The East Asian Electronics Sector: The Roles of Exchange Rates, Technology Transfer, and Global Value Chains

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Introduction

- East Asia has become the center for electronics manufacturing.
- When 90% of advanced semiconductors are made in Taiwan, there are risks if wars, natural disasters, and other events disrupt the flow of chips from Taiwan.
- The U.S. and other countries are seeking to re-shore semiconductor manufacturing.
- Are there lessons from East Asia’s successes?

Outline of the Presentation

- This presentation will consist of six parts:
- 1) Framework for Understanding Learning and Technological Advancement in East Asia
- 2) Japan’s Experience
- 3) Taiwan and South Korea’s Experiences
- 4) Thailand and Malaysia’s Experiences
- 5) China’s Experience
- 6) Lessons for the U.S.

1) Framework for Understanding Learning and Technological Advancement in East Asia

- Beneficial initial conditions
- Workers' technical competence affects ability to absorb new technologies
- Exporting (competition necessitates technological advances, vast markets lead to learning-by-doing)
- First stage (Importing technology and performing basic research)
- Second stage (Leveraging technologies)
- Third stage (Approaching the technological frontier)
- Entrepreneurship crucial (transforms ideas into profitable activities)

Regional Value Chains

- MNCs lower costs by slicing production into fragmented blocks based on wage levels, factor endowments, physical and human infrastructure, and other factors.
- Firms fragment production when the resulting cost saving exceeds the service cost of linking separated production blocks.
- Service link costs reflect costs of imperfect information, unstable contracts, uncredible partners, and costs due to transportation, telecommunications, and intra-firm coordination.
- Corruption increases the service link costs and high-quality highways, ports, airports, and infrastructure reduce these costs.

Foreign Direct Investment

- Mundell: Capital inflows cause the capital-intensive industry to expand and the labor-intensive industry to contract.
- Kojima: Capital inflows cause the labor-intensive industry to expand and the capital-intensive industry to contract.
- Kojima viewed FDI as transmitting capital, managerial skill, and technical knowledge to the host economy.

Exchange Rates throughout the Supply Chain Matter

Consider Asian economies providing value-added through parts and components and China providing value-added through capital and labor. Exchange rates will impact the dollar value of China's exports to the U.S., $XV^{\$}$, as follows:

$$XV^{\$} = P_X^{\$} \cdot x = \pi^{\$} \cdot x + w^{rmb} \cdot L \cdot E^{\$/rmb} + \sum_i Pm^i \cdot m_i \cdot E^{\$/i}, \qquad (1)$$

where $P_x^{\$}$ is the dollar price of China's exports to the U.S., x is the volume of China's exports to the U.S., $\pi^{\$}$ is the Chinese exporter's dollar profit per unit of export, w is the Chinese nominal wage rate measured in renminbi, L is the quantity of labor, $E^{\$/rmb}$ is the Chinese exchange rate (USD per renminbi), Pm^i is the price of imported inputs from supply chain country i measured in the supply chain country's currency, and $E^{\$/i}$ is the supply chain country's exchange rate (USD per supply chain country's currency).

The China Shock

- U.S./East Asia imbalances soared after China’s 2001 WTO Accession.
- The Stolper–Samuelson theorem implies that trade liberalization benefits capital and harms labor in the U.S.
- Autor, Dorn, and Hanson (2013) found that job losses in the United States following China’s WTO accession occurred in sectors exposed to competition from China.
- Acemoglu and colleagues (2014) reported that China’s imports caused “stunning” losses in US manufacturing jobs.
- Pierce and Schott reported that US counties exposed to imports from China experienced more of these “deaths of despair”
- US workers’ losses led to protectionism and a trade war.

2. Japan’s Experience

Rocket Sasaki

- Tadashi Sasaki visited Bell Labs and made transistors.
- Sasaki had studied at Kyoto and Dresden Universities and collaborated with Stanford Professor Spangenberg.
- Sasaki believed adding transistors to an IC could lead to a battery run calculator, though his engineers doubted.
- He wanted MOS chips and convinced the American company Autonetics to make MOS chips for calculators.
- In 1970 Sharp introduced EL-8 battery-powered calculator that weighed 0.72 kg.
- Sasaki asked RCA to make LCD panels for calculators, instead RCA licensed the technology to Sharp.
- Sharp then mastered the technology and used it to make calculators and award-winning 14-inch thin screen TVs.

Sony

- In 1953 Akio Morita signed an agreement with Western Electric in the U.S. to make transistors. Sony researchers visited U.S. factories and laboratories and studied *Transistor Technology.*
- In 1955 Sony made 140 x 89 x 38.5 mm transistor radio and in 1957 pocket-sized radios, popular in U.S., sold 7 million.
- In 1968 Sony made Trinitron TVs. Consumers loved picture quality and Sony's patents protected it from strenuous price competition.
- In 1973 Sony vice president pushed engineers to study CCDs. Bell Labs researchers in US freely shared about CCDs.
- Sony engineers were free to research and play around with CCDs. Used these to make camcorders. Very profitable.
- Sony cofounders Morita and Ibuka goaded engineers to make the Walkman. Since 1979 Sony has sold 400 million units.

Semiconductors

- Sharp and Seiko in 1970s made C-MOS (complementary metal oxide semiconductors) chips without first learning to make the industry standard P-MOS (positive channel MOS) and N-MOS (negative channel MOS).
- U.S. semiconductor companies focused on P-MOS and N-MOS chips, though C-MOS required 10^{-5} less power.
- Manufacturing C-MOS was difficult, but Japanese firms persevered and by 1980 produced high quality chips.
- U.S. firms missed C-MOS's potential until the late 1970s. When C-MOS became the industry standard Japan was far ahead
- Japanese companies gained price competitiveness from 65% USD appreciation between 1979 and 1985.
- No Japanese firm was a top ten producers in 1980 but by 1986 Japan was the world's top semiconductor supplier.

Japan’s Educational, Macroeconomic and Trade Policy Backdrop

- In 1950, average schooling years of working age population in Japan was 70% of frontier country and by 1970 had increased to 80% percent. 5,000 engineers graduated in 1940, jumped to 50,000 in 1970. Until ‘75 engineers got technical and broad liberal arts training.
- Japanese consumers saved large share of income increases after WWII, providing funds for investment.
- The trading environment in Japan’s largest market, the U.S., was tilted towards free trade until 1980s when 65% USD appreciation caused U.S. trade deficits to soar.
- U.S. in 1980s targeted Japanese semiconductor industry. After agreement, MITI pressured Japanese chip firms to raise prices and lower export quantities.

Interpreting Japan’s Experience

- Entrepreneurs (e.g., Tadashi Sasaki) guided companies to take intelligent risks. The U.S. (the frontier country) freely shared discoveries with Japanese researchers, licensed technology, and provided experts to impart manufacturing know-how.
- Japanese workers were well educated and hard-working, enabling them to assimilate imported technologies.
- Households saved, financing investment, and firms channeled profits into R&D and gave engineers freedom.
- Engineers multiplied and received both technical and liberal arts education. Engineers were passionate about research and loyal to their companies.
- Japanese firms could not receive lucrative U.S. defense contracts, so focused on consumer electronics. Had

Interpreting Japan’s Experience (continued)

- incentive to continually innovate to escape cutthroat price competition.
- Public research institutes (e.g., Electro-Technical Laboratory) disseminated technical knowledge. For example, in 1947 they spearheaded attempts to understand transistor technology. They also provided a training ground for companies that could not afford to send workers abroad to study.
- Japanese firms benefited from open markets in the world’s largest consumer market, the U.S. They exported millions and millions of radios, televisions, watches, calculators, and other electronic products to the U.S. This led to huge efficiency gains through learning-by-doing.

3. Taiwan and South Korea’s Experience

Taiwan Abandons Import Substitution

- ROC lost War in 1949 to PRC and evacuated to Taiwan. ROC and PRC had conflicts in 1954 and 1958. ROC’s GDP per capita in 1960 was below Haiti and Zimbabwe’s.
- Economic development was imperative for survival.
- The Taiwanese government abandoned import substitution policies and encouraged exports. Also invested in education.
- By 1966 Tatung Company exported 2 million radios for Japanese *sogo shosha*. Taiwanese firms obtained technology and training from Japanese companies. By 1973 Taiwan was the world’s third leading exporter of televisions and vibrant supplier of TV & electronic P&Cs.

Taiwan Faces Crisis in 1974

- In early 1970s Taiwan faced quotas on textile exports, had to leave the UN after U.S. established relations with the PRC, severed relations with Japan in 1972, lost access to Japanese capital goods and technology, and faced a 47% CPI increase.
- In this crisis environment Taiwan conferred extensively with Chinese experts from the U.S. Wen-yuan Pan, director at RCA’s prestigious Sarnoff Laboratories in Princeton, New Jersey, identified semiconductors as a key product Taiwan could make that had future potential and inter-industry connections.

Industrial Technology Research Institute (ITRI) Spins off United Microelectronics Corporation (UMC)

- Pan and Technical Advisory Committee made up of Chinese researchers from the U.S. recommended Taiwan assimilate 7.0 micron C-MOS technology when the frontier technology was 3.0 microns. RCA transferred technology, trained engineers (many had US PhDs).
- Engineers at ITRI built chips and by 1979 surpassed RCA. ITRI spun off the private company UMC.
- UMC joined HSBIP (established by government in 1979). HSBIP was next to two universities and its director had received 36 U.S. patents. UMC was close to researchers and received low interest loans, inexpensive land, and tax holidays from HSBIP. Today UMC is a leading semiconductor company.

Taiwan Semiconductor Manufacturing Company (TSMC)

- ITRI then invested in very large scale integration and spun off TSMC.
- ITRI transferred 150 employees to the new company and rented its VLSI manufacturing plant to TSMC.
- TSMC's first chairman, Morris Chang, had been vice president of Texas Instruments.
- TSMC makes ICs according to other firms' specifications rather than designing them in-house. This assures customers that it is a partner rather than a competitor. It is now the world's largest semiconductor manufacturer.

Korea Pursues Export-Oriented Growth

- Korea’s GDP per capita in 1960 was below Haiti and Zimbabwe’s. President Chung-Hee Park imitated Japan’s export-oriented growth. Economic development was imperative to resist the military threat from the north.
- The government provided loans at below market interest rates and rescinded credit if firms failed at exporting.
- Korea invested in education, progressing from 25% of average schooling years of frontier country in 1960 to 75% percent in 2000.
- 1960s imported packaged technologies to produce consumer electronics. Japanese MNCs provided P&C and training and know-how.
- By 1975 domestic R&D grew, with innovation driven by entrepreneurs and capable work force.

Samsung

- Samsung in 1960s and 1970s had partnership with Sanyo, NEC and others. Japanese firms provided know-how while Samsung provided low-cost labor, management, engineering and overhead. By 1978 Samsung had made 5 million televisions.
- Samsung also performed its own R&D. Took apart foreign color televisions to learn how to make them. Grit in producing color televisions for export showed its commitment to the government's plan.
- Sony was a guinea pig providing guidance for companies like Samsung as to what products to move into next.

Samsung (continued)

- In 1980s Samsung founder Byung-Chull Lee focused on DRAM chips. DRAM is standardized commodity, short product cycles, prices fall 80% within 2 years.
- Recruited engineers from U.S. and sent engineers to US for training. Soon produced quality chips.
- Japanese producers were compelled by agreement with U.S. to restrict supply and raise prices. Samsung could sell as much as it wanted and recycled earnings into R&D and capital formation. In the early 1990s Samsung became the world’s leading producer of DRAMs.
- In 1995 Chairman Lee demanded and received a substantial improvement in the quality of Samsung’s cellphones and consumer electronics goods.

Interpreting Taiwan and Korea’s Experiences

- Japanese firms provided know-how, technology and training. Local engineers were educated and adept at assimilating technologies, reverse-engineering products, and innovating.
- ITRI promoted semiconductors by identifying and absorbing new technologies, training researchers, and spinning off companies. The ITRI’s promotion of the semiconductor industry came as Taiwan faced a crisis. The government focused on development to survive. When national security concerns are paramount, the polity reacts as a unified actor. At other times, interest group competition, rent-seeking, and distributional struggles can predominate.

Interpreting Taiwan and Korea’s Experiences (continued)

- Government officials’ knowledge also matters. Taiwan accessed knowledge from overseas Chinese diaspora. They provided exceptional knowledge free of charge.
- Korea promoted semiconductors and used a carrot and stick approach. Korea faced 750,000 troops in the north and the credible threat of invasion. Korean workers were patriotic and determined for Korea to succeed. For Korea as well as Taiwan, the unified actor framework provides a credible model of the political economy interactions in this crisis environment.
- Korea accessed knowledge by following Japan’s industrial progression.

Interpreting Taiwan and Korea's Experiences (continued)

- The importance of entrepreneurs is seen in Samsung Chairman Lee's prioritizing DRAM production and his son's insistence that Samsung improve quality.
- The importance of worker migration in transplanting know-how is seen by the return of many successful researchers from the U.S. to work in Taiwan. They brought the skills they had acquired back with them. The close proximity of electronics firms, the Hsinchu Science Based Industrial Park, ITRI, and universities meant that scientists, researchers, and engineers could be in close contact with their peers. They would migrate from firm to firm, allowing human capital spread throughout the cluster.

4. Thailand and Malaysia's Experience

HDD Manufacturing in Thailand

- In late 1980s Developed Asia experienced appreciations and lost price competitiveness. They transferring factories to lower wage locations in ASEAN.
- HDD manufactures moved to Thailand and sourced P&C from nearby. This aided communication with supplier firms. Suppliers sent engineers to communicate and dispatched technical workers when defective parts were delivered. Discussed production efficiency & cost savings. Teams coordinated production schedules, evaluated performance, and considered how to improve quality.
- Upgrading occurred. Foreign engineers trained Thai engineers. Thai engineers then trained Thai engineers in Thai language. Competition forced engineers to innovate (e.g., when yields fell, workers solved the problem).
- R&D and technicians from Asian Institute of Technology helped.

Malaysia’s Attempt to Upgrade the Semiconductor Industry

- Malaysian IC industry was mired in lower value added activities (e.g., assembly and testing). The government used industrial policy to try to upgrade into higher value added activities (e.g., R&D, design, and fabrication).
- It established MIMOS in 1985 to promote semiconductor firms. MIMOS acquired very large scale integration technology and created Silterra in 2000.
- Silterra didn’t join ranks of TSMC and Samsung. Politics dominated by preferences to promote *bumiputera* over ethnic Chinese and Indian Malaysians. When choosing leaders for Silterra, high tech parks, and other institutions, Malaysia did not choose the best candidates endowed with tacit and experiential knowledge.

Malaysia’s Attempt to Upgrade the Semiconductor Industry (cont’d)

- Malaysia did not choose Loh Kin Wah, managing director of Qimonda, to lead.
- Was reluctant to provide grants to ethnic Chinese firms, even though these were dynamic in the electronics sector.
- Did not withhold benefits to firms that performed badly.
- Educational system did not create enough high quality engineers and scientists as admissions were strongly influenced by the politics of ethnicity.

Interpreting Thailand and Malaysia's Experiences

- HDD procurement illustrates slicing up of the value chain. Sourced parts from nearby, coordination improved efficiency.
- Taiwan and South Korea used industrial policy to reach frontier while Malaysia failed. Different outcomes due to different political equilibria. Taiwan and Korea in the 1970s faced threats of invasion. Political leaders, citizens, and diaspora united to see economy succeed.
- Malaysia had overcome threats of rural unrest. Government was focused on redistributing wealth and firm ownership to *bumiputera*. When making decisions on leadership at semiconductor companies, admissions to college, and grants to firms, it did not choose the most qualified candidates. The emphasis on redistribution also led to rent-seeking activities. In this environment, industrial policy failed to achieve structural transformation.

5. China’s Experience

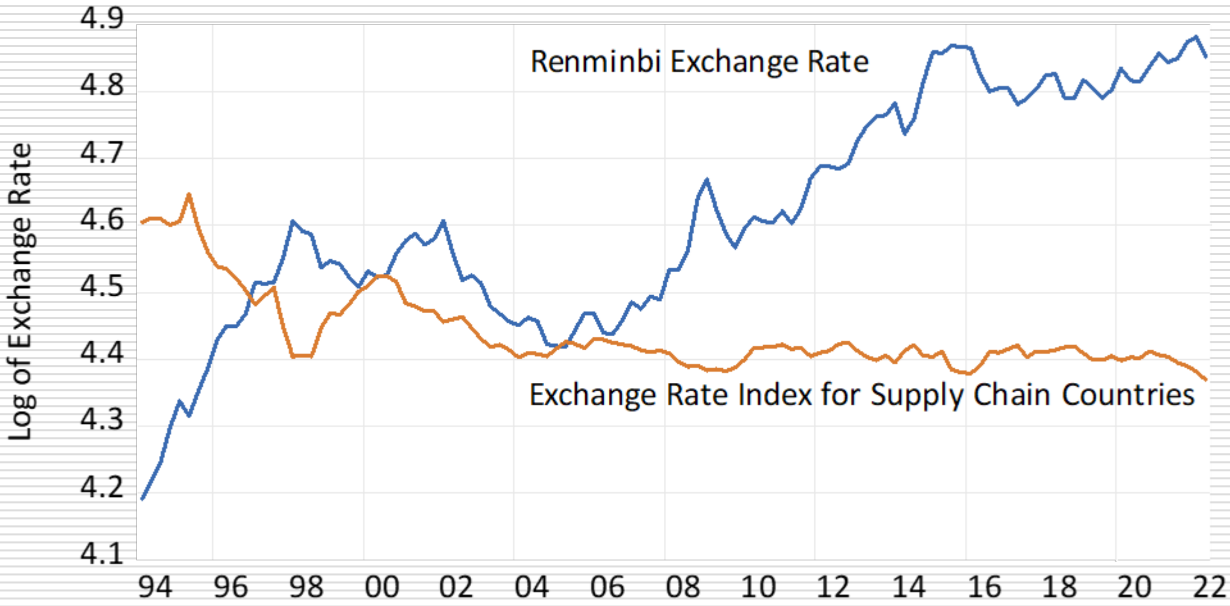
Taiwan’s Notebook PC Industry Migrates to China

- China established SEZs with lower taxes and reduced regulations in Pearl River and Yangtze River Deltas. Deltas had superb network of highways, ports, airports, and other infrastructure.
- China joined WTO in 2001, increasing confidence of foreign investors that China would respect the rule of law.
- Sea change in electronics occurred. An example is offshoring of Taiwan’s notebook PC industry to Yangtze River Delta.
- Taiwanese ODMs attracted by low wages and good infrastructure in the Yangtze River Delta. Taiwanese suppliers provided connectors, batteries, switches and displays. ODM employees trained supplier employees. ODMs produced for HP, Apple, and others. Intel provided microprocessors, Microsoft provided OS. Chinese SMEs performed casting, forging, plating, & assembling.
- ODMs kept inventories lean by processing 98 percent of order within 3 days. Productivity growth in cluster mushroomed.

Exchange Rates and China's Electronics Exports

- China became center of exports for computers, phones, other final electronics goods.
- South Korea, Taiwan, Japan and other countries flooded China with semiconductors, image sensors, other parts & components.
- Much of the value-added came from upstream Asian countries rather than China.
- This implies that exchange rates in upstream countries matter for China's exports.
- While the RMB has appreciated, exchange rates in upstream countries have not.

Renminbi REER and Exchange Rates in Countries Supplying Electronic P&C to China



Interpreting China’s Experience

- China attracted FDI by implementing business-friendly laws, SEZs with low taxes, reduced regulation, and superb infrastructure, and by reassuring investors that it would follow the rule of law.
- Taking these steps reduced the service link cost of establishing production blocks in China, and MNCs moved factories to China.
- China also had the locational advantage of low-wage labor.
- MNCs produced parts and components in upstream Asian countries and assembled final goods in China.
- Because value-added comes from upstream countries, a concerted appreciation across East Asian supplier countries would impact the price competitiveness of China’s exports more than an RMB appreciation alone.

6. Lessons for the U.S.

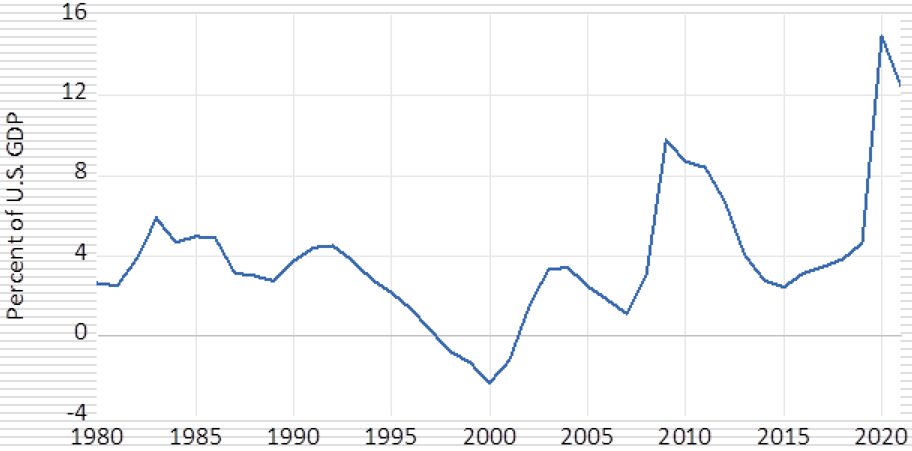
Invest in Education and Learning

- Taiwan, Korea, and other East Asian countries invested in education and learning.
- Educated and competent workers are better able to absorb new technologies.
- The rankings in the 2018 PISA tests in math, science, and reading were: China 1st, Singapore 2nd, Macao 3rd, Hong Kong 4th, Japan 6th, Korea 7th, Taiwan 8th, and the U.S. 25th.
- The U.S. should invest starting at an early age.
- In the digital economy, education should impart advanced cognitive skills such as complex problem-solving, social skills such as teamwork, and adaptive skills such as reasoning and self-efficacy.
- U.S. firms should also actively recruit engineers and scientists from Asia who are endowed with tacit knowledge.

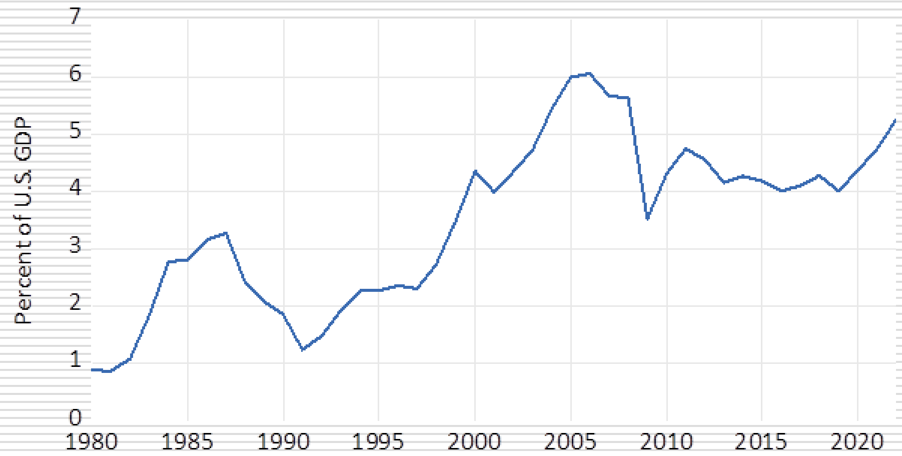
Practice Fiscal Discipline

- Semiconductor manufacturing requires massive and continuous investment.
- Asian countries during the eastward migration of the electronics industry had high national saving rates. This provided funds for capital formation.
- The U.S. has run large budget deficits year after year. These budget deficits reduce national saving and siphon off funds that could go to private investment. They have also contributed to the large U.S. trade deficits. To strengthen the manufacturing sector the U.S. government should reduce its budget deficit.

U.S. Budget Deficit Relative to GDP over the 1980-2021 Period.



U.S. Trade Deficit Relative to GDP over the 1980-2021 Period.



Confront Competition and Harness Incentives

- U.S. researchers invented transistors, CMOS semiconductors, LCD displays, and other breakthroughs.
- Usually Asian rather than U.S. electronics firms profited from these. Asian firms competed in demanding markets while US electronics firms were coddled by lucrative defense contracts.
- Hufbauer and Jung (2021) found that protectionism and largesse towards individual firms usually failed while subsidies for research and development were effective when allocated by researchers without political interference.
- U.S. firms must face the discipline of competition in world markets.

Encourage Entrepreneurship

- Entrepreneurs in Asia drove technological change. They took risks with no assurance that they would succeed (Akio Morita at Sony, Tadashi Sasaki at Sharp, Byung-Chul Lee at Samsung).
- As the U.S. seeks to promote the semiconductor industry it should give pride of place to entrepreneurs.
- They should be allowed to take risks and to fail.
- Their incentives should be to pass market tests rather than to lobby for government largesse.

Create a Positive Research Atmosphere

- Seiko and Sharp first used liquid crystal display (LCD) panels to make televisions. Sharp developed a 14-inch LCD TV that required one million thin film transistors.
- Sharp won the Eduard Rhein Technology Award for its invention. This award is considered the Nobel Prize of the audiovisual world.
- Researchers at Seiko and Sharp said that the companies provided positive research environments and enabled their engineers to pursue their dreams.
- Innovative breakthroughs often come, not when companies demand in a militaristic manner that researchers produce results, but instead when they give engineers freedom to come up with ways to accomplish assigned tasks.
- So as the U.S. tries to regain a place at the cutting edge of semiconductor manufacturing, firms should give their researchers space to develop innovative solutions.

Other Considerations

- Lobbying and rent seeking are endemic in the U.S. In this atmosphere, industrial policy is likely to fail.
- In addition to expenditure-reducing policies such as reducing the budget deficit, expenditure-switching policies can strengthen U.S. manufacturing.
- Tariffs are problematic. Exchange rate adjustments are preferable. However, weak exchange rates in Taiwan, Korea, Japan, and other Asian supply chain countries will make it difficult for electronics firms producing in the U.S. to compete with producers in Asia.
- Industrial clusters would be helpful.

- Thank You