Policy Debates:
Semiconductor Policy and Geopolitics
When Economic Tradeoff Meets National Security

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* Based on joint work with Wen-Chieh Lee and Shinn-Shyr Wang, “Glopalorization of the Semiconductor Industry”

A Tale of 3 Multi-Polarized Views

Taiwan	U.S.	China

Our View is by and large aligned with MSMC

- Mark Liu (TSMC CEO) and Matt Pottinger (former top Asia official on National Security Council) both dismissed the idea that Taiwan's Silicon Shield would deter China.
- Stimson Centre study of Taiwan's Silicon Shield (2022) suggested that the U.S. could lift some sanctions and export bans against China in return for a commitment from Beijing to adopt a less threatening posture.

Rise of the Semiconductor Industry

- Rapid industrialization and digitalization → strong demand for chips
- Continual
  - (i) technical progress
  - (ii) expansion of scales economics
  - (iii) modularization (component sourcing without upfront payment of fixed costs)
  - (iv) improvements in organization capital
  - → continual reduction in unit cost of chips making
- Cost reduction further induces more demands
- Trend reversal since trade wars, the pandemic and the rapid rise of China
  - In the name of national security
  - Glopolarization with intertwined global power configurations beyond multi-polarization (with separated powers)
  - Systematic economic tradeoff not yet carefully computed (counterfactual exercises)

Global Supply Chain Development

- The global supply chain has evolved significantly over years, shaping the way goods are produced, distributed, and consumed around the world.
- Past: Traditional Sequential (Linear) Supply Chains
  - Historically, supply chains emphasized cost-efficient outsourcing, yielding lengthy, intricate cross-border networks. This lowered expenses but heightened susceptibility to disruptions like natural disasters and geopolitics.
- Transition: Just-in-Time and Lean Practices
  - Late 20th century: Just-in-time & lean practices cut waste, enhanced efficiency, and supplier collaboration. Integrated supply chains emerged, yet dependency on few critical suppliers risked disruptions.
- Present: Globalization and Complexity
  - Modern supply chains are intricate and global, fueled by tech, communication, and transport progress. Firms procure globally for lower costs, yielding savings and market access, yet intensifying exposure to risks like disruptions, trade tensions, and regulations.
  - Better lithography equipment by ASML => TSMC can make smaller and more powerful chips => more profitable for NVIDIA and AMD to design even better chips.

Human Capital, Human Capital, Human Capital

- Within high-tech skilled labor, one must have
  - Firm-specific skills
  - Fit with firm-specific organization capital & culture
  - Loyalty to maintain business secrets
- This makes labor associated with high adjustment costs, much higher than capital that is known to be more flexible nowadays in the IT industry
- New plants in a location with stronger union and less government incentive provision (public infrastructure, utility, among others) will lead to
  - Reconfiguration
  - Overinvestment in capital to compensate misfit in human capital/business culture
  - Lower productivity, especially measured by the average product of capital (labor productivity would be biased due to overinvestment in capital)

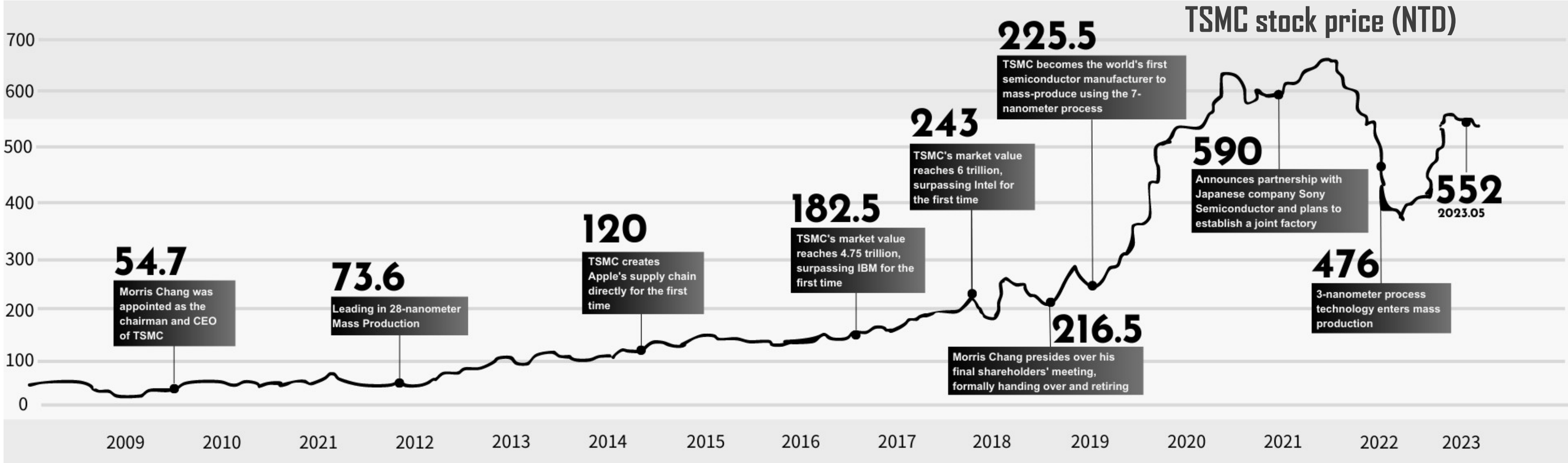
Geopolitics and National Security

- Economic security
  - Main players in the semiconductor industry such as TSMC have been pure-play foundry manufacturers.
  - Compared with other integrated device manufacturers (IDMs), foundry manufacturers have advantages on the order acceptance and process evolution.
  - Less worry about Trade Secret Theft.
- Global slowdown is expected when reverting the trend of modularization.
- The US's 1930 Smoot-Hawley tariff is believed to induce tariff wars and defensive trade blocs and later political and military alliance, eventually as a trigger of WWII (Kindleberger 1989).
- Boulevard of Broken Dreams: Why Public Efforts to Boost Entrepreneurship and Venture Capital Have Failed (Josh Lerner 2012) – VC subsidy after the Great Recession failed.
- After 25 years of operation, TSMC-Camas still incurred 50% higher cost in its production of legacy chips (Morris Chang).
- Protection and misaligned subsidy policy such as Export Control and Chips Act (including the US $52 billion subsidy) may not ensure national security while leading to misallocation and harming economic security – likely a lose-lose strategy.

Why Taiwan? Not Korea? Not Other Countries?

- Taiwan's education system cultivates disciplined and adaptable students for the high-tech industry.
  - Despite similar education systems in Japan, South Korea, and China, why choose Taiwan?
  - Taiwan's predominantly small and medium-sized enterprise (SME) system lacks prominent international brands and has no ambitions to develop them, thus posing no threat to business collaborators in America and other countries.
- Rise of science park facilitates clustering of human capital:
  - repatriation of tech talents from Silicon valley
  - local tech graduates
- A unit ecosystem with
  - integrated production chain such as TSMC/UMC fabs, TSMC CoWoS packaging, ASE Group testing/packaging and MediaTek micro designs
  - easy commute between various science parks via high speed rail.

Rise of TSMC: A Chronicle



2009

Jun

Morris Chang resumes roles of Chairman and CEO, doubling 2010 capital expenditures. TSMC invests 6.2 billion NTD in Mediatek, holding 20% stake, becoming its largest shareholder.

2010

Groundbreaking for LED lighting research center, TSMC becomes the world's third-largest semiconductor company by revenue.

2011

Oct

TSMC pioneers 28nm mass production, meeting soaring smartphone demand, creating supply challenges. Subsidiaries TSMC Solar and TSMC Solid-State Lighting formed. TSMC Fab 15 achieves high-volume wafer production.

2012

Strong demand for smartphones, tablets, and gaming consoles; competitors struggle with yield improvement. TSMC's 28nm holds nearly 100% market share.

2013

Morris Chang's second handover, assumes role as dedicated Chairman. Mark Liu and C.C. Wei appointed Co-CEOs and General Managers.

2014

Sep

Apple introduces the larger iPhone 6, featuring TSMC's 20nm A8 processor. TSMC directly establishes Apple's smartphone supply chain for the first time.

2015

TSMC sells TSMC Solid-State Lighting to Epistar for 825 million NTD. iPhone 6s and 6s Plus launch, TSMC processors consume 30% less power than Samsung's, sparking anti-Samsung sentiment in Asia.

2016

Sep

iPhone 7 and 7 Plus launch, TSMC wins processor orders, overtakes IBM with a market value of 4.75 trillion.

2017

Morris Chang announces retirement after the June 2018 shareholders' meeting. TSMC adopts dual leadership, with Mark Liu becoming Chairman and C.C. Wei as CEO. In October, TSMC's market value surpasses 6 trillion, surpassing Intel.

2018

Jun

Morris Chang formally hands over and retires.

Aug

TSMC hit by computer virus infection.

Oct

TSMC becomes the world's first semiconductor manufacturer to mass-produce using the 7-nanometer process.

2019

Apr

Confirmed: 5-nanometer process enters trial production. In the 2018 annual report, the shareholder's report states that the 7-nanometer process leads competitors by at least a year.

Jun

Announced mass production of enhanced 7nm+ process, N7+, utilizing EUV lithography.

2020

COVID-19 speeds up digital transformation: TSMC focuses on AR/MR remote collaboration, enhances factory-to-factory tech transfer, and revamps manufacturing using MR, IoT, and big data. TSMC also aims for global expansion to boost operational capabilities.

2021

Announced partnership with Sony Semiconductor to establish a joint venture subsidiary in Kumamoto City, Kyushu, Japan, and to begin construction of the facility by the end of the year.

Jun

Applied to donate 5 million doses of BNT vaccine.

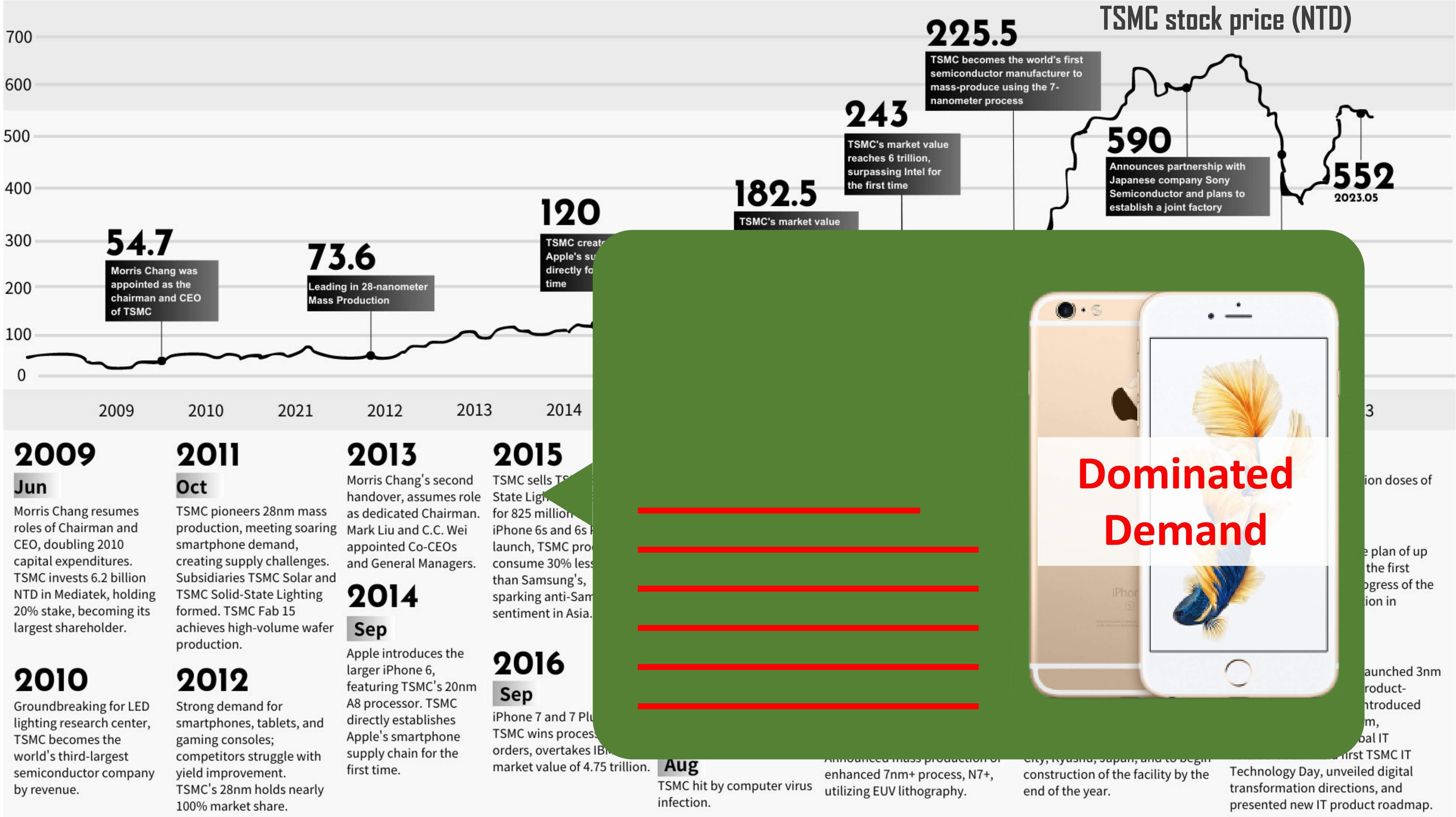
Aug

Initiated a price increase plan of up to 20%, and announced the first public update on the progress of the US aid factory construction in October.

2022

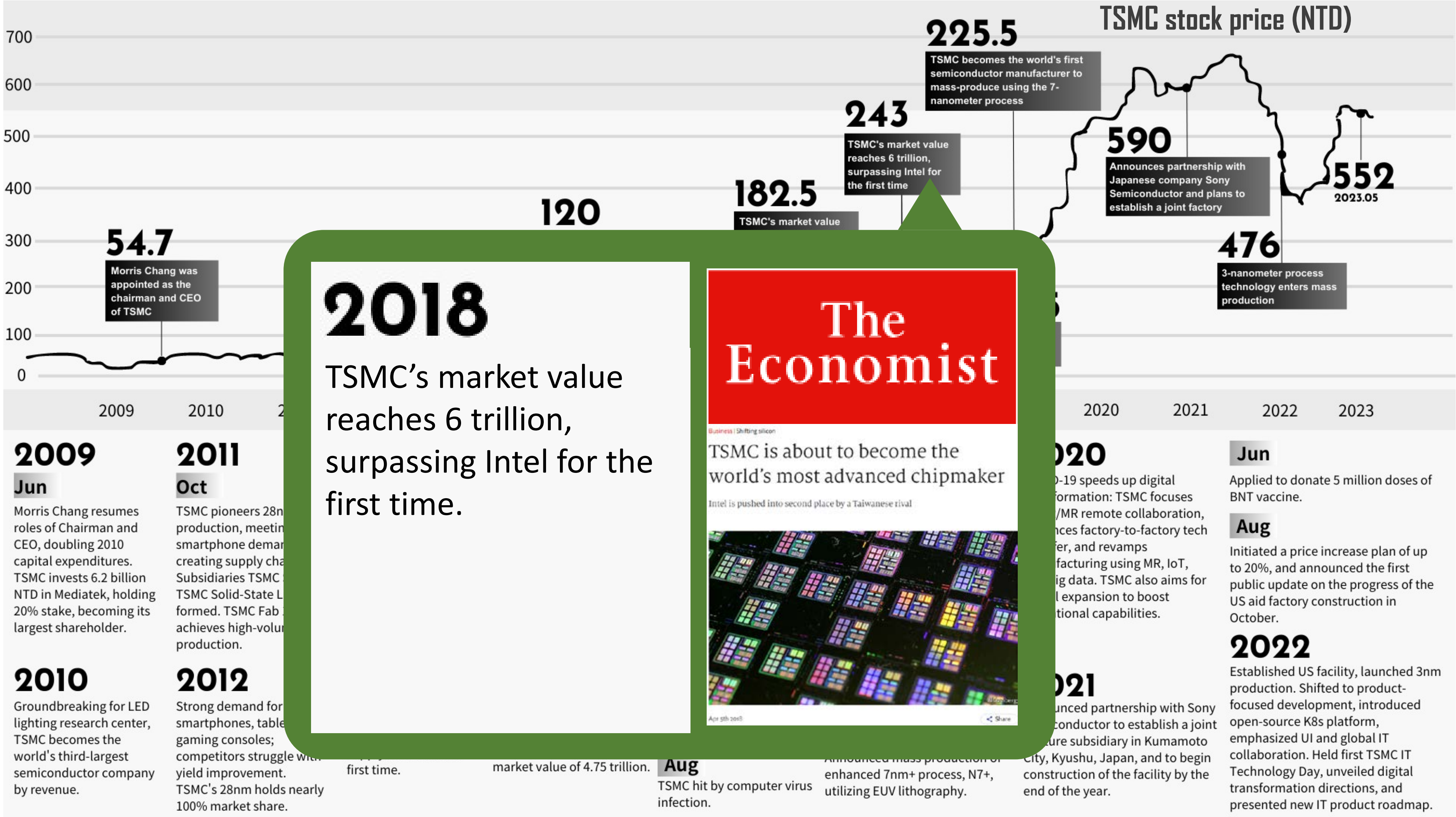
Established US facility, launched 3nm production. Shifted to product-focused development, introduced open-source K8s platform, emphasized UI and global IT collaboration. Held first TSMC IT Technology Day, unveiled digital transformation directions, and presented new IT product roadmap.

Rise of TSMC: A Chronicle

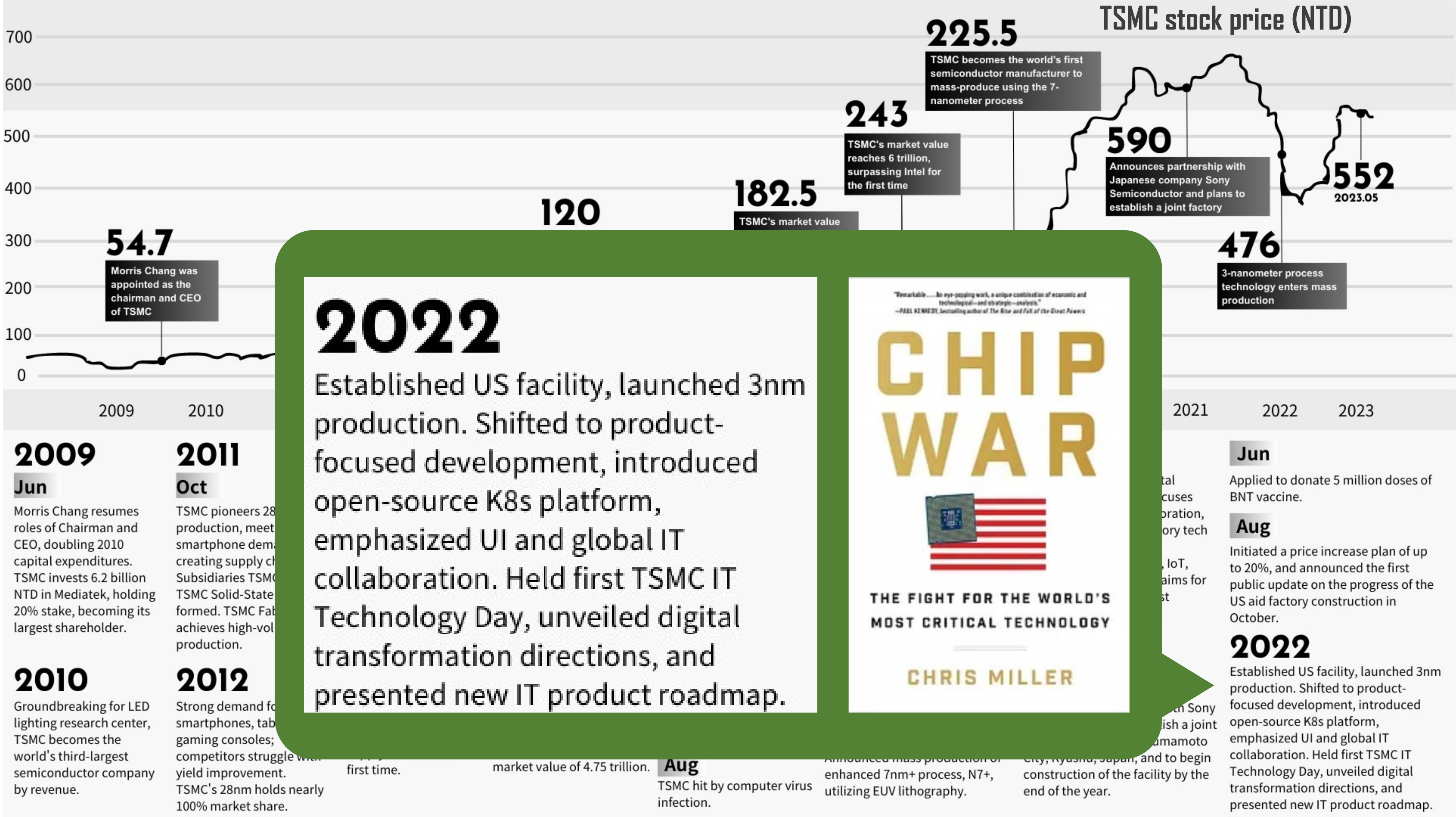


Source: TSMC is about to become the world’s most advanced chipmaker, The Economist, Apr 5th 2018

Rise of TSMC: A Chronicle



Rise of TSMC: A Chronicle



Rise of TSMC: Productivity Comparison

Production Efficiency in Korea and Taiwan

$\gamma = 0.6$

Korea	2004	2005	2006	2007	2008
DRAM	0.9686	0.9679	0.9576	0.9537	0.9667
Foundry					
LCD	0.9365	0.9216	0.9138	0.8897	0.9111
Korea Total	0.9524	0.9445	0.9354	0.9212	0.9385
Taiwan	2004	2005	2006	2007	2008
DRAM	0.5873	0.6120	0.8434	0.9433	0.9407
Foundry	0.9772	0.9616	0.9578	0.9583	0.9846
LCD	0.9455	0.9727	0.9121	0.9286	0.9324
Taiwan total	0.9019	0.9140	0.9200	0.9415	0.9527

$\gamma = 0.8/\gamma = 0.9$

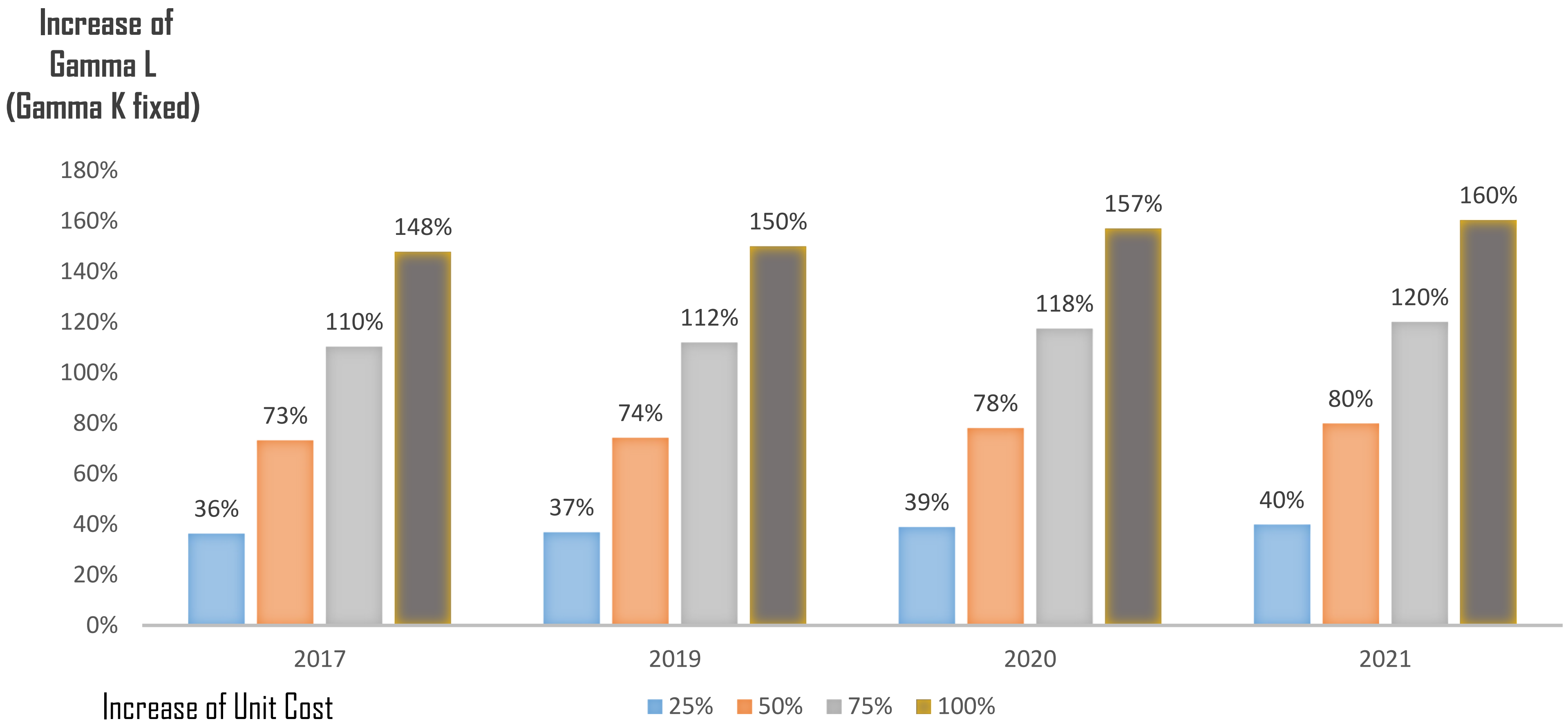
Korea	2004	2005	2006	2007	2008
DRAM	0.9493/0.9135	0.9529/0.9330	0.9225/0.8523	0.9233/0.8688	0.9558/0.9502
Foundry					
LCD	0.8910/0.8121	0.8537/0.7486	0.8161/0.6847	0.7315/0.5885	0.7922/0.6573
Korea Total	0.9197/0.8613	0.9019/0.8357	0.8677/0.7639	0.8218/0.7151	0.8701/0.7903
Taiwan	2004	2005	2006	2007	2008
DRAM	0.2884/0.1909	0.3112/0.2057	0.6715/0.5500	0.8771/0.7268	0.8590/0.6820
Foundry	0.9477/0.9147	0.9201/0.8835	0.9140/0.8774	0.9158/0.8798	0.9661/0.9455
LCD	0.9049/0.8704	0.9388/0.9006	0.7523/0.6047	0.8028/0.6636	0.8179/0.6906
Taiwan total	0.7981/0.7335	0.8116/0.7434	0.7979/0.6871	0.8528/0.7461	0.8760/0.7757

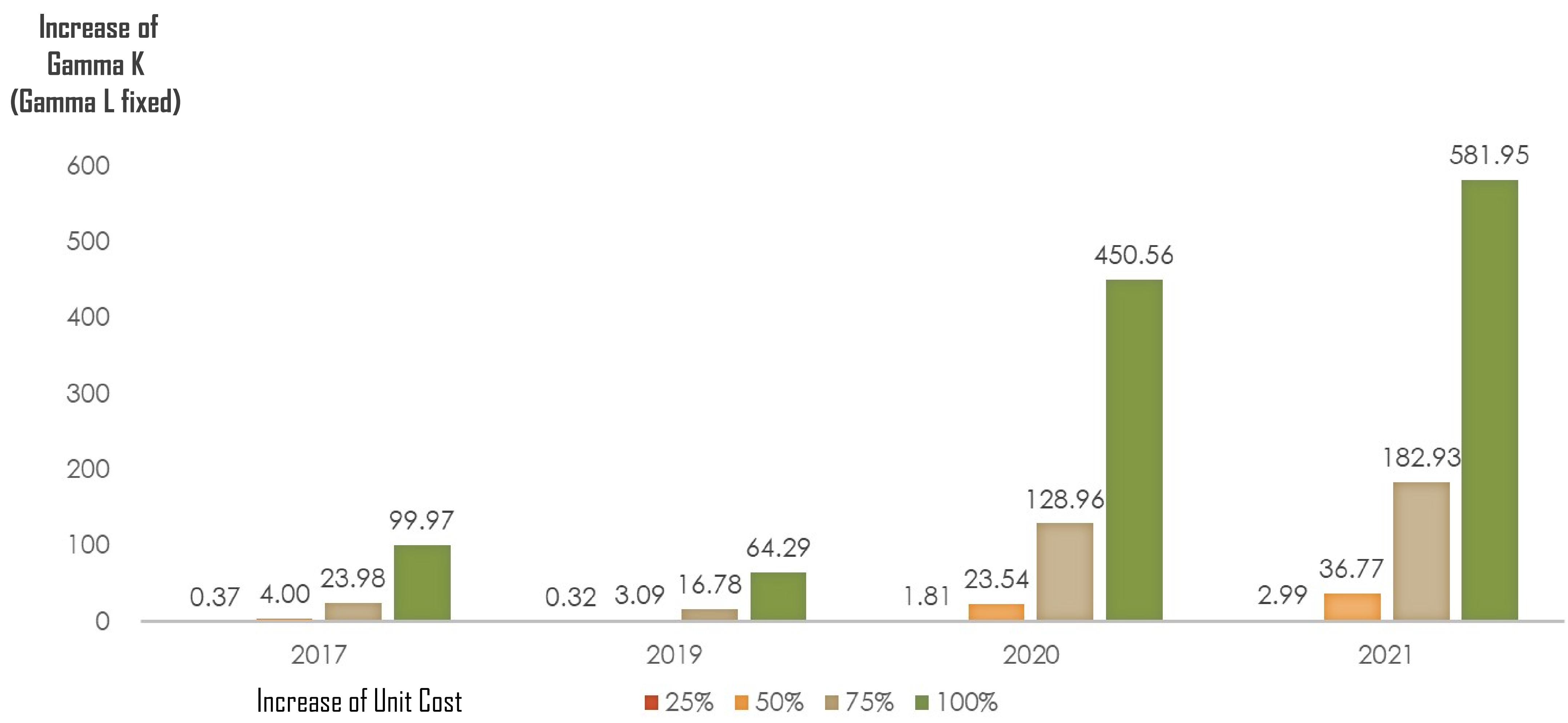
- Taiwan vs. South Korea in DRAM, foundry and TFT-LCD under various organizational span-of-control γ (Lee-Wang 2010)
    - Taiwan's DRAM lagged behind in scales and unit costs
    - Taiwan’s TFT-LCD comparable.
- Taiwan’s foundry had comparative advantages with **modularization 2.0**: Specialization in semiconductor manufacturing only, but with micro and implementation designs that help further reduce the cost and improve the success of the upstream industry:
    - 2015: TSMC outbid Samsung with quality
    - 2018: TSMC market value reached 6 trillions, surpassing Intel

Challenges Facing TSMC

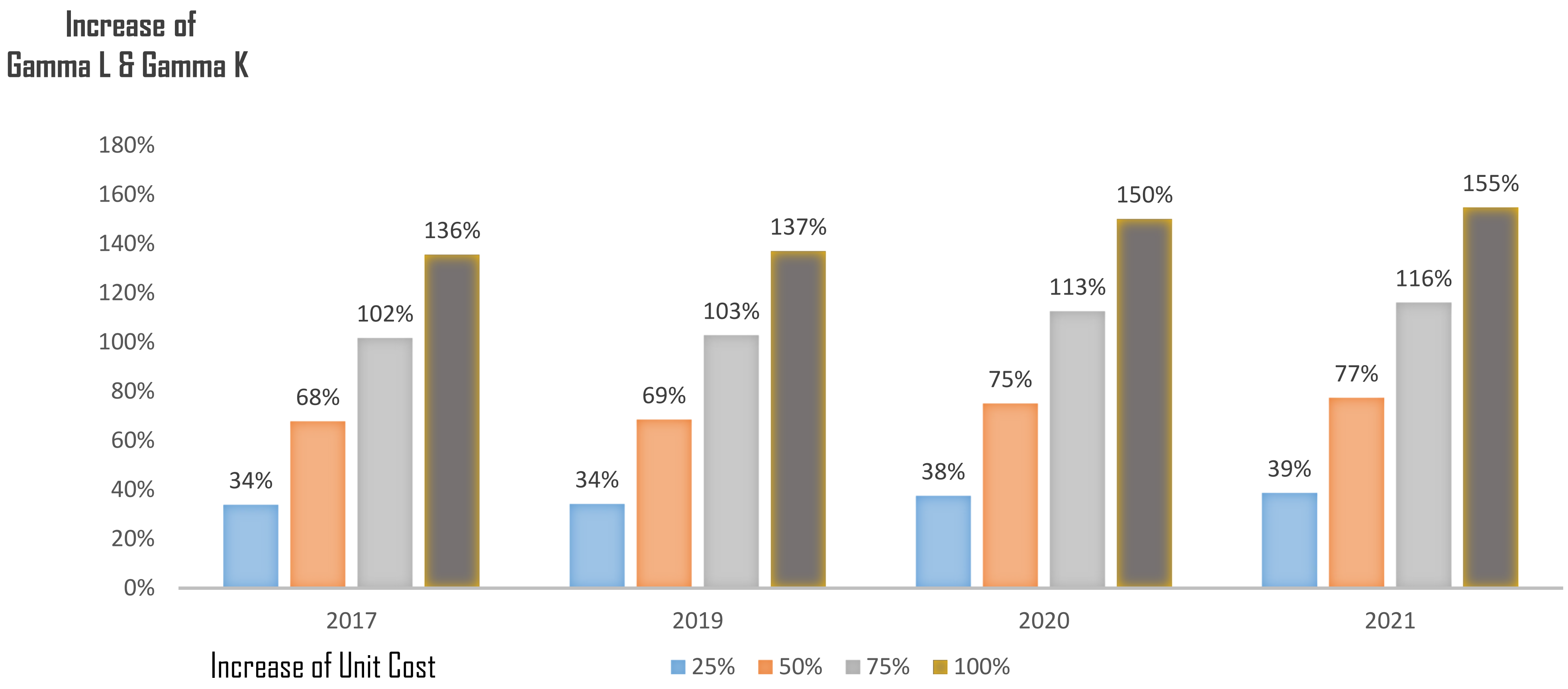
- TSMC faces major adjustments in response to Chip War with large reconfiguration cost – large labor adjustment costs and moderate capital adjustment costs (Lee-Wang-Wang 2023)
- Large manpower gaps in the U.S. as well as other international fabs is the chief concern (more so also in Germany, but somewhat less so in Japan)
- Increasingly sophisticated semiconductor manufacturing harder to re-establish in economies with deindustrialization (such as the U.S.)
  - Shortage of high skilled semiconductor labor as most international universities have not offer comprehensive courses
  - Shortage of peripheral manpower (such as in construction and operational jobs)
- Possible shortage and misalignment in government incentive and infrastructure provision
- Possible “downgrade” from skill intensity to capital intensity.

Reconfiguration with 25%-100% Unit Cost Increase due to Rises in the Adjustment Cost of Labor (Gamma L) and/or (Gamm K)





Increase of
Gamma K
(Gamma L fixed)
600
500
400
300
200
100
0
0.37
4.00
23.98
99.97
0.32
3.09
16.78
64.29
1.81
23.54
128.96
450.56
2.99
36.77
182.93
581.95
2017
2019
2020
2021
Increase of Unit Cost
25%
50%
75%
100%



Increase of
Gamma L & Gamma K
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
34%
68%
102%
136%
34%
69%
103%
137%
38%
75%
113%
150%
39%
77%
116%
155%
2017
2019
2020
2021
Increase of Unit Cost
25%
50%
75%
100%

A Win-Win Strategy

- TSMC-Phoenix as a natural experiment guiding future semiconductor policy
  - More economics
  - Less politics, regulations or interventions
  - Diversified locations: Japan, Germany, etc.
- **Modularization 3.0**:
  - Continual adoption of modularization to avoid cost hikes, with US up-stream, Taiwan/South Korea middle-stream, LDC down-stream, which has proven a feasible and efficient value chain suiting for just-in-time and lean practices and product complexity
  - Enhanced ties between up and middle streams with long term contracts and tax incentives to ensure economics and national security
  - Diversification in multinational chip making and in downstream to mitigate some geopolitical concerns
  - Rapid catch up by China unlikely because the TSMC model of modularization 2.0 in human capital, organization capital and business culture dimensions is hard to replicate
  - Reduced sanctions and export controls against China for less cross-Taiwan Strait threads.