Manufacturing, Competitiveness and Technological Leadership in the Semiconductor Industry

An assessment of the economic impacts of the proposed joint venture project of AMD and the Advanced Technologies Investment Corporation to build and operate the Fab 4X semiconductor foundry manufacturing project in Saratoga County, New York

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Executive Summary

Advanced Micro Devices (AMD), the world's second largest producer of microprocessors, has announced its intent to build a new $4 billion-plus leading edge semiconductor foundry manufacturing facility in Saratoga County, New York as part of a joint venture with the Advanced Technologies Investment Corporation (ATIC) of Abu Dhabi, U.A.E. When completed in 2012, the proposed manufacturing facility, currently known as Fab 4X, will be the most technologically advanced in the world and the largest leading edge semiconductor foundry facility in the United States. The Fab 4X facility will be capable of manufacturing semiconductor chips on wafers that are twelve inches (300 mm) in diameter, ultimately etching circuits a mere 22 nanometers in width across their surface – so narrow that 5,000 of them would be as wide as a human hair.

The construction of a new, cutting-edge foundry fabrication facility in the United States is more than a milestone in the U.S. semiconductor

industry's technological progress. It is an event with significance for the long-term competitiveness of both the national and regional economies. This is because many semiconductor companies either have or are in the process of exiting the manufacturing business and moving to a foundry contract manufacturing business model to reduce costs for manufacturing related research, facilities and operations. The Fab 4X foundry facility would reverse this trend, and will provide a much-needed U.S. source of contract manufacturing. Further, the Fab 4X project is expected to include capital investments exceeding $4 billion, provide thousands of new jobs, and generate additional economic growth in the region. In fact, New York and Saratoga County targeted the semiconductor industry for economic development because experience in other regions has demonstrated the industry not only provides well-paying jobs, it also serves as a catalyst that has transformed those regions into technology industry "clusters" that generate additional jobs, investment and economic diversity.

This paper considers the competitiveness impacts of the plan to build this new semiconductor fabrication facility in Saratoga County, New York. It will examine the significance of Fab 4X from a variety of perspectives: from that of economic growth and jobs at the national and regional level; from the vantage point of American productivity and competitiveness; and from the perspective of American technological leadership.

The paper will also demonstrate that investment in new, advanced manufacturing facilities plays a central role in building economic growth. In fact, the strengthening of New York's already substantial presence in

nanotechnology plays an increasingly important role in national competitiveness.

Consistent with a variety of estimates of the positive impacts of manufacturing, the construction and operation of the Fab 4X project can be expected to have the following beneficial impacts on New York and, through New York leadership, on U.S. competitiveness:

- A $4 billion plus capital investment to complete the Fab 4X facility.
- The direct creation of approximately 1,465 permanent manufacturing jobs by the end of 2014, representing an annual payroll of about $88 million.
- An immediate stimulus to the regional economy through local expenditures of as much as $800 million in the construction of the new manufacturing facility, which would be expected to begin in the first half of 2009. The construction alone is expected to support about 1,600 jobs during this phase of the project, with a total payroll of $102 million. The stimulus created by this employment has the potential to create additional 2,700 jobs through economic multiplier effects during this phase of the project, with a total payroll of an additional $108 million.
- An additional 550 long-term jobs are estimated to be created among local firms and individuals providing services to the fab, in such areas as computer sales and maintenance, fab garment

cleaning, delivery services, maintenance, security, waste disposal, and other on-site activities, with an annual local payroll of $22 million.

- Indirect impact on the regional economy as a result of the Fab 4X project and its ongoing activities through the creation of jobs that support the manufacturing workers and their families, such as retail establishments, health services, education, home maintenance and repair, and other personal consumption. The New York Empire State Development Corporation (ESDC), in its own analysis, concludes that for each job directly created by the new facility, an additional 2.25 “indirect” jobs would ultimately be created in New York’s economy. Thus, the 1,465 direct fabrication facility jobs and the estimated 550 related service jobs, or about 2,000 jobs in all, would lead to an additional 4,500 jobs based upon the spending capability generated by these “direct” jobs, with a payroll of $180 million.
- In all, the combined economic impact of all of this activity is likely to total 6,500 sustained, long-term jobs, as well as many as 4,300 additional jobs during the construction of the plant, with sustained annual payrolls of $290 million during the operation of the plant and $210 million during the construction phase.
- The total effect of the Fab 4X project will also be enhanced as a result of the synergies that result from the “clustering” of the

> combined nanotechnology and semiconductor presence in New York's Capital Region, of which the new facility will be a crucial part. Substantial literature on competitiveness, led by Michael Porter's pioneering work on regional clusters, demonstrates the virtuous cycle generated by regional concentrations expertise, R&D, employment and education. In concert with IBM, and with the presence of leading educational institutions and other high-technology companies in the area, the Fab 4X manufacturing facility will help to further New York's high-technology leadership which, in turn, will be a powerful force in creating additional innovation, investment and employment.

After a brief review of the announced plans for Fab 4X, this paper will review (i) the importance of the semiconductor sector to innovation, investment and employment, (ii) the benefits of job creation and economic growth in New York, and (iii) the larger implication for U.S. competitiveness, informed by an understanding of the positive impact of advanced manufacturing.

Background: AMD's plans to build Fab 4X

In 2006, AMD announced its intent to construct a state-of-the-art computer chip manufacturing facility in upstate New York. That decision came after New York state officials offered the company $1.2 billion in state

incentives to build the leading-edge fab in Saratoga County's Luther Forest Technology Campus (LFTC) – located in the towns of Malta and Stillwater.[1] AMD has until July 31, 2009, to make a formal decision whether to proceed. AMD has announced that the project will be ready to break ground approximately four to six months after the project is formally initiated with the State of New York.

Fab 4X will be designed to manufacture microprocessors and associated logic products on 300mm wafers using the industry's most advanced process technologies. A 300mm wafer is 12 inches in diameter, with 2.25 times the wafer area of a 200mm wafer. Additionally, 300mm wafers have a higher clean room utilization efficiency and a reduced defect density, lowering die cost and ultimately making these wafers more cost-effective to manufacture.

Advancing from the current leading-edge of 45nm to 32nm technology helps ensure chips produced will be faster, consume less energy with more transistors and ultimately be more cost-effective. (Fab 4X will begin manufacturing product at the 32 nm node, and will later move to 22 nm technology as the availability of product designs, and customer demand move in that direction.) Further, the operations at the new facility will draw on the longstanding research partnership AMD has with IBM for advanced process technology development.

[1] [Explain combination of subsidies and tax exemptions]

Beyond Productivity: The Transformation of Economic Life

The U.S. semiconductor industry is both an economic anomaly and, at the same time, a vindication of what economists preach. It is an anomaly because of the way it stands out in the U.S. economy and among U.S. manufacturing industries. While U.S. manufacturing has lost employment annually since 1998, employment in semiconductor manufacturing, after bottoming out following the demise of the technology boom at the beginning of the decade, was higher in 2006 than it was in each of the three preceding years. In fact, about two out of every hundred jobs in American manufacturing today is involved in the production of semiconductors or the capital goods used to make them. Moreover, these are among the best jobs manufacturing offers. Even in New York, where the Fab 4X facility will be built, and where the average private industry wage is the second highest among the fifty states (owing to the presence of a variety of high-end services), the differential between semiconductor and other jobs' wages is still over 50 percent.

And while the U.S. trade deficit has burgeoned, the semiconductor industry persists in being a national export champion. Behind the aircraft industry, the semiconductor industry is the largest net exporter in the manufacturing economy – it sells abroad fully 77 percent of its output. U.S. semiconductor exports totaled $52.4 billion in 2006 (having grown by more than 10 percent in dollar terms in that year), and produced a trade surplus of $25 billion.

Semiconductors are an exception to more pervasive, negative trends in the economy because they abide by vaunted economic rules – they increase their value through innovation and investment. The semiconductor industry invested over $18 billion in research and development in 2006, the last year for which we have data, or over 15 percent of sales in that year. This constitutes about one out of every 12 dollars spent on R&D in the U.S. by private industry, and one out of every 8 dollars spent by U.S. manufacturing.

And beyond this commitment to research, the industry made capital expenditures of $14.9 billion in 2006. The semiconductor industry spends the highest proportion of its revenues on capital expenditures of all U.S. manufacturing industries, as this chart demonstrates. In fact, it leads all manufacturing in investment in both equipment – the etchers and other highly sophisticated machinery that produce semiconductors – and structures – the buildings that house them.

Capital Expenditures as a Percentage of Total Shipments, 2006

3344	Semiconductor and other electronic component manufacturing	**12.6%**
3273, 3274, 3279	Cement, concrete, lime, gypsum, and other nonmetallic mineral product manufacturing	**7.2%**
3121	Beverage manufacturing	**6.8%**
3271, 3272	Clay and glass products manufacturing	**5.9%**
3254	Pharmaceutical and medicine manufacturing	**5.7%**
3391	Medical equipment and supplies manufacturing	**5.7%**
3361, 3362, 3363	Motor vehicle, body, trailer, and parts manufacturing	**4.9%**
3336	Engine, turbine, and power transmission equipment manufacturing	**4.8%**
3341	Computer and peripheral equipment manufacturing	**4.7%**
3253	Pesticide, fertilizer, and other agricultural chemical manufacturing	**4.6%**
321, 327, 33	**Durable goods industries**	**4.1%**
31-33	**Manufacturing**	**3.8%**
31, 322-326	**Nondurable goods industries**	**3.5%**

The beneficiaries of this burgeoning investment, innovation, and productivity growth have been the consumers of a wide array of products, ranging from health care imaging and diagnostic devices, to energy saving features for commercial and residential equipment, to weather modeling supercomputers, to the PC on your desktop, to the telecommunications equipment that drives the Internet. The semiconductor has become to our time what the steam engine was to civilization 250 years ago – the gateway

to a new economy. But it has transformed economic life more rapidly and pervasively than James Watt's invention did. The ability to turn any fact, creation, image, sound, or other phenomenon into digital information, and to move it and use it virtually without cost, has fundamentally changed every aspect of the contemporary economy. It has restored productivity growth to the levels it achieved in the decades immediately following the Second World War, after two decades of post-OPEC decline. It has allowed companies, government agencies and other institutions to function more efficiently with fewer resources and lower costs. It has allowed the economy to free up hundreds of billions of dollars in inventories, parts and components, and other redundancies by creating seamless supply chains. It has allowed our firms to restructure themselves, focusing their strategies and investment on their core skills and allowing network-based production chains, partnerships and electronic commerce to supplement their focus. The global economy, in turn, has become a more efficient and productive one.

The investment and innovation embodied by facilities like the proposed Fab 4X factory in Saratoga County, New York has allowed semiconductor devices to leap out of the computer and into a host of now-ubiquitous applications – digital televisions, MP3 players, cell phones, and beyond – such that the value of the electronics in the average automobile now far exceeds the cost of the steel that goes into it. As one economist once put it,

the semiconductor is an epochal innovation in the truest sense of the word – more money will be made using it than producing it.[2]

Job Creation and Economic Growth in the Empire State

After a global search, AMD chose to locate the facility in Saratoga County because the area has the ingredients necessary to develop and sustain a world-class advanced semiconductor manufacturing facility: a skilled workforce, colleges and universities with highly competitive engineering and related programs, a growing number of technology firms and research and development efforts, proximity to strategic partners such as IBM, and competitive incentives to attract investment and job creation. Central to New York's strategy to attract technology investment is the Empire State Development Corporation's Empire Zones program, which was initiated with bipartisan support from state leaders.

Along with IBM's R&D facilities in East Fishkill, New York, Fab 4X will play an integral role in establishing upstate New York as a global semiconductor and nanotech cluster.

This "Tech Valley" corridor currently has over $13 billion invested in technology-related facilities, either by corporations or local and regional educational and technical training institutions that graduate thousands of

[2] My discussion refers to the semiconductor sector generally and should not be taken as a description of any portion of it. In particular, I am aware of allegations that Intel has engaged in anti-competitive conduct in the market for x86 microprocessors. Nothing in this paper indicates any view on the validity of those allegations; it is axiomatic, of course, that economic benefits of the kind I describe, including innovation, investment, productivity and higher employment, cannot be sustained over the long term absent the dynamism provided by competitive markets.

highly skilled workers each year. In addition to IBM, leading-edge innovation firms that are contributing to a growing global presence in the region include Tokyo Electron and German semiconductor company Infineon. In fact, over 250 companies now operate in the area, and the Fab 4X will accelerate dramatically the economic expansion in the region.

The agglomeration of these firms and other institutions, now to be joined by the Fab 4X facility, is an important event in terms of advancing the state of the art for semiconductor manufacturing and the next-generation microprocessors it will produce. But it also reinforces the synergies that are part of the "clustering" economic strategy for New York's Capital Region.

Regions are subject to the same economic forces as nations – they must develop competitive advantages and sustain them through unrelenting innovation and investment in order to thrive.[3] When firms with similar interests and competencies locate in the same area – as semiconductor companies have in California's Silicon Valley, in Austin, Texas, and now in the Albany region, suppliers, skilled workers, investors, and other groups associated with the industry locate near them, for obvious reasons. This improves the economic fertility of the region and, in turn, produces a virtuous cycle of growth.

The state's development strategy sought out candidates for this type of clustering using three criteria: a technologically intense sector; the ability to serve global markets; and a reliance on skills found in the state. The nanotechnology focus logically fits this bill and is now bearing fruit.

[3] Michael Porter, The Competitive Advantage of Nations, 148-165 (1990).

Moreover, the contribution that a new, state-of-the-art facility will make to furthering the strategy raises the possibility that even more advanced manufacturing facilities will be constructed in the region.

It is not possible to calculate directly the job or payroll benefits of a world-class innovation "cluster". But that does not diminish the value of a "virtuous cycle" of technology leadership. The self-reinforcing leadership that comes from the continuous interplay of innovation and knowledge between industries, research institutions, including institutions of higher education, and local governments has been established as a fundamental driver of business creation, growth and regional economic success – the kind of success that translates into additional jobs, tax revenues and investment.

Of course, the Fab 4X facility will have great significance in the local and regional economy. AMD has had an economic presence in New York , going back to its decision to conduct R&D together with IBM at the latter's facility in 2003. The Fab 4X project is expected to spend some $4 billion to build and tool the plant. This project will generate permanent, direct employment, stimulate the economy in the short-term, create collateral jobs supporting the new workforce, and support the stimulative effect of the larger Upstate nanotechnology cluster.

That economic activity will come at a critical time:

- Over the past year, New York has seen a 3.3 percent decrease in manufacturing jobs – or 18,300 jobs. (The Public Policy Institute of New York State, Inc.)

- Unemployment in the New York Capital Region (including Saratoga County), for July 2008 was 5.0 percent – up .1 percent from the previous month. (New York State Department of Labor)
- From July 2007 to July 2008, the Albany-Schenectady-Troy region lost 1,000 private sector jobs. (New York State Department of Labor)
- In the past decade, New York has seen 30.6 percent of the state's manufacturing jobs lost. (The Public Policy Institute of New York State, Inc.)

As disclosed in the Grant Disbursement Agreement with the State of New York, AMD has committed to hire a minimum of 1,205 full-time employees at its facility by the beginning of 2014. But AMD has also disclosed to the town of Malta, NY, as part of the local zoning process, that the estimated full-time employment at the Luther Forest campus could reach 1,465 by the end of that year. We use the latter number in this analysis.

In a related analysis of the employment generated by fabrication facilities, the research firm Semico demonstrated that for each eight manufacturing jobs at a fab, approximately three other jobs are created in on-site services in such areas as computer sales and maintenance, fab garment cleaning, delivery services, maintenance, security, and others. This suggests about 550 jobs related to the fab over and above its direct manufacturing employment of 1,465.

Both of these classes of jobs would create income and economic activity in the local economy, a phenomenon known as the "multiplier effect." In the Grant Disbursement Agreement, the State of New York concluded that "for each permanent, direct job generated by this project, an additional 2.25 indirect jobs are anticipated in the state's economy." This means that the 1,465 manufacturing jobs and 550 on-site service jobs created by the AMD plant, or slightly over 2,000 jobs in all, would produce an additional 4,500 jobs in the overall economy.

During the construction of the wafer fabrication facility and associated administration, engineering, and central utility buildings, the estimated construction related workforce would reach about 1,600 employees. That estimated workforce will vary depending on the time allotted to complete the project – a shorter schedule demands more workers but over a shorter period of time. Following the estimating convention used by Semico (which is distinct from New York State's analysis of full-time workers), construction jobs are estimated to have a multiplier of 1.7, so that construction-related employment, including multiplier effects, could total as high as 4,320 while the facility is being built.

To calculate payrolls, an annual wage of $60,000 was assumed for all fab employees; this is lower than the national average for the semiconductor industry because a fabrication facility may not employ as many highly-paid engineers as would, say, a design facility. An average annual wage of approximately $64,000 was assumed for construction employment, and a wage of $40,000 was assumed for on-site service and "multiplier" jobs.

The relevant wage rates were then multiplied by the estimated job creation to arrive at payrolls. Thus, the 1,600 construction jobs yield a total payroll of $102 million, and the associated 2,700 “indirect” jobs a total payroll of $108 million during the construction phase. The 1,450 manufacturing jobs are projected to produce a payroll of $88 million, and the 550 associated, on-site service jobs an added $22 million, with the 4,500 “indirect” jobs adding $180 million, yielding a sustained *annual* payroll of $290 million during Fab 4X operations.

JOBS TOTALS:

Job Description	Number of Jobs	Annual Payroll
Fab 4x Manufacturing Jobs	~ 1,465 jobs	$88 million
Construction & Construction-Related Jobs	~ 4,300 jobs	$210 million
Regional Service/Support Jobs	~ 5,050 jobs	$202 million

Job Description	Number of Jobs	Payroll
Permanent Manufacturing jobs by 2014	~ 1,465 jobs (annual)	$88 million
Fab 4x Service Jobs (computer maintenance, fab garment cleaning, and other on-site activities)	~ 550 jobs (annual)	$22 million
"Indirect" Fab-related Jobs	~ 4,500 jobs (annual) (for each job directly created by the new facility, creates an additional 2.25 "indirect" jobs – ESDC stat)	$180 million
TOTAL, Fab and Fab-related	**~6,500 jobs (annual)**	**$290 million (annual)**
Fab 4x Construction Jobs	~ 1,600 jobs (total)	$102 million
Construction "Multiplier Effect" Indirect Jobs	~ 2,700 jobs (total)	$108 million
TOTAL, Construction and Construction-related	**~4,300 jobs (total)**	**$290 million (total)**
Note: Fab-related jobs and payrolls are annual. Construction and construction-related jobs and payrolls are total for that phase of the project.		

Preserving American Leadership

New York's leadership in nanotechnology directly promotes U.S. competitiveness. Right now, U.S. technological leadership is being challenged. While semiconductor output is growing rapidly, the world market is growing at an even more rapid rate and U.S. market share is declining. Moreover, the U.S. is not keeping up with regard to creating new and cutting-edge capacity. The U.S. share of what the Semiconductor Industry Association classifies as "leading edge" chip production is declining. In fact, the Fab 4X facility is the only 300mm, 22nm fab currently slated to be constructed in the U.S. (The Luther Forest AMD facility will begin manufacturing product at the 32nm node, and will later move to 22nm technology as the availability of product designs, and customer demand move in that direction.) Other than for R&D purposes, the last major 300mm production facility built in the U.S. prior to this one was built in 2007, and no others are now known to be contemplated.

What is technological leadership and why is it important? Economists understand that an economy cannot be "best" at everything. But being best at the *right* things is a critical part of maintaining the long-term U.S. standard of living. Long-term leadership in the semiconductor industry is a matter of more than output and employment, although these obviously accrue to leadership. Leadership allows U.S. manufacturing firms to set the research agenda for the global industry, and lets the U.S. be the innovation leader for the entire semiconductor value chain, including not just production, but design and engineering and research and development. This

is critical to the U.S.' long-term prospects because foreign competitors have their own advantages, including the ability to imitate U.S. innovations. Moreover, competitors may be advantaged by tax policies, labor costs, or, as is sometimes alleged, trade protection, corporate governance practice, or outright subsidy. The only way for the U.S. to sustain its competitiveness, therefore, is to stay ahead of its competition through innovation. – to be the rabbit that the greyhounds chase but never catch.

Industry leadership has other benefits. For example, the industry relies on a variety of engineering standards to which all firms comply, such as those of the International Standards organization regarding quality. The National Institute for Science and Technology plays a leading role in the promulgation of those standards, but only because of American technological leadership. Absent that leadership, influence over the development of industry standards could migrate to other organizations outside the U.S.

Conclusion

The benefits to New York and the United States from the construction of the Fab 4X project will be both tangible and important, including:

- A $4 billion plus capital investment to complete the Fab 4X facility;
- Permanent employment of about 1,465 workers at the new manufacturing facility by the end of 2014, and an added 550 in related on-site services provided to the project;

- In the interim, construction-related employment of about 1,600 workers in the years 2010, 2011 and 2014, with an added 2,700 “multiplier” jobs, supporting a total payroll of about $210 million;
- The creation of an additional 4,500 “indirect” jobs, supported by the economic activity created by the Fab 4X project, which, together with the direct jobs, would be expected to generate an annual payroll of approximately $290 million; and
- A stronger New York State nanotechnology “cluster”, which provides the benefits of technology leadership to Upstate New York and to the United States generally.

The semiconductor is the landmark innovation of our economic age. The decision to build the world’s most advanced fabrication facility in Upstate New York is a milestone on several levels: as a step towards ever smaller, faster, and cheaper microprocessors that fuel productivity improvements; as a building block of American technological leadership in the industry; and as an integral part of a strategy for economic growth and high-wage employment for New York.

Biography of Everett M. Ehrlich

Dr. Everett M. Ehrlich is one of the nation's leading business economists. His firm, ESC Company, combines economic analysis, business development, and communications skills to solve a wide range of business problems. ESC's diverse clientele have included leading firms in the financial, accounting, pharmaceutical, automotive, and other industries, and such diverse organizations as the Pew Center for Global Climate Change and the Major League Baseball Players Association. He also recently served as Executive Director of the CSIS Commission on Public Infrastructure under co-chairmen Felix Rohatyn and Warren Rudman; a bipartisan bill to enact their recommendations was introduced in the 110th Congress.

Dr. Ehrlich served in the Clinton Administration as Under Secretary of Commerce for Economic Affairs, the principal economic policy official for Commerce Secretaries Brown and Kantor and chief executive of the nation's statistical system. As such, he led the first comprehensive strategic review of the nation's economic statistics in four decades, leading to a major modernization of featured measures of the economy. He supervised the redesign of the 2000 decennial census. He co-chaired the White House working group on the restructuring of the U.S. economy in the face of information technology, was a leader in the U.S. planning effort of the two G-7 Jobs Summits, and oversaw the Administration's economic analysis of global climate change.

Prior to his service as Under Secretary, Dr. Ehrlich was Vice-President for Economic and Financial Planning, and for Strategic Planning, of Unisys Corporation, from 1988 to 1993. As such, he had responsibilities concerning corporate development and finance, formulating business strategy, and economic forecasting. He reported directly to two chairmen of the company. He has also been the Senior Vice-President and research director of the business-based think tank, the Committee for Economic Development.

Dr. Ehrlich earlier served as Assistant Director of the Congressional Budget Office, where he directed the CBO program in trade and technology, infrastructure and space transportation, energy and the environment, and agriculture. He joined CBO in 1977, after having served as a Legislative Aide to Congressman John Conyers, Jr., and having briefly taught economics at the university level.

Dr. Ehrlich is the author of two critically-acclaimed novels: *Big Government* (1998), and *Grant Speaks* (2000), both by Warner Books. He was, for eight years, a regular economics commentator on National Public Radio's *Morning Edition*, and his writings have appeared in *The Financial Times*, *Investors Business Daily, The Christian Science Monitor, The Washington Post*, *The International Economy,* and other publications.

Dr. Ehrlich was born in New York City in 1950 and is a product of its public schools. He received a B.A. in 1971 from S.U.N.Y. Stony Brook and a Ph.D. in economics in 1975 from the University of Michigan. He lives with his family in Bethesda, Maryland, where he has coached little league, acted in children's theater, been wardrobe master for the high school chorus, and waits for the Washington Nationals to win the World Series.