TECHNOLOGY: CONNECTING THE MACRO WITH THE MICRO

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ABSTRACT

This paper presents unique lecture material for a workshop on the role of technology in the economy. Technology is the vehicle to show the connection between macroeconomic and microeconomic concepts, a relationship neglected in many classrooms. The topic area is space and research and development (R&D). Technology's role in growth and development develops into the issue of public funding for R&D and NASA's technology transfer program. Tempur foam is examined as a successful innovation that evolved into a public company, the microeconomic application of a macroeconomic idea. History, government and mathematics are included to increase the applications of the lecture.

INTRODUCTION

In the current environment of testing combined with a lack of time in the classroom, economics becomes a more difficult subject to teach. Modern education requires that students understand the relationships between ideas and how those concepts interact. Unfortunately, integrating material is easier said than done. As one begins to draw the comparisons, the story becomes longer and the possibility that the students become lost increases. The length of the example and the knowledge gained by the students are sometimes inversely related. Thus, clear examples of economic ideas combined with other disciplines are needed to increase the opportunity to teach economics and the probability of student understanding. This paper presents a unique

way to consider the roles and interaction between basic macroeconomics and microeconomic concepts.

Through work for the West Texas Center for Economic Education, it became clear that one area the teachers found difficulty with is the production possibilities frontier (PPF). While they were able to define and apply it to simple issues, the teachers did not know how to connect it to microeconomics. To them, it is purely macro. While the production possibilities frontier is a macroeconomic idea, its movements affect the microeconomic world and visa versa. The PPF is dynamic not static. Thus, the issue becomes how the PPF affects the firm and how the firm affects the PPF.

By not showing the students how the entire economy interacts, the students are left without the ability to see how the macroeconomic ideas and policies of the country affect themselves as individuals and their firms. One reason young individuals vote at reduced levels to other age groups may be because they don't see how the various government actions affect them. Showing how macroeconomic ideas and microeconomic ideas are interrelated may encourage students to see themselves in the economy.

The Executive Summary of the National Summit on Economic and Financial Literacy focuses on the areas lacking in economic education (NCEE, 2002). In particular, economic education is important for informed citizens. It also identifies the need to integrated examples with other disciplines. The findings of the Survey of the States Report Card (NCEE, 2003) coincide with Executive Summary. Most states short change economic education even it they acknowledge its importance. Both reports note that the comprehensive understanding of an idea involves knowing how it affects and is affected by other concepts. This lecture addresses this concern.

As a focal point for the workshop, space was chosen. With the renewed interest in space, space technology is timely and interesting to students. In addition, space technology allows the teacher to integrate economics with science, history, government, and mathematics.

Economics is one discipline that connects the other disciplines to each other. Showing how the technology from space affects our everyday lives

increases the importance and relevance of science. Science benefits because economics tells us why it is important and how society uses it. A historical comparison is included to show how society has always explored and innovated. Government expenditures and the role of government funding for research adds a political element to the discussion. Mathematical extensions on the stock price of the private company are included to show how math is used in microeconomics. Thus, the lecture can be included in a variety of courses not just economics.

This paper presents the classroom material, which is divided into seven subtopics. The topics start with a broad macroeconomic idea and evolve into a discussion of a firm. Economic growth and development is the first topic, which leads into the role of technology. Reasons for public funding of space research and development (R&D) extend from technology and include a discussion of efficiency. A comparison with historical exploration provides the connection from public funding to the technology transfer of R&D. Finally, Tempur-Pedic International, Inc. is discussed as the microeconomic application of technology and economic growth and development.

CONNECTING ECONOMICS TO TECHNOLOGY: PEDAGOGY

Space is an engrossing topic for students. It provides the needed hook to engage not just the students but also the teachers. When the general public thinks of the National Aeronautics and Space Administration (NASA), the space shuttle and the international space station are immediately brought up. However, the public and the students forget about the amount of technological innovation it is taking to produce the international space station. The next step is to show how the technology innovation affects the students' homes.

While there are a multitude of space technologies invented, tempur foam is readily understood by every student. Some of the technologies from NASA are so complicated, that students are unable to fully grasp the idea.

Again, losing students before the lesson really begins. Tempur foam's best-known use is mattresses, a good which students easily understand.

ECONOMIC GROWTH & DEVELOPMENT: EMPHASIS ON TECHNOLOGY

The basic outline of the lesson is to start with economic growth and development and how the economy grows. In its basic form, the Solow growth model shows that there are three ways for an economy to grow. The economy can increase the quantity of labor or increase the quantity of capital. The economy can also grow via technological advances. The technological advances allow the existing labor and capital to be more productive. It increases the quality of our work. We are able to do more with fewer inputs. This is called capital and labor augmenting technical change.

The production possibilities frontier and its outward shift are introduced as a visual to show an economy growing. Technology advances allow society to be more productive. Greater productivity allows for greater consumption and a higher standard of living. The economy expands permanently. It is interesting to point out to the teachers and students that the expansion is permanent. Once we learn to do something, we don't forget. In addition, it is important to point out that the technology can be things like advances in health care not just a faster computer chip.

The expanding PPF leads to an increase in the standard of living for a country. For a country or company to remain as the leader, it must continue to innovate or else it will be surpassed by another country/company. Once knowledge or skills are made public, the information can be duplicated and improved. Countries and companies do not always respect patents and copyrights. Thus, a country/company must continue to improve or else fall behind. The continual growth results in a steadily increasing standard of living. The teacher can discuss with the students that countries with high investment in R&D have higher gross domestic product per capita than other countries. Notice that the responsibility for innovation rests with the country or company. Here is the first addition of microeconomics into the discussion. Not only does a country need to innovate to move ahead so does a company.

The final idea of this section is that technological innovation begets more technological innovation. This allows the PPF to shift out faster, steadily increasing the standard of living. Some students need a visual and an inverted triangle does the trick. Basic research is the research done in the bottom part that is very narrow. As innovations occur, they lead to more innovations and the economy moves up the triangle as the entire amount of R&D increases.

A common statement by a student is that a certain technology (usually for the military) hasn't benefited him/her personally. This allows the instructor to address the idea of public goods and public benefits versus private goods and private benefits. An innovation may improve society and as a member of society, it positively affects the student even if the individual can't document the improvement on personal standard of living.

REASONS FOR PUBLIC FUNDING OF R&D

After the instructor has established the role of technology in the PPF, the next step is to address whether the R&D into technology should be public or private. Basically, why don't we let firms do the R&D instead of the government?

The risk-return or cost-benefit relationship from the R&D is not favorable in the time frame firms require. As risk/costs increases so does the required return/benefit. But the return to some R&D initiatives cannot be projected with a great amount of certainty because space exploration has too many unknowns.

Market failure exists when there is a divergence between social and private costs and benefits of a particular activity. Research that generates growth has social benefits that exceed private benefits. Government can encourage research where the market would fail.

Notice how an instructor with an intuitive class can discuss the social benefits and the social costs of an innovation. A new technology may decrease the need for certain types of jobs. This frees up the labor for new uses. However, the news covers the loss in jobs and not the new jobs created by the increase in technology.

The next logical step is to discuss the characteristics for public funding of R&D. The lesson focuses on six main issues: cost, size, success, time frame, uses, and danger.

The first two issues are cost and size. Basic research is expensive. Firms conduct R&D on projects with a high probability of profit. Space exploration and R&D are too expensive for any one firm to undertake. In addition, the magnitude of this research is best handled by an entity of comparable size.

A related example is that of pharmaceutical firms that work on medications for diabetes, heart disease, arthritis, etc. Very little work is done on rare diseases, which usually are more deadly or debilitating but have very little profitability. New drugs for common ailments typically cost more than $300 million to innovate. A firm won't spend that amount of money unless it believes it can recoup the amount in profits.

R&D is an uncertain process. There are many more failures than there are successes. A private firm has profitability measures to meet. Failures could limit or eliminate the firm's ability to secure funding and maintain cash flows.

R&D takes a long time. NASA has 10-year and 25-year objectives. Financial markets want quarterly results. How would the average investor react if a firm announced it wouldn't be profitable for at least 10 years and then maybe not profitable at all even if its R&D were successful? The time frame of basic research does not match the time frame of Wall Street.

Profitable uses of basic research are not known at the time of innovation. Basic research can be applied to many different fields/industries. It may take years before the secondary products are developed. One example of this is electricity. Ask the students to think about how many current products use electricity. The products were developed after electricity. Electricity came first.

Space exploration is risky. It is one thing to design it on a computer and quite another to build a space station. The liability is cost-ineffective. How many lawyers would be ready to sue following a space death?

EFFICIENCY

Economies look for efficient solutions to problems. Public support of R&D allows the economy to deal with the free rider problem. Major technology advances benefit everyone. But if one person or firm had to pay the initial costs, it might not be undertaken. Even if a firm or an individual did do the research, others might use the benefits without ever having paid for the research. A free rider is an individual who receives a benefit without paying for it.

An example is national defense. We let the federal government organize and run the national defense because it is too costly and too difficult to do it individually. If an individual did form his own defense system, it is likely his neighbors would take free advantage of the system.

Public payment of R&D also involves externalities. Innovation has positive externalities. The marginal private benefit is less than the marginal private cost. It is not cost effective for a firm or individual to undertake the activity. However, the marginal social benefit is greater than the marginal private cost. Thus, by spreading the cost out over everyone, the individual cost is reduced and no one entity is burdened. In return, all of society earns the positive externalities.

The government supports certain activities that benefit all of society but are too expensive for many individuals to pay for on his/her own. First-time home ownership programs, education, roads, medical research and Social Security are examples.

Allocative efficiency results when the marginal social benefit equals the marginal social cost. If firms did do this research, the results would belong to the firm. The firm has an incentive to keep the technology a secret, thereby limiting its use. National funding of R&D allows for knowledge spillover to the entire economy. Various industries and firms can take the same technology and apply it to a specific product or technique. This increases national output and wealth at a greater pace than without knowledge spillover.

In essence, let the nation fund the basic research to build the mousetrap. Then let the firms improve and specialize the mousetrap for you and me.

So just how much does the United States spend on NASA? Table 1 shows the percentage of total federal government expenditures on NASA. Other major expenditures are included for comparison. From the chart, expenditures on NASA tend to range around 1%, substantially less than the amount on other areas.

Table 1: Expenditures on NASA

Percentage Distribution of Outlays by Agency: 1962-2003

Department or other unit	1962	1967	1972	1977	1982	1987	1992	1997	2002	2003
National Aeronautics & Space	1.2	3.4	1.5	1.0	0.8	0.8	1.0	0.9	0.7	0.7
Agriculture	6.0	3.8	4.8	5.7	6.1	4.9	4.1	3.3	3.4	3.4
Defense-Military	46.9	44.5	33.7	23.3	24.2	27.3	20.7	16.1	16.5	18.0
Energy	2.6	1.4	1.0	1.2	1.6	1.1	1.1	0.9	0.9	0.9
Health and Human Services	3.3	6.1	11.0	11.4	11.9	13.1	16.8	21.2	23.2	23.4

Table 1: Expenditures on NASA

Percentage Distribution of Outlays by Agency: 1962-2003

Transportation	3.6	3.3	3.1	2.9	2.4	2.3	2.1	2.3	2.8	2.4
Social Security	13.4	13.8	17.4	22.1	21.9	21.8	22.2	24.5	24.3	23.5
Administration (On and Off-budget)										

Source: Office of Management and Budget

COMPARISON WITH HISTORICAL EXPLORATION

Most economics classes are viewed as part of the social studies curriculum and taught by instructors with history backgrounds. It is beneficial to include a comparison with historical exploration. Historical exploration revolved around finding resources and information.

Exploration was a means to find resources. Referring back to the PPF, an increase in natural resources shifts out the frontier. The Spanish and Portuguese explorers wanted to find riches. There was a profit motive.

Historical exploration was also about finding information. What is out there? Lewis & Clark mapped the land of the Louisiana Purchase.

Exploration has always used technology. The Wright Brothers wanted a business but they also just wanted to fly and to be first.

Current exploration does not have the explicit profit function that earlier explorations had. There is a profit function but it has a much longer time frame than we are used to today. Lewis & Clark explored during

1804-06. The settlers came in the 1860s - 1880s, 60 to 70 years after the exploration. Very few firms have this type of time frame.

Current exploration is much more about finding information and using and developing technology. The technologies and information are meant for the public. But the time frame involved means the gains are for the future public. The time frame implies an altruistic nature to basic research and exploration. The gains are for other generations.

TECHNOLOGY TRANSFER

After establishing the role of technology for economic growth and development, the reasoning for public funding of innovations is presented. The next step is the tie-in with microeconomics. Capitalism relies on firms to meet consumer demands. Public funding for R&D allows for allocative efficiency for the initial innovations. Once the basis has been developed, firms take over. This is called technology transfer.

In 1962 NASA started its technology transfer program by which technologies could be transferred to companies enabling the firms to develop commercial products.

Some of the everyday products or services that use NASA technology and have been a part of the technology transfer program are listed in Table 2. It is not an exhaustive list but meant to give the students a flavor of some areas NASA as influenced.

Table 2: Technology Transfers by NASA

Communications	Everyday products	Transportation	Healthcare	Computer industry
Satellites	Rechargeable batteries	Airplanes	Textured medical implants	Internet
UHF television transmitters	Cameras	Ability to fly in bad weather	Hip and Knee artificial implants	Photo-imaging

Table 2: Technology Transfers by NASA

Communications	Everyday products	Transportation	Healthcare	Computer industry
Wireless communication	High temperature electrical insulation	Inflight control system	Ultraviolet blocking material	Networking
GPS	Lubricating products	Turbo engines	Pacemaker	Logistics
Weather prediction models	Food and beverage packaging	Suspension systems for autos	X-ray machines and ultrasound (photography)	Structural analysis software for bridges, skyscrapers, cars, etc

A logical question is to ask what types of technology NASA deems successful. The Space Technology Hall of Fame has five criteria in its selection process.

The first criterion is economic benefit. Higher ratings are given to technology that has been the basis of or a significant part of a successful product or company. Additional points are awarded for those technologies that were developed from a partnership with the private sector. In other words, NASA does not want its R&D to be done in isolation. It wants private firms to be actively involved from the beginning.

A third criterion is the amount of public awareness a technology has generated and if it highlights the benefits of space R&D. Technology is also judged on its impact on society and how long of an impact or commercial application the technology has.

TEMPUR-PEDIC

While the microeconomic aspect of the workshop has been hinted at, it now moves to the forefront of the discussion. Tempur-Pedic is a 1998 inductee into the Hall of Fame for Space Technology. Tempur is a foam that is temperature sensitive and adjusts to weight and temperature changes. In

the 1970s, scientists at the Ames Research Center originally developed tempur foam to relieve the intense pressure of G-forces experienced by astronauts during rocket launches. Innovating firms were Ames Research Center (NASA), Becton Dickinson Dynamic Systems, and Southwest Research Institute. Notice how the initial research includes Becton Dickinson, a private company.

In the early 1980s, NASA released the technology to the public through the tech transfer program. One of the original innovators saw the potential of tempur foam and developed it under the name Tempur Foam. By 1989, Tempur-Pedic, Inc. was formed. Eventually, it became Tempur World.

There are have been numerous spin-offs for products such as mattresses, footwear, wheelchairs, hospital beds, etc. Tempur foam has been added to helmets to better protect the head. Individuals bound to wheelchairs or beds use the tempur foam to relieve the stress of sitting or lying down all day.

Numerous other firms have licensed the technology to develop their own good. Fagerdala World Foams of Sweden was one of the original firms to find applications of the technology for mattresses and cushions. Modellista Footware used tempur foam for shoe cushioning. In addition, the shoes are resistant to blood, urine and other elements and is used in the health care field.

Venture capital was used to fund the young company. Venture capital is equity funding from private investors. It is difficult to obtain and because of the risk, venture capitalists want a high return. Venture capitalists don't enter the life cycle of a business until it has a proven product. Thus, venture capitalists wouldn't fund the initial R&D to innovate tempur foam but they would fund the development of tempur foam into its various uses.

After Tempur-Pedic demonstrated sales and profitability, the entrepreneurs decided to sell the entire firm to the venture capitalists, which took the company public. In November 2002, two venture capitalist groups, TA Associates and Friedman, Fleischer & Lowe, formed Tempur-Pedic International to purchase Tempur World for $268.00 million plus $88.8 million in refinancing. Going public means to sell stock in the company to outsiders and to have the stock traded on an exchange. It is also called an initial public offering (IPO). The firm is able to gain capital but with a loss

of autonomy over the firm because now it is responsible to the shareholders. The IPO allows the venture capitalists to get their money back through the sale of stock.

The investment banks that took Tempur-Pedic public were Lehman Brothers and Goldman, Sachs & Co. Investment banks are financial institutions that assist firms in issuing stock, setting the initial price, complying with the rules and regulations of the Securities & Exchange Commission, and selling the stock. The commissions investment banks receive are called flotation costs.

It went public on December 18, 2003 on the New York Stock Exchange under the ticker symbol TPX. The initial price for the IPO was $14.00, of which $0.91 of each share went to the investment banks. The stock rose to $15.50 on its first day.

For those classes with a little more time and interest, the prices can be examined in greater detail. From the Yahoo! Finance website, one is able to download the historical closing prices into an Excel spreadsheet. Using the time period set by the instructor, a stock price chart can be generated. Table 3 shows the prices of the first two months of TPX. The students can also access a stock price chart at various Internet sites including bigcharts.com and stockcharts.com.

Students can also find the average price, the minimum and maximum of the stock price as in Table 4. The instructor is able to discuss the volatility of the stock price and how stock prices fluctuate with demand and supply for the stock. For example, the stock price rose on the first day from $14.00 to $15.50, indicating demand was greater than supply. The closing stock price has ranged from $14.74 to $17.90 over the first two months.

An alert student will note that the supply of stock in a firm is perfectly inelastic. There are a limited number of shares outstanding or available for purchase. Every share of stock is not traded every day. Instead buyers and sellers meet in the marketplace of the New York Stock Exchange each day to conduct trades. The number of buyers versus the number of sellers determines the price at that time. The example is reinforcing the ideas of demand and supply presented earlier in the class.

Table 3: Stock Prices for TPX					
Date	Stock Price	Date	Stock Price	Date	Stock Price
12/18/03	$15.50	1/12/04	$17.40	2/3/04	$17.00
12/19/03	$15.25	1/13/04	$17.76	2/4/04	$17.35
12/22/03	$15.36	1/14/04	$17.63	2/5/04	$16.83
12/23/03	$15.24	1/15/04	$17.90	2/6/04	$17.07
12/24/03	$14.90	1/16/04	$17.35	2/9/04	$17.17
12/26/03	$14.74	1/20/04	$16.20	2/10/04	$17.00
12/29/03	$14.75	1/21/04	$16.00	2/11/04	$17.00
12/30/03	$15.09	1/22/04	$16.38	2/12/04	$17.10
12/31/03	$15.50	1/23/04	$17.07	2/13/04	$16.60
1/2/04	$15.75	1/26/04	$17.32	2/17/04	$16.50
1/5/04	$16.15	1/27/04	$17.25	2/18/04	$16.44
1/6/04	$16.54	1/28/04	$17.00	2/19/04	$16.25
1/7/04	$16.62	1/29/04	$16.34	2/20/04	$16.25
1/8/04	$16.75	1/30/04	$16.20	2/23/04	$16.45
1/9/04	$16.88	2/2/04	$17.09	2/24/04	$16.14

Table 4: Descriptive Statistics for TPX	
Mean Price	$16.47
Median Price	$16.54
Minimum Price	$14.74
Maximum Price	$17.90
Standard Deviation	0.123

To finish the circle all one has to note is that Tempur Pedic pays taxes, which can be used by the government to fund further R&D to innovate new technologies for economic growth and development, which can be used by other firms to make goods for customers creating a higher standard of living for all.

CONCLUSIONS

Connecting macroeconomics and microeconomics demonstrates to students the dynamic nature of the economy. Instead of viewing growth and development as an isolated idea from the profitability of a firm, the integration of the ideas allows students a deeper understanding of the working of the economy. By completing the circle within the extended example of tempur foam, the progressive nature of innovation is more easily seen. As a result, students have a better understanding of how the economic cycle works. This workshop was been conducted several times with great success. In particular, the teachers appreciated the integration of macroeconomic and microeconomic ideas, noting that nothing else like it was in the standard textbooks. In addition, the inclusion of history, government and mathematics increased the likelihood of the lecture material being used in the classroom. Because so many states have knowledge or skills requirements, Table 5 presents the key vocabulary terms so the teachers can match the lessons with their evaluation rubrics.

If a goal of economic education is to increase the analytical skills of students, examples that show the integration of ideas must be presented to assist the students in their development of critical thinking skills. Technology can be a very general term to students. However, its role in economic growth and development of a country and of a firm is very specific.

Table 5: Keywords

	Economics	
Allocative efficiency	Capital & labor augmenting technical change	Economic growth & development
Externalities	Flotation costs	Free rider
Inelastic supply curve	Initial public offering	Investment banks
Knowledge spillover	Market failure	Private benefits and costs
Production possibilities frontier	Productivity	Profit motive

Table 5: Keywords		
	Economics	
Public benefits and costs	Public funding	Public goods vs. private goods
Research & development	Solow growth model	Standard of living
Stock prices	Technology	Venture capital
	Mathematics	
Mean	Median	Standard deviation

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