chronic under-investment in technology adoption — are policy choices with identifiable costs and available alternatives.

These challenges interact. Tariffs raise the cost of imported automation equipment. Immigration enforcement shrinks the workforce. Firms that cannot automate and cannot hire see productivity stagnate. And stagnant productivity erodes the fiscal base for the public investments that could break the cycle.

This paper does not claim to identify causal effects through original econometric analysis. Its contribution is *synthetic*: it assembles descriptive evidence, cross-economy comparisons, and estimates from the empirical literature into an integrated framework. The causal estimates it cites are drawn from peer-reviewed studies employing their own identification strategies.

C. Relevance to Other APEC Economies

Japan and South Korea face more acute aging but have responded with aggressive robotics strategies. China is automating at a pace that dwarfs all other APEC economies. Canada, Australia, and Singapore are expanding skilled immigration while the United States contracts it. What distinguishes the U.S. case is that all adjustment margins — automation, immigration, and trade openness — are being constrained simultaneously. The resulting stagnation offers cautionary evidence for any APEC economy contemplating similar combinations.

II. Demographic Headwinds: An Aging and Shrinking Labor Force

A. Declining Fertility and Natural Population Growth

The U.S. total fertility rate has fallen to approximately 1.62 (2023 NCHS), well below the replacement rate of 2.1 and among the lowest in American history. The decline has persisted since 2007, shifting long-run projections from gradual aging to outright natural population decline. Births minus deaths are projected to turn negative within the next decade under Census Bureau middle-variant projections, making the United States entirely dependent on net immigration for population growth — a transition Japan crossed in the 2000s and that South Korea and China are approaching.

B. Workforce Aging Across Sectors

Manufacturing and utilities have the oldest workforce profiles of any major U.S. industry. Deloitte and the Manufacturing Institute (2024) project that 3.8 million new manufacturing positions will be needed by 2033, with up to half potentially going unfilled. A companion Deloitte analysis (December 2025) frames the labor shortage as the binding constraint on U.S. manufacturing ambitions.

Foreign-born workers are disproportionately concentrated in the sectors facing the most acute shortages: approximately 68 percent of farm laborers, 30 percent of construction workers, and significant shares of food processing and manufacturing line workers (BLS). Figure 2 displays this "demographic squeeze": the share of manufacturing workers aged 55 and over rose from 23.7 percent in 2010 to 27.4 percent by 2024 (IPUMS CPS ASEC), 4.0 percentage points above the all-industry average of 23.4 percent (BLS CPS). The foreign-born share of manufacturing employment rose from 17.2 to 20.1 percent over the same period, consistent with the Manufacturers Alliance (2025) estimate of approximately 20 percent. BLS data from later in 2025 show a decline of over one million in the foreign-born workforce, coinciding with expanded enforcement actions (Section VI).

C. Cross-APEC Demographic Comparison

Table 1 presents old-age dependency ratios for key APEC economies, drawing on World Bank data for 2023 and UN WPP projections for 2040 (see also Figure 5 in Section IV).

Japan leads at 50.3 percent in 2023, projected to reach 64.5 percent by 2040. South Korea's ratio is projected to rise sharply from 25.9 to 46.0 percent; China's from 20.7 to 39.5 percent. The United States, at 26.8 percent (2023) and projected 34.5 percent (2040), occupies a middle position — aging faster than Southeast Asian economies such as Vietnam (12.7 percent), Indonesia (10.4 percent), and the Philippines (8.0 percent) but slower than Northeast Asia.

The United States faces the demographic challenge early enough that a response is warranted, but slowly enough that it retains policy options that faster-aging economies have exhausted. Japan and South Korea have responded with economy-wide robotics strategies (Section IV.A). Canada, Australia, and Singapore have expanded skilled immigration. The United States is doing neither.

D. Implications for Labor Supply

BLS projects labor force growth slowing to 0.2 to 0.3 percent annually. Under the current immigration restriction trajectory, growth could approach zero. The Deloitte/Manufacturing Institute projection of up to 1.9 million unfilled manufacturing positions by 2033 underscores the scale of the challenge.

Economy	Old-Age Dep. (2023)	Old-Age Dep. (2040 proj.)	Robot Density
South Korea	25.9%	46.0%	1,012
Singapore	17.4%	34.5%	770
China	20.7%	39.5%	470
Germany *	36.0%	49.0%	429
Japan	50.3%	64.5%	399
United States	26.8%	34.5%	295
Canada	29.6%	39.0%	176
Australia	26.9%	33.5%	92
Thailand	21.0%	33.0%	74
Malaysia	10.6%	16.5%	55
Mexico	11.9%	17.0%	40
Vietnam	12.7%	21.0%	15
Indonesia	10.4%	15.0%	10

Notes: Old-age dependency ratio = population 65+ / population 15-64 x 100. Robot density = operational industrial robots per 10,000 manufacturing employees. * Germany included as non-APEC comparator (major robotics producer). Sources: World Bank (2023) and UN WPP 2024 medium variant (projections) for dependency ratios; IFR World Robotics 2024 and 2025 for robot density.

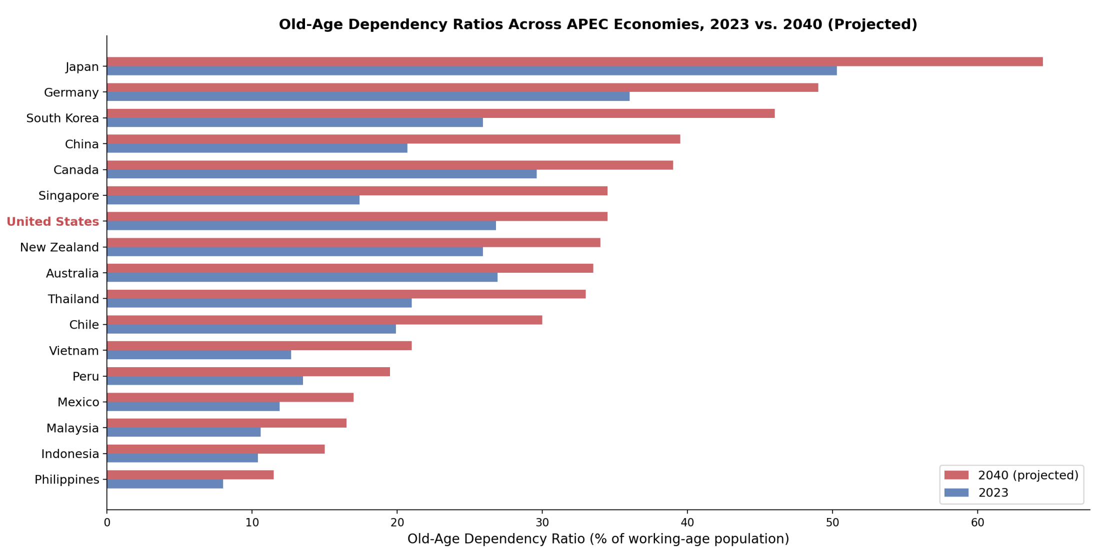

Figure 1. Figure 1: Cross-APEC Old-Age Dependency Ratios, 2023 and 2040 Projected. Source: World Bank (2023), UN WPP 2024.

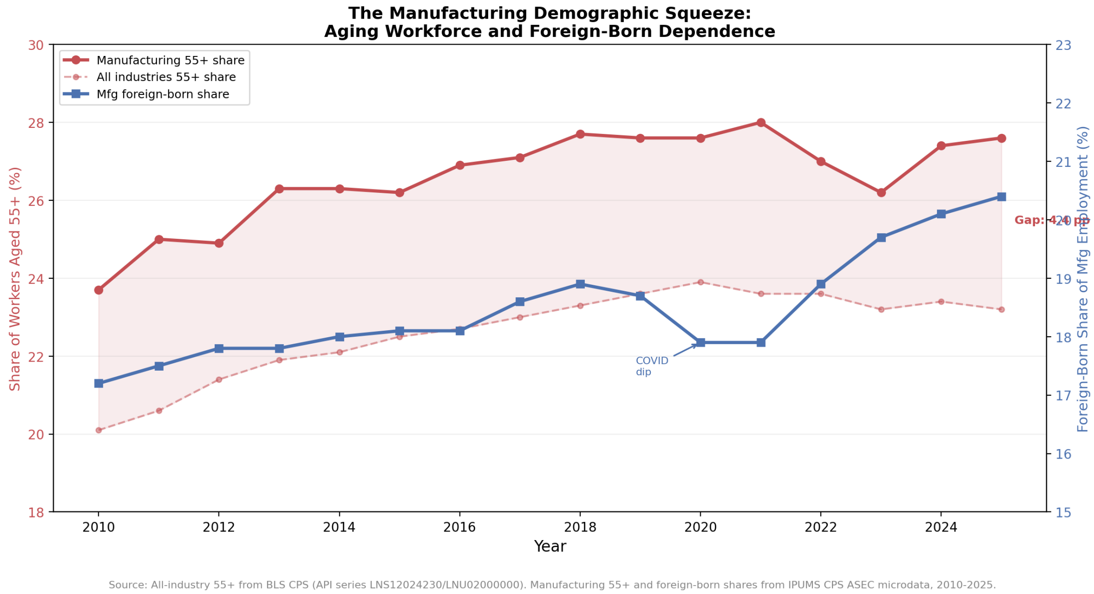

Figure 2. Figure 2: The Manufacturing Demographic Squeeze — Aging Workforce and Declining Immigrant Share, 2010–2025. Source: BLS CPS annual averages.

III. Productivity Stagnation in U.S. Manufacturing

A. The Manufacturing Employment-Output Paradox

Manufacturing employment declined from roughly 17 million in 2000 to approximately 12.7 million by early 2025, before shedding an additional 82,000 jobs between April and December — a period coinciding with tariff escalation (BLS 2025). Yet real output has remained near its historical peak. The resilience of aggregate output masks a composition shift toward higher-value subsectors — pharmaceuticals, aerospace, semiconductors — consistent with rising within-sector concentration documented by Autor et al. (2020).

B. The Productivity Gap

Between 2008 and 2024, nonfarm business labor productivity grew 31 percent cumulatively. Manufacturing managed just 3 percent (BLS 2025). From 2010 to 2024, nonfarm productivity grew 22 percent while manufacturing output per hour *declined* by 4 percent. Lashkari and Pearce (2024) quantify the decline at approximately 0.5 percent per year from 2010 to 2022.

Atalay, Hortacsu, Kimmel, and Syverson (2025) argue that part of the stagnation reflects mismeasurement — quality-adjustment bias in producer price indices. Even under their more optimistic correction, manufacturing TFP grew at roughly 0.6 percent per year after 2009, a sharp deterioration from the historical trend of 2 percent or more.

C. The Adoption Gap

The bottleneck is adoption, not ideas. The declining productivity of research effort (Bloom, Jones, Van Reenen, and Webb 2020) means the economy cannot innovate its way out of the slowdown. Only 23 percent of U.S. manufacturers report engaging in process innovation (ITIF 2024). The U.S. generates the knowledge but fails to embed it in production processes.

D. Growth Accounting: Quantifying the Slowdown

A Solow growth decomposition using Penn World Table 11.0 (alpha = 0.33) provides the quantitative spine. Table 4 presents U.S. results by decade.

Decade	GDP growth	Capital deepening	Labor quantity	Human capital	TFP
1970s	3.16	0.78	1.42	0.63	0.33
1980s	3.05	0.67	1.70	0.21	0.47
1990s	3.17	0.73	1.31	0.27	0.86
2000s	1.88	1.17	-0.30	0.22	0.79
2010s	2.37	0.21	1.59	0.11	0.45
2020s	2.25	0.63	0.44	0.36	0.83

Table 4: U.S. Growth Accounting Decomposition by Decade (pp/yr). Source: Penn World Table 11.0, alpha = 0.33.

The labor contribution collapsed from 1.59 pp/yr in the 2010s to 0.44 in the 2020s — a decline of 1.15 percentage points consistent with the demographic and immigration dynamics documented in Sections II and VI. Over 1970–2023, labor contributed 41 percent of total growth (computed from PWT annual data), making immigration restrictions particularly costly.

U.S. capital deepening contributed just 0.33 pp/yr over 2010–2023, compared to 1.23 for Korea and 3.16 for China. This nearly four-fold gap is consistent with the automation under-investment thesis in Section IV.

While aggregate TFP appears strong (0.83 pp in the 2020s), this reflects gains concentrated in services. The aggregate figure masks manufacturing-specific stagnation (Lashkari and Pearce 2024). This multi-factor diagnosis motivates the policy recommendations in Section VII: solutions should address multiple constraints simultaneously.

IV. The Automation and AI Adoption Gap

The productivity stagnation documented in Section III has a physical correlate: the United States is falling behind its APEC peers in the deployment of industrial robots. In an economy where the labor force is shrink-

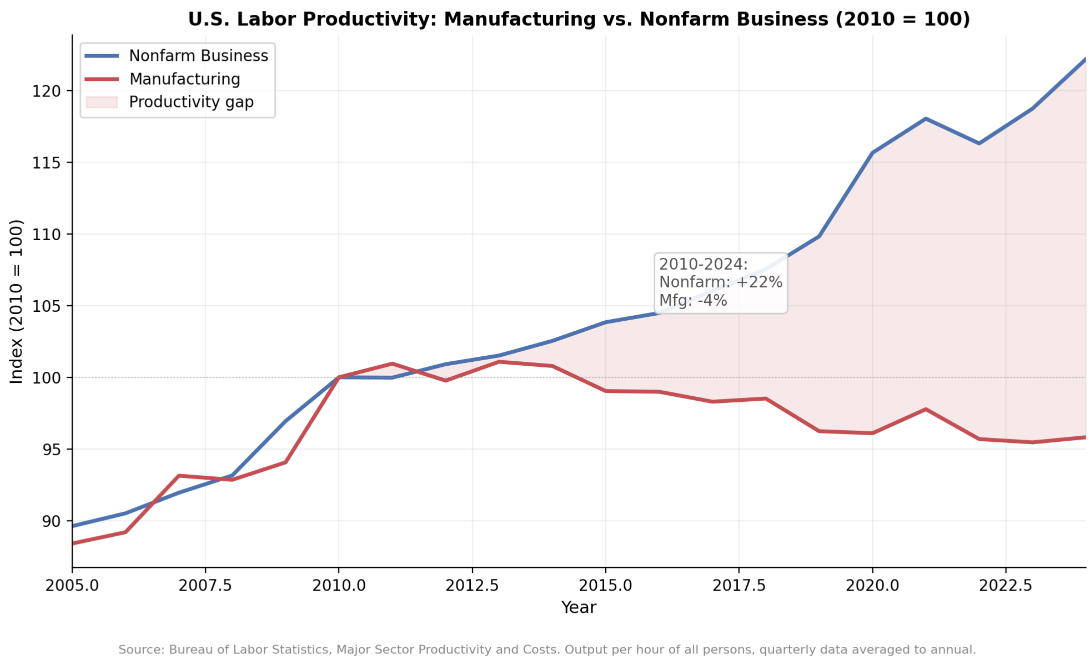

Figure 3. Figure 3: U.S. Manufacturing vs. Nonfarm Business Labor Productivity, 2005–2024 (output per hour, indexed). Panel A: 2008 = 100. Panel B: 2010 = 100, highlighting post-recovery divergence. Source: BLS Major Sector Productivity and Costs.

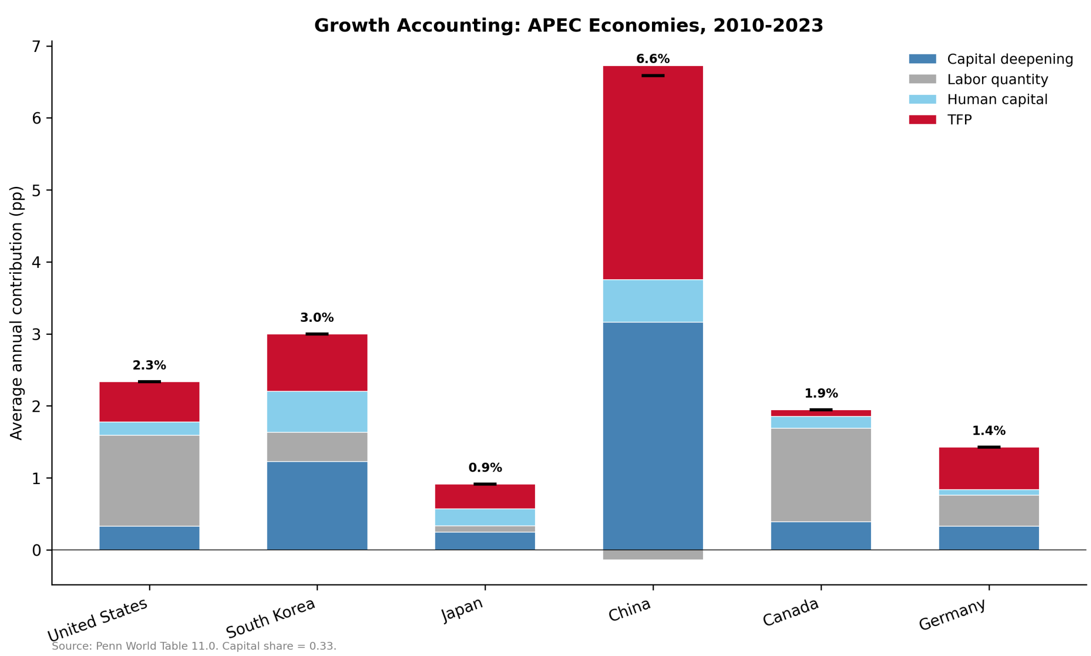

Figure 4. Figure 4: Cross-APEC Growth Accounting Decomposition, 2010–2023 (percentage points per year). Source: Penn World Table 11.0.

ing (Section II) and research productivity is declining (Section III), capital substitution through automation represents one of the few remaining margins for sustaining output growth.

A. Robotics Deployment

The IFR's robot density measure — operational industrial robots per 10,000 manufacturing employees — places the United States outside the top five globally at approximately 295 (2023). South Korea leads at 1,012, followed by Singapore (770), China (470), and Germany (429) (IFR 2024).

The trend is more concerning than the level. China's installations rose from 36,600 units in 2013 to 295,000 in 2024, accounting for more than half of all robots installed worldwide. U.S. installations have been flat at 27,000–40,000 per year; in 2024 they fell 9 percent to 34,200 units. The U.S. share of global installations has fallen from 13.3 percent (2013) to 6.5 percent (2024).

The United States has no major domestic producer of conventional articulated industrial robots. Japan (Fanuc, Yaskawa), Germany (KUKA), Switzerland (ABB), and increasingly China supply the critical hardware. American manufacturers seeking to automate generally purchase foreign equipment at prices inflated by trade policy.

Several APEC economies have adopted explicit robotics strategies that the United States lacks. South Korea is investing $2.2 billion through 2028. Singapore allocated $60 million for full expensing of automation equipment. China provides provincial purchase subsidies. Japan offers accelerated depreciation. The U.S. flagship initiative — the ARM Institute — operates on approximately $30 million per year (ITIF 2025).

B. Robot Density, Productivity, and the Korea Counterexample

Figure 5 plots robot density against manufacturing value added per worker across APEC economies ($r = 0.65$). Panel B shows that economies increasing robot density faster also tended to see faster productivity growth ($r = 0.54$). The U.S. sits in the bottom-left corner.

South Korea — the highest robot density in the world — faces a persistent productivity gap between chaebols and smaller firms, suggesting automation is necessary but not sufficient. Singapore's approach differs instructively: its programs bundle equipment financing with consulting, process redesign, and workforce training, addressing the full adjustment cost of technology integration. For SMEs, adjustment costs often exceed equipment costs.

Acemoglu and Restrepo (2019) model automation through displacement and productivity channels. In a context of labor scarcity driven by demographic aging, under-automation means the United States is forgoing capital-for-labor substitution that could partially offset labor force shrinkage.

C. The Small Firm Gap

Across every dimension of technology adoption, smaller firms lag and the gap is widening. Yotzov et al. (2026) quantify the investment gap: approximately 30 percent of large firms plan to invest $1 million or more in AI in 2026, while roughly 60 percent of small firms plan less than $20,000. The United States has roughly 250,000 manufacturing establishments. Frontier performance among a few thousand, while the remaining 90-plus percent stagnate, produces exactly the pattern observed: rising R&D spending, flat aggregate TFP.

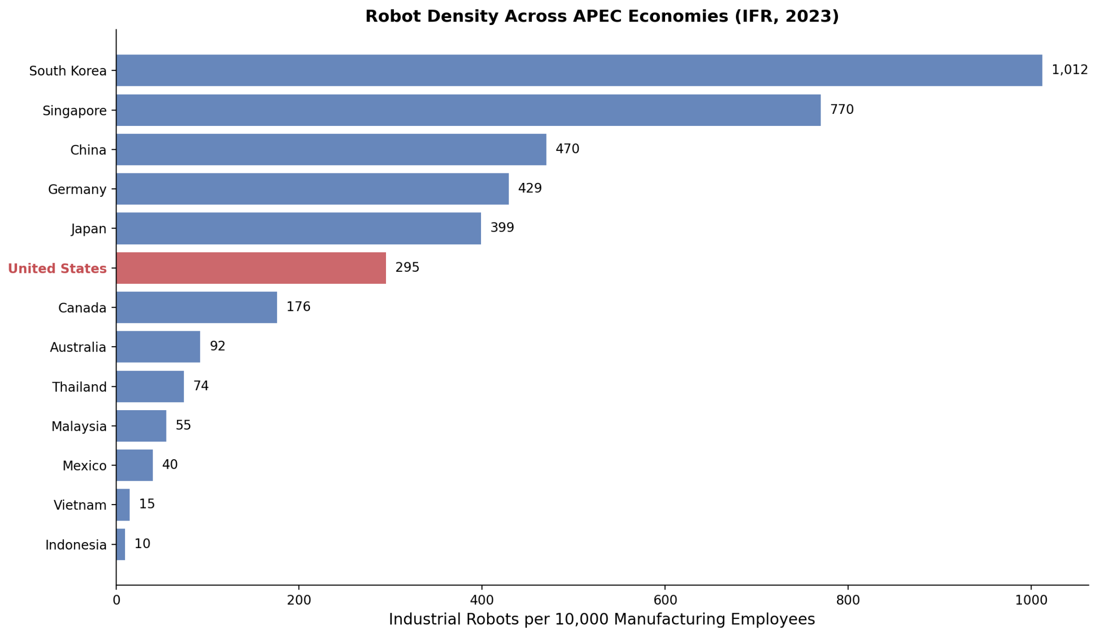

Figure 5. Figure 5: Robot Density Across APEC Economies, 2023 (robots per 10,000 manufacturing employees). Source: IFR World Robotics 2024.

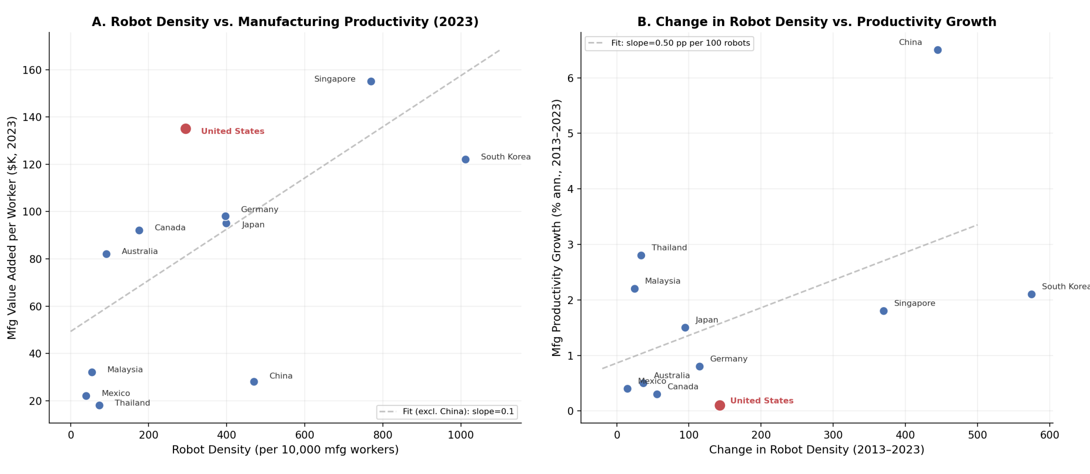

Figure 6. Figure 6: Robot Density vs. Manufacturing Labor Productivity Across APEC Economies. Sources: IFR, World Bank, OECD STAN, Conference Board TED.

V. Trade Costs and the 2025 Tariff Regime

The challenges documented in the preceding sections — demographic aging, productivity stagnation, and under-investment in automation — are primarily structural. They would exist regardless of trade policy. But the tariff regime that took effect in 2025 has compounded each of them, raising costs on the intermediate inputs and capital goods that manufacturers need to produce, compete, and automate.

A. The Tariff Escalation

Fajgelbaum and Khandelwal (2026) estimate that the average effective U.S. tariff duty rose from 2.4 percent in 2024 to 9.6 percent by the end of 2025 — the highest trade-weighted effective rate in at least 80 years and a fourfold increase in a single calendar year. Unlike the Section 301 tariffs on Chinese goods initiated in 2018, which were targeted by product and origin, the 2025 regime applies broadly across trading partners and product categories. Roughly 90 percent of tariff costs have been passed through to U.S. importers rather than absorbed by foreign exporters, consistent with findings from the 2018–2019 rounds (Fajgelbaum and Khandelwal 2026).

The compositional effects are especially concerning. The Yale Budget Lab's general equilibrium estimates project that long-run GDP contracts by 0.4 percent under the 2025 tariff regime, but the effects are unevenly distributed: advanced manufacturing output declines by 3.3 percent while low-technology manufacturing expands by 4.5 percent (Yale Budget Lab 2025). The tariff regime may thus be shifting the composition of U.S. manufacturing toward less sophisticated, lower-value-added production — precisely the opposite of what the productivity and automation challenges documented in Sections III and IV require.

The manufacturing employment losses documented in Section III coincided with the tariff escalation, complicating the protection rationale. The Richmond Federal Reserve estimates that the tariff measures reduce business investment growth by 0.5 to 1.0 percentage points in 2025 and 2026, as firms defer capital expenditure decisions amid uncertainty about future trade policy (Richmond Fed 2025). For manufacturers already under-investing in automation relative to APEC peers, this additional drag on capital spending widens a gap that was already the paper's central concern. Because the United States imports virtually all of its industrial automation equipment — from Japan, Germany, Switzerland, and increasingly China — the tariffs function as a tax on the very capital deepening that Section III identified as essential.

B. Implications for the APEC Trade Agenda

The 2025 tariff escalation moves the United States further from the principles that have guided APEC trade policy for three decades. For APEC member economies that are both trading partners and suppliers of automation equipment — Japan, South Korea, and China, as well as non-APEC suppliers such as Germany — the tariffs create mutual costs. Japanese and Korean robotics manufacturers face reduced demand in their largest export market. U.S. manufacturers face higher costs for the equipment they need to remain competitive.

For this paper, the trade policy prescription gains empirical grounding from the preceding analysis. Lowering tariffs on automation inputs is not a general free-trade argument; it is a targeted productivity argument. The United States does not manufacture industrial robots at scale, so tariffs on them generate no domestic production benefit — only cost. The APEC cooperative framework offers a natural vehicle through the FTAAP agenda.

VI. Immigration Policy as a Productivity Variable

The demographic pressures documented in Section II have a straightforward policy remedy: immigration. That remedy is now being curtailed at precisely the moment the demographic arithmetic most demands it.

A. The Skilled Immigration Bottleneck

The H-1B visa program is the primary channel for skilled foreign workers entering the U.S. labor market. The statutory cap has remained essentially unchanged for two decades. A newly imposed fee of $100,000 per petition functions as a regressive tax that disproportionately harms startups and small firms. The National Foundation for American Policy (2025) reports that 61 percent of H-1B employers were approved for a single petition in FY 2025; CSIS (2026) notes that the fee structure advantages large firms over smaller competitors.

B. Immigration and Innovation

The empirical literature on skilled immigration and innovation is extensive. Kerr and Lincoln (2010) find that higher H-1B admissions increase immigrant patenting without displacing native-born inventors. Immigrants produced 23 percent of U.S. patents between 1990 and 2016 despite constituting 16 percent of the inventor workforce (Bernstein et al. 2023). Forty-six percent of 2024 Fortune 500 companies were founded by immigrants or their children (American Immigration Council 2024). Dimmock, Huang, and Weisbenner (2022) show that startups with higher H-1B lottery win rates are more likely to secure venture capital and file patents.

At the firm level, Doran, Gelber, and Isen (2022) find that the causal effect of an individual H-1B hire on firm-level patenting is small. But aggregate and firm-level results are not contradictory: the system-wide contribution of skilled immigrants to the U.S. innovation ecosystem is large even if each individual hire has a modest firm-level effect.

When restrictions bind, firms offshore. Glennon (2024, *Management Science*) documents that firms with high H-1B dependency respond to visa cap reductions by increasing foreign affiliate employment. The American Competitiveness in the 21st Century Act of 2000 temporarily raised the H-1B cap to 195,000, but the increase expired at the start of FY2004, reverting the cap to 65,000 — a change that accelerated offshoring of R&D-intensive jobs.

C. Deportation, Labor Supply, and Macroeconomic Effects

Immigration enforcement has escalated sharply. Figure 7 presents ICE's average daily detained population from TRAC data. After declining from approximately 49,000 (September 2019) to roughly 15,000 during the pandemic, the detained population surged to over 67,000 by early 2026 — a 37 percent increase over pre-COVID levels. The acceleration after January 2025 is especially pronounced, with populations rising from approximately 38,000 to over 67,000 in a single year.

East, Hines, Luck, Mansour, and Velasquez (2023) provide causal microeconomic evidence: for every one million deportations, native-born employment falls by approximately 88,000 in affected local economies through labor market complementarity. Multiple macroeconomic analyses estimate the GDP growth drag from immigration restriction at 0.2 to 1.0 percentage points annually (Brookings 2026; Dallas Fed 2025; Penn Wharton 2025; NFAP 2025).

The sectoral impacts are already visible. Foreign-born workers declined by more than one million between January and August 2025 (BLS CPS household survey). Agriculture, construction, hospitality, and healthcare — all immigrant-dependent — report weakening job growth and unfilled positions.

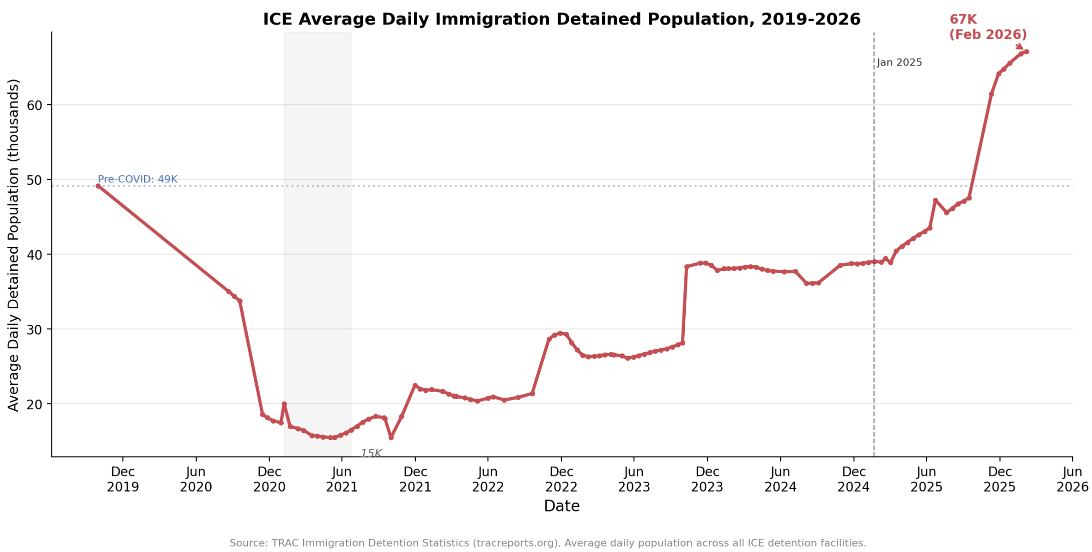

Figure 7. Figure 7: ICE Average Daily Immigration Detained Population, 2019–2026. Source: TRAC Immigration Detention Statistics.

VII. Policy Recommendations and Lessons for APEC Economies

The challenges documented in the preceding sections are unlikely to be resolved through action in any single policy domain. This section presents four recommendations drawing on the experience of APEC peer economies.

A. Invest in Embodied AI and Automation, With a Focus on SMEs

U.S. manufacturing productivity is stagnating, robot density lags peer economies, and the gap is concentrated among small and medium firms. The policy response should target adoption and diffusion, not frontier research. The APEC peer models — Korea's $2.2 billion robotics program, Singapore's bundled equipment-plus-consulting approach, Japan's accelerated depreciation — demonstrate proven alternatives. One approach would be to create a national network of automation institutes and provide accelerated depreciation for automation equipment purchases by firms below a size threshold.

B. Lower Trade Costs on Automation Inputs

Section V documented how tariffs function as a tax on automation investment. Eliminating or substantially reducing tariffs on industrial automation equipment that is not domestically produced would lower costs without sacrificing domestic production — the United States does not manufacture industrial robots at scale. The APEC FTAAP agenda offers a natural vehicle.

C. Reform Skilled Immigration Pathways

Three reforms merit consideration: modernize the H-1B cap to reflect current demand; reduce or restructure the $100,000 fee that functions as a barrier to small firms; and streamline visa processing for documented shortage occupations. Canada, Australia, and Singapore are actively recruiting the talent that U.S. restrictions push away.

D. Align Industrial Policy With Trade and Immigration Policy

Industrial policy that contradicts trade and immigration policy defeats itself. A government that simultaneously subsidizes advanced manufacturing through the CHIPS Act and Inflation Reduction Act while taxing imported automation equipment and restricting the skilled labor pipeline illustrates the cost of policy incoherence. The binding constraint is often not funding but policy alignment.

VIII. Conclusion

The United States faces demographic, technological, and policy-induced challenges that together suppress long-run productivity growth. Some are exogenous: an aging population and declining research productivity. But the most consequential constraints are self-imposed. Tariffs at their highest level in 80 years raise the cost of intermediate and capital goods. Immigration enforcement — with ICE's detained population reaching 67,000 by early 2026 — contracts the workforce when demographics most demand expansion. And the absence of a national technology adoption strategy leaves most manufacturers without the tools to close the productivity gap.

Growth accounting confirms that the labor contribution to U.S. GDP growth has contracted by more than one percentage point per year, while capital deepening lags Korea by a factor of four and China by nearly ten.

For APEC, the cautionary message is that even the world's largest economy can undermine its own productivity through policy incoherence. The constructive message is that peer economies have demonstrated workable alternatives — from Korea's robotics investment to Singapore's immigration openness to Japan's automation incentives. The APEC cooperative framework provides a vehicle for collective action on these shared challenges.

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X. Appendix