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SCIENTIFIC KNOWLEDGE AS TECHNICAL KNOWLEDGE: MIT'S
ECONOMICS DEPARTMENT AND THE TRANSLATION OF
FUNDAMENTAL RESEARCH INTO APPLICATIONS

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Scientific knowledge as technical knowledge. MIT's Economic Department and the translation of fundamental research into applications.

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*For 150 years [MIT] has been an engine,
translating esoteric research into the
tools with which we lead our lives every day.*

David Kaiser (2010)
Becoming MIT: Moments of Decision

*In economics, as in other sciences, the test of a
model is not just how much it describes but the
economy with which it does so.*

Robert M. Solow (1958)

The economics Department at the Massachusetts Institute of Technology provides a field well befitting to study the translation in the discipline of economics of “esoteric research” into “tools”. Certainly, MIT was not the only bridge in economics connecting the academic and the practical arenas. Nevertheless, at MIT the connection was accomplished throughout a particular conception of science as a technical form of knowledge. Concretely, at MIT the translation was operationalized through the use of mathematical, yet simple, models that aimed first to understand a few aspects of a

situation, and then to be applied to a wide range of issues. Although Samuelson's and Solow's approaches to modeling were different, their work put forward the guidelines and incarnates MIT's way of translating "esoteric research" into "tools". This paper analyses how in the context of an engineering school closed related to the war and postwar political and military powers, MIT economists advanced the frontier of the discipline into the practical arena.

As Theodore Porter has shown, the "confinement" of the scientists to the domain of technicality is one of the signal developments of modern history of science (Porter 2009). If right up to the 1920s and 1930s, the most prominent advocates of science emphasized their direct —and almost personal— contribution to a moral, economic, and intellectual order to secure symbolical and material resources, World War II opened a period where a vast expansion of scientific institutions was accomplished through the restriction of science to matters *technical*. Associated to technical knowledge, science is presented as highly demanding craft that can only be mastered with years of study and practice which main propose is to connect "esoteric" research and concrete "tools". In this context, practical consideration and the development of booth the tools and the necessary skills to use them became key elements of the scientific enterprise. For its very nature, engineering schools are central shackle of this process.

The pressures of efficient use and allocation of resources during World War II, so as those associated to warfare, exacerbated the demand for a type of knowledge connecting fundamental research and practical considerations. Section one, introduces the main changes in the organization and production of knowledge that simultaneously made possible and reinforced the development of this type of knowledge. Section two, presents how, by placing the laboratory at the heart of the research and instruction process, MIT administrators effectively connected "esoteric research" with practical questions and problems. Section three, explores how MIT's emphasis in in this connection, and the concurrent efforts to understand the impact of science and technology in society, shaped the Department of Economics's project. Section forth and five, study respectively Paul Samuelson's and Robert Solow's

decisive role determining the department's orientation. Section six, explores how the laboratory-like context recreated at the Department of Economics a mixture of "basic science" and "engineering applications" was put together.

1. CONNECTING FUNDAMENTAL RESEARCH WITH PRACTICAL CONSIDERATIONS DURING THE AFTERMATH OF WORLD WAR II

The massive investments of government in research related to the military enterprise, and the parallel national demands linked to war time, deeply influenced the structure of knowledge production, and thus the practice of science, in the United-States during the second half of the 20th century. If in the 1920s and 1930s the dominate discourse stated that knowledge advances the most quickly and surely when its pursuers are liberated from any direction from society. Early as the 1940s, a new framework for science-government partnership was developed, a framework where research was funded according to military needs, and independently of any disciplinary or institutional boundary. The military demands for procedures capable of dealing with the complexity of war issues brought together scholar from different disciplines — from the social and non-social sciences alike— and simultaneously straddled university, military and industry settings. The comparison between the Soviet Union and the United States motivations for scientific developing and their respective knowledge infrastructures during the first years of the Cold War illustrates well how both, the disciplinary and institutional boundaries of science were durably blur during the war years:

In the Soviet Union, the military knowledge infrastructure existed in parallel to the civilian infrastructure (centered on the Academy of Sciences), with only limited points of connection —and as in the United States, the scale of military support greatly outweighed non-military sources of funding. In this context, academic trends did not proliferate and cross-fertilize in the same way as in the United States, where civilian contactors moved in and out of military consultancies with dizzying frequency. The kink of interlink hybridization between, for example, RAND, the US Department of Defense and, universities

[...] was not present to nearly the same degree in the Soviet Union. (Erickson et al. 2015, 20)

The Project for the Scientific Computation of Optimum Programs (Project SCOOP) is good example of the interdisciplinary and across-the-board infrastructure that characterized the new framework for science-government partnership that emerged from war and post-war demands. The mandate of the project was to mechanize the planning process of the airlift that would provide basic supplies to Berlin during the Soviet blockade.¹ During its 5 years of life (1948-1953), the project circulate in different sites hardening the contract between the military, the executive branch and the university: the Air Force, the National Applied Mathematics Laboratory of the National Bureau of Standards, Harvard University, the Pentagon, RAND, the Cowles Commission, the Bureau of Labor Statics, the Department of Defense and The Carnegie Institute of Technology. Likewise, it comprised people from a plurality disciplines that included: George Dantzig (mathematics and operations research), Robert McNamara (business), Edmund Learned (business), Tjalling Koopmans (economics), Jerome Cornfield (statistics), Marshall Wood (military research at the U.S. Air Force), Murray Geisler (statistics and operations research), Franco Modigliani (economics), John Muth (engineering) Herbert Simons (economics and political sciences).²

The eclectic character in disciplinary terms of this group contrast with the similarities in the professional trajectory of its members. They all shared the career history of a *new type* of scientist that appeared in the context of World War II, one merged into the bureaucratic elites, mingling “with government ministers and bureaucratic heads, rather than merely conducting research and writing official reports” (Porter 2009).

¹ The idea was to construct computable algorithms to determine alternative inputs and activities that could be combined to achieve a goal of maximum output (or minimum cost), subject to constrains. George Dantzig 1947's linear programming model was the kernel of this project that ultimately led Herbert Simon to defend the necessity of non-optimizing decision rules.

² For a detailed history of Project SCOOP in relation to the development of Cold War rationality see: (Erickson et al. 2015).

Immediately after the World War II, the alienation between military priorities and government funding of scientific research started to be regarded as a danger for the “advancement of science”. On the one hand, the economic dependence upon the public and the military appeared to threaten autonomy of science towards the political powers. On the other hand, the dependence upon the public and the military appeared to menace scientists’ need to be free of any constraints to *lead their curiosity*.

In this context, a specific political consciousness on the part of scientists and science’s place in society emerged. Vennevar Bush’s *Science —The Endless Frontier* can be seen as an attempt to reconcile the political autonomy of science with the priority of practical considerations.

1.1. The Endless Frontier: translating “basic” into “applied”.

At the heart of Bush’s reconciliation plan was the translation of “basic” research into “applied” knowledge. MIT’s organization of instruction and research in laboratories settings is central to understand how Bush expected “basic” research be actually translated into “applications”.

Since the 1930’s scholars associated to the Massachusetts Institute of Technology occupied important positions related to science policy in the government. Notably, MIT president from 1930 to 1948 Karl Compton became, in 1933, chairman of the Science Advisory Board —the first presidential advisory board appointed by Franklin D. Roosevelt. In this role, Compton advocated for a recovery program for science under the National Industrial Recovery Act. His proposal for a National Research Administration, called for expenditures of 100 million dollars for fellowships, contracts, and grants for scientific research (Kaiser 2010a, 3). Compton’s proposal was not initially accepted, it was nevertheless later reanimated by MIT provost Vennevar Bush, an adroit administrator of science. Bush was indeed a key agent in the designing and building of a new framework for science-government partnership during World

War II. He particularly helped to lay out the postwar path of funding of scientific research³. In 1944 President Roosevelt asked Bush, at the time director of the Office of Scientific Research and Development (OSRD), to prepare a report that latter become *Science —The Endless Frontier*⁴. The objective was to inquire on what the American government could do to support science after the war in order to ensure the long-term safety and prosperity of the country.

While Bush wanted massive federal funding of science, he did not want the specific allocation of these funds to be determined by the government. His idea was to secure the resources for American science in the early postwar period while preventing state intervention in the domain. More broadly, as David Hollinger put it, for Bush “Society’s contribution to knowledge was as narrow, as knowledge’s contribution to society was broad.” (Hollinger 1990, 902)

In this context, the connection between (basic) research and society (applications) was secured by a particular vision of scientific progress based on what is known as “the linear model of innovation”⁵. Rupert Maclaurin’s 1949 book “Invention and Innovation in the Radio Industry”, a book where *Science—The Endless Frontier* was prominent⁶, exemplifies clearly this vision of scientific progress. Maclaurin’s book traced the development of the radio industry, from its roots in *pure research*, to its *applications*⁷. Concretely, Maclaurin detailed how the (unplanned) discoveries of scientists such as Faraday and Maxwell were translated into marketable products via entrepreneur-inventors like Marconi. The book was enthusiastically endorsed by President Compton. Compton particularly emphasized the importance of the distinction between *advances in fundamental science* and their *practical applications* in new or

³ The Endless Frontier was release shortly before the dropping of the atomic bomb, the making of which Bush himself had overseen in his capacity as the American government’s chief science advisor.

⁴ On the Bush Report and the creation of the National Science Foundation see within many others (Kevles 1977).

⁵On the linear model of innovation see (Godin 2006).

⁶ For instance, Maclaurin placed a quotation from Bush about the importance of “pure research” at the very beginning of the preface.

⁷ Pure research and applications are the terms employed by Maclaurin.

improved products. For Compton, Maclaurin's greater contribution was to draw a clear distinction between the scientist (at the *pure research* extreme of the chain) and the inventor (at the *applications* end), distinction which was of major significance for the understanding of the *process of technological change*.

2. "TURN LIGHT INTO FRUIT": LABORATORY RESEARCH AND INSTRUCTION AT MIT

The thirties were at Massachusetts Institute of Technology a turning point. Indeed, Compton and Bush were key in fostering MIT's transformation into a research university where "pure" science was translated into practical subjects—in opposition to an exclusively applied-oriented institution. The specific target was what Compton called—in contrast to "mere technical education"—*technological education*, "education in the fundamental principles along with a training in their applications to important basic process and problems" (Lécuyer 2010, 62). As Backhouse and Mass have recently shown, both President Compton and Provost Bush shared one belief: even if the fundamental breakthroughs in science were "almost impossible to plan," this did not mean that "the ensuing process to application could not be managed and controlled" (Backhouse and Maas 2017, 102–3). This trajectory, from basic research discoveries to applications, was the niche where they aimed to place MIT. Concretely, their project was to establish at MIT the institutional conditions necessary to "turn light into fruit." Laboratory research and instruction was the pivot of their project. Indeed, the *right* mixture of "basic science" and "engineering applications" was crystalized at MIT laboratories, settings where theory and practice were brought together. The idea was to enhance the research profile of MIT by strengthening its bonds with government and industry while endorsing the "scientist" independence throughout laboratory research and instruction.

2.1. Military research at MIT's laboratories

Having signed some four hundred contracts, MIT was the largest wartime research and development contractor of the United-State government. Conspicuously, Compton's wrote in his 1945's Annual Report, "MIT spent on its war contracts as much

money as it had spent on its normal activities during the previous 80 years of existence". (Kaiser 2010b). Fourteen percent of the Institute's total budget for the 1939-1940 academic year came from a contract to create a new laboratory to develop microwave radars. Headquartered at MIT, the Radiation Laboratory (Rad Lab), so named to disguise its real research objective, started operations in 1940 under the auspice of the Office of Scientific Research⁸. This was but the first step in forging a new partnership with the military: all across MIT a new hybrid model of laboratory, where military problems were solved while a pedagogical enterprise was developed in parallel, took hold. Yet, while projects generated in the laboratories served as students' thesis, MIT hosted special training courses for the military and government agencies (which included meteorology, aeronautical engineering, and chemical engineering).

Partnership with military agencies permanently transformed the Institute and continued after the end of World War II. Indeed, with the entrance of the United-States to the Korea War, MIT's volume of the research conducted under contract with the government rapidly raised. The Institute operating budget leaped 36 percent during the first year of the new conflict and another 31 percent the following year – the fastest rates of growth since World War II (Kaiser 2010b, 105). During the 1950-1951 academic year, more than 96 percent of MIT researchers' contracts came from the federal government (virtually all from the Department of Defense, the Atomic Energy Commission and the National Advisory Committee on Aeronautics). Yet, after the Korean conflict defense spending at MIT continued to climb exponentially well into the late 1960s. Adjusted for inflation, the volume of military sponsored research doubled every six years between 1948 and 1968 (Kaiser 2010b, 105). Throughout the 1950s and 1960s, sponsored research accounted for roughly 80 percent of MIT

⁸ The importance of the Rad Lab should not be underestimated. Twenty percent of the nation's physicists worked on the Rad Lab, only the Manhattan project employed more. For further information on the Rad Lab see *Ibid.*, p. 88.

operation budgeted (Kaiser 2010b, 105). As Alvin Weinberg, physicist and director of the Oak Ridge National Laboratory (ORNL)⁹, noted in 1962:

[...] it had become difficult to tell wheatear the Massachusetts Institute of Technology is a university with many government research laboratories appended to it or a cluster of government research laboratories with a very good educational institution attached (Kaiser 2010b, 109).

Nor MIT was the only university equipped with an Industrial Relations Section —seven other universities received the same Rockefeller grand—, neither the Institute was the only institution signing important contracts with the government. Nevertheless, as Paul Samuelson said, at the beginning of the 1940s, when “government money came in heavily to the universities and enriched their research opportunities [...], MIT was at the frontier”(Samuelson 2007). During the academic year 1950-1951, the Division of Industrial Cooperation processed more than 15 million of USD (nearly 135 million in 2008 dollars). More than 96 percent of which came from the Federal Government, virtually all from the Department of Defense, the Atomic Energy Commission, and the National Advisory Committee on Aeronautics. Twenty years later the patron looked remarkably similar. In 1956 the Division of Industrial Cooperation was renamed Division of Sponsored Research. Conspicuously, most of these funds went to special interdisciplinary laboratories and federal contract research centers. The Instrumentation Laboratory and the Research Laboratory of Electronics —the result of the transfer of the research wing of the RadLab to the direct control of MIT— are the initiators and archetypes of this kind of arrangement. In the forthcoming years, several laboratories were set up and explicitly molded on this pattern¹⁰.

⁹ The ORNL is the largest science and energy national laboratory in the Department of Energy system. ORNL’s scientific programs focus on materials, neutron science, energy, high-performance computing, systems biology and national security.

¹⁰ The Laboratory of Nuclear Science and Engineering, the Lincoln Laboratory, the Gas Turbine Laboratory, the Aeronautics and Structures Laboratory, the Center of Material Sciences and Engineering are but some examples at MIT of this model of federal, mostly military, patronage laboratory model.

This was likewise a moment during which the confidence of the Institute raised

A long tradition of leadership in professional education at MIT has culminated in a magnificent record of national service. At no time has the Institute stood so high in the public esteem. One senses a feeling of confidence and power. The frontiers of knowledge are being attacked with boldness and enterprise. We take pride in our fine body of students; our relations with industry have never been more cordial; and we have been called upon to participate in national planning and defense on an unprecedented scale. (Lewis 1949, 3)

2.2. The consequences of World War II's expenditure of higher education at MIT

During and immediately after World War II, while justifying the rise of expenditures associated to military, one of the main arguments of government patrons and MIT administrators alike was the number of students trained. Increasing the number of qualified scientist and engineers —especially as the Cold War with the Soviets intensified— became an urgent priority: in the wake of wartime projects, arguments connected with “scientific manpower” probed very effective. In this context, policy began to reflect rhetoric: in the name of getting more students into sciences classrooms a huge number of new federal fellowships was created and draft deferment policies were rewrite. The United-States student population grew fast during these years. As Craig Calhoun, sums it up

Every quantity that could be measured revealed rampant growth, be it “dollar volume” of government contracts, the rapid expansion of the physical plant, sudden increases in faculty, administration, and student population, and more (Calhoun 2000, 8).

A pattern of rapid growth was already underway at the turn of the century, but it was only after World War II that higher education really became a mass phenomenon in the United States. Following World War II, the country's colleges strained their facilities and accommodated a total enrollment 75 per cent greater than their prewar

record. In the process many schools doubled their earlier enrollments. In 1948, the peak of the postwar years, there were ten universities with over 20,000 students, in 1967 there were 55. During the same period more than 60 universities pushed their enrollments past the 10,000 mark for the first time¹¹. Returning veterans supported by special government funding flooded American colleges and universities, helping to spark expansion even in relatively hard times. The Serviceman's Readjustment Act of 1944, also known as the G.I. Bill, was crucial at this point. By providing a range of benefits for returning World War II veterans including tuition and living expenses to attend university, the GI Bill brought about substantial transformation to the United States higher education system. Yet President Franklin D. Roosevelt initially promoted the law as a means to maintain economic health during the postwar years. The idea was to stimulate the economy through the veterans. By the time the G.I. Bill's education title officially ended, 37 per cent of all veterans had used its benefits. At the college level alone, a total of 2,232,000 veterans utilized their G.I. Bill, with over a million veterans crowding on American campuses during the banner year of 1947-1948¹². On a smaller scale, the same thing happened after the Korea War.

With the return of war veterans, MIT's enrolments increased significantly —by both, expanding access to already established programs and creating new (specially graduates) ones¹³. For instance, at the end of the World War II, the Institute enrolments high-up 80 percent from the prewar levels. Moreover, MIT's annual operation budget —after the few years of decrees following the end of the conflict—increased systematically from the early 1950s. During its first decade (1945-1955) the Laboratory for Nuclear Science and Engineering served as the training ground for nearly 300 graduate thesis and 1000 undergraduate theses. Likewise, between 1946 and 1958 the Research Laboratory of Electronics supported 600 students' theses.

¹¹ The data is from (Calhoun 2000; Kaiser 2002b)

¹² Data on the GI Bill is from (Weintraub 2014; Olson 1973)

¹³ In 1900, graduate students had amount 0,4 percent of MIT's total student population; by 1930, even after steady growth, they still accounted for less than 17 percent. Immediately after World War II the number of graduate students began to grow exponentially. By the late 1960's, fully half of the students at MIT were in graduated programs. See (Kaiser 2010b, 110)

During the 1958-1959 academic year, MIT awarded one in eight of all the doctoral degrees in engineering in the United States. (Kaiser 2002a)

3. ECONOMICS IN THE CONTEXT OF AN ENGINEERING SCHOOL

While the rise on students, programs and budget was a general phenomenon that involved American higher education system as a whole, the discipline of economics was particularly concerned. Both, during and after the conflict, the number of students enrolled in economics programs grew.¹⁴ The magnitude of this phenomenon can be appreciated when it is realized that the post-war crowd represents nearly one-third of all the doctorates in economics ever awarded in the United States. Returning veterans sought credentials and useful knowledge. As Roy Weintraub points out, a classical humanities-based education was a luxury that GI Bill students could not afford. In this context,

From a prewar liberal arts education that looked down on economics as a practical subject fit only for those unqualified by breeding or availability of leisure to study the humanities, postwar economics became an important academic discipline. (Weintraub 2014, 9)

Yet, the link between economics and MIT was old. For instance, Francis A. Walker, MIT's president from 1881 to 1896 was also the first president of the American Economic Association (1986)¹⁵. Furthermore, since Compton and Bush's restructuration program increasing importance was attached to economics and business as part of the training of engineers. Nevertheless, it was just in the midst of the influx of students brought by the GI Bill, in 1941, that an economics Ph.D. program was officially created at MIT. These developments also led to the establishment of a new undergraduate program of studies in economics and engineering in 1946, and

¹⁴ A hint of the rise of economics programs is the editorial success of *Economics*, Paul Samuelson's famous textbook. For instance, advanced order was so high that McGraw-Hill printed forty-five thousand copies, an exceptional run for an economics textbook at that time. See (Teixeira 2014)

¹⁵On Walkers role at the AEA see: (Coats 1985)

latter to the establishment of an actual department of economics. The context of an engineering school shaped the teaching portfolio, in which economics was often regarded in connection with practical training. Both, the mathematical background of MIT's students and the Institute's efforts to understand the impact of science and technology in society are also key elements to explain the specificity of the Department of Economics translating "esoteric" research into "tools".

As Paul Samuelson pointed out, in the early 2000s, if students "were allergic to anything mathematical, [MIT was not] the place that they would be" (Samuelson 2007). Samuelson knew this before he arrived at the Institute. Roger Backhouse's account of Samuelson's *move* from Harvard to MIT gives significant archival evidence in this regard (Backhouse 2014). For instance, in 1940, when Edwin Bidwell Wilson, Samuelson's mentor at Harvard, reassured him in his decision to accept MIT's offer, he stressed the students' mathematical and scientific training. Indeed, because it was an engineering school, MIT students were all required to have two years of mathematics, physics and chemistry, with many of them having studied applied mechanics and thermodynamics. If Samuelson was "too mathematical" for Harvard — as for most economics departments at the early 1940s —, MIT was a perfect fit in this regard. During the 1940s economics was not in the United States the mathematical discipline it later became, as the academic background of graduate students indicated¹⁶. For instance, late as the early 1953, just a very small proportion of economics graduate students (14 out of 358) responding to Howard Bowen's questionnaire for his pioneer report on the state of graduate education in economics, indicated that their undergraduate major has been in mathematics (11 graduate students) or engineering (3 graduate students). (Bowen 1953)

Beyond its mathematical background, MIT's students distinguished from other universities by the applied character of its training. Economics, and more widely, humanities and social sciences were institutionalized at the Institute as a means to

¹⁶ On the postwar process of intensification in the use of mathematical tool in economics see, for example, (Backhouse 1998; Weintraub 2002)

reinforce engineer students' connections with consequences of science and technical changes in society. The appointment in 1949 of the Committee on Educational Survey, directed by Warren K. Lewis, to determine whether the education at the Institute was adapted to the "conditions of a new era emerging from social upheaval and the disasters of war"(Lewis 1949, 3), illustrates well this point. After evaluating both undergraduate and graduate curriculum, the committee urged for a revamp. The idea was to foster the training of a new kind of engineer, one capable of meeting the special challenges of the postwar era and understand the human consequences of its work. Accordingly, one of the major recommendations of the committee was a decisive strengthening of the Institute's work in the humanities and social sciences. For the committee,

In our increasingly complex society, science and technology can no longer be segregated from their human and social consequences. The most difficult and complicated problems confronting our generation are in the field of the humanities and social sciences; since they have resulted in large measure from the impact of science and technology upon society, they have an intimate relationship with the other aspects of the MIT program. As a scientific and technological institution, MIT has obvious and challenging opportunities in this area: the opportunity to make a larger contribution to the solution of urgent social problems, the opportunity to help prospective scientists and engineers to understand better the forces that are molding contemporary society, and the opportunity to give students of the social sciences and the humanities a better insight into the meanings and implications of science and technology. (Lewis 1949, 42)

Concretely, the Committee on Educational Survey recommended to broaden the mission of humanities and social sciences, from the service fields concerned primarily with instruction at the elementary level they have been in the past at the Institute, to areas of knowledge equipped with a staff and institutional conditions comparable in importance and status to those of engineering and physical sciences. To develop the humanities and social sciences at an advance professional level, the Lewis committee

recommended two particular changes. First, the extension of the time devoted to the humanities and social sciences in the common curriculum (from eight term-subjects to ten). Second, the creation of a new School of Humanities and Social Sciences on an equal footing with the existing schools of Engineering, Science, and Architecture and Planning. For the committee, the School of Humanities and Social Sciences should “assume the responsibility for planning and administering the program of general education as a part of the common curriculum, and [...] offer professional courses leading to graduate as well as undergraduate degrees”. (Lewis 1949, 45)

One year after the submission of the report of the Lewis Committee, in 1950, the School of Humanities and Social Studies was created. Under the new institutional conditions, as the Committee on Educational Survey anticipated, the Institute attracted “outstanding men” in the humanities and social sciences fields. Moreover, the school quickly settled into the postwar patterns of funding, interdisciplinary collaboration and laboratory articulation of “basic” research and applications¹⁷. For instance, the Center of International Studies, that attracted substantial funding from the Pentagon, was added in 1951 to the School of Humanities and Social Studies. In the multiple MIT’s laboratory settings, social scientist, economist so as sociologist, political scientist, anthropologists, and psychologist interacted with scholars coming from mathematics, biology, physics, statistics, engineering, and other non-social disciplines. If social science were initially excluded from Vennevar Bush’s proposal¹⁸, at MIT as the Lewis Committee expected, humanities and social sciences “benefited from MIT’s atmosphere”. Specifically, the Lewis Committee was certain that “the

¹⁷ Indeed, MIT recruited “outstanding men” ... and very few women. On discrimination against women at MIT and the process that made it visible in the late 1990s see (Bailyn, n.d.) The situation at the Department of Economics was no better in the 1970s. In a letter to Frank Hahn about a PhD candidate, Robert Solow said: « More important, the committee concluded that a woman with husband and very small children was inevitably a bad risk as a Ph.D. student - I have no answer to the question how she could hope to go to classes, use the library, write papers, etc. So, we decided to put what little money we had into a couple of homely, single male who could confidently be expected to grind through to a Ph.D. in three years » Robert Solow Papers Box 55.

¹⁸ On the exclusion of social sciences see for example (Renisio 2017; Solovey and Pooley 2011; Solovey 2004)

concepts and techniques of science and engineering [will] give important insight into certain kinds of human, social, philosophical, and historical problems.”¹⁹

The study of the links between the technical and social consequences of scientific research had deep roots at MIT. Notably, Rupert Maclaurin, who was one of the main driving forces behind the transformation that the Department of Economics undertook during the 1940s, conducted a study on the economics of technological change²⁰. Maclaurin’s aim was to interpret the process of technological change and its economic and social implications. The project was strongly supported by president Compton. As Compton had expressed in his “technological education project”, for Maclaurin economics at MIT should be, on the one hand, developed in close relation with engineers’ interest and expertise. And, on the other hand, be useful for engineers to understand the economic impact of their work. While the Department of Economics did not evolve around Maclaurin’s project, questions related with the economic consequences of technological change did structured the future of economics at MIT.

Indeed, the new institutional conditions created by the implementation of the recommendations of the Lewis Committee opened an opportunity for social scientist, economists in particular, to extend and to strengthen its credentials at the Institute. The project to build an economics department started in the 1940’s began to settle in this context. The Institute’s deep rooted concern with connection “basic” research with “applied” knowledge, so as its interest —intensified after the war— in studying the interplay between science and technology, the new circumstances of the American higher education system —specially the rise of students—, the financial and institutional support of the Institute to develop social sciences, and the *concepts and techniques* coming from natural science and engineering to which scholar from the social sciences were exposed during interdisciplinary collaborations in laboratory

¹⁹ (Lewis 1949, 27) No emphasis in the original.

²⁰ It is relevant to mention that between 1941 et 1945 Maclaurin’s project obtained important funds from the Rockefeller Foundation. On Maclaurin’s project see (Maas and Backhouse 2016)

settings are all central elements to understand how economics translated “esoteric” research into applied “tools” at MIT. In other words, enabled and reinforced by the peculiar context and demands of an engineering school close related to the war and postwar political powers, on the one hand, and interested in study the intertwine between the technical and social consequences of scientific research, on the other hand, economics at MIT was bridged the academic and the practical arenas. Samuelson’s participation in the Bowman Committee give us elements to understand how the relations between science, innovation, and economic progress structured the orientation of the Department of Economics at MIT.

3.1. Paul Samuelson *Foundations* and the economic spin-offs of research

Together with the time he spent at the RadLab, where he worked primarily as a mathematician, Paul Samuelson engagement on wartime science included his participation in the Bowman Committee, a committee appointed in 1944 by Vennevar Bush to prepare *Science —The Endless Frontier*. Concretely, Bush requested the committee to write a report on the actions that the American government should undertake to aid research activities produced by public and private organizations. Samuelson, who was named assistant secretary, participated in the Bowman Committee next to Rupert Maclaurin (who acted as it secretary), Henry Guerlac (who was appointed to head up the secretariat that would undertake research and prepare materials for the committee), and Bernard Cohen (who was member of the secretariat). Isaiah Bowman was named chair. As Backhouse and Maas have shown, for Samuelson —contrary to Compton and Bush’s views— “the main issue was not to preserve individual freedom as a necessary condition for fundamental research but, rather, to acknowledge the relation between planned military research and its spin-offs in the economy at large” (Backhouse and Maas 2017, 88). This was not the final message of the Bowman Report. Contrariwise, the report stressed the importance of protecting the freedom of individual scientists to pursue their own research agendas without any governmental direction. Yet, during the elaboration of the report Samuelson used his experience at the RadLab to highlight the ambivalence of the links

between the demands made to the laboratory staff and their concrete modes of proceeding.

In 1947, two years after the final version of the Bowman Committee report was sent to Vennevar Bush, the same year Samuelson was awarded the first John Bates Clark Medal, he published what came to be a watershed work: *Foundations of Economic Analysis*. The book promoted Samuelson's already awarded reputation in the discipline, and consequently the department's visibility. It was as well key to consolidate Samuelson's leadership at the department putting forward the guidelines to translate "esoteric research" into "tools". Concretely, *Foundations* stated a series of principles and established the scope of the approach distinguishing MIT economics: 1) microeconomic behavior was modeled as maximization under constraints and macroeconomic behavior as the interaction of aggregate demand and aggregate supply; 2) imperfect competition was included to increase accuracy; and 3) comparative statics was used to apprehend changes.

3.2. Robert Solow's growth model and the intertwine between technological change and economic consequences

During the 1950s most research at the MIT's Department of Economics converged on growth issues. While Samuelson had already published papers that investigate the function of an ideal capital market and the behavior of interest rate, Solow's researches are capital. Indeed, the artifact that came to be known as Solow's growth model, gave insight into both, the translation of "esoteric research" into "tools" by MIT economists and the centrality of the study of the intertwines between scientific research, technological change and economic consequences during this process. The translation relies in both existence of underlying rather simple causality relation between individual behavior and aggregate economic variables, and the possibility to access this form of causality through simplifications. Concretely, Solow's growth model incarnates MIT's way of modeling economic behavior through mathematical, yet simple, models aiming to understand, first, a few aspects of a particular situation

that will be latter applied to a wide range of issues (for example, trade, consumer behavior, and public expenditure)²¹.

At the end of the 1950's Robert Solow published three influential papers. One on steady state growth (Solow 1955) and two on the technical change in aggregate production functions (Solow 1956, 1957). The three papers shared and objective: provide an "accurate" explanation of a "real world" situation by grasping its "essential" features in the simplest way possible so that, on the one hand, causality could be identified, and, on the other hand, data could be interpreted. It is worth mentioning that, Solow's research took place at the beginning of a period of rapid grow of the European economies, while, simultaneously, the United States, were not experiencing the post-war recession which had been so largely expected. In this context, the questions "in the air", as Solow reminisced latter²², were related with the account of the growth paths of modern developed economies. More precisely, with the explanation of why some economies grow faster than others. What at the time Solow considered "the legitimate existing literature", namely Roy Harrod (Harrod 1939) and Evsey Domar (Domar 1946), missed what he thought was the key feature of the problem: the exceptional character of crisis.

For Solow, Harrod and Domar work started from a wrong implication: growth paths were unstable. If they "couldn't have the thing right", was because, in Solow's opinion, "The Depression of the 1930s [...] was so important precisely because it was such an exception. It was not the routine thing" (Solow 2007). Solow's idea was thus to grasp in the simplified form of a model this characteristic, the fact that in the "economies we know", "there are deviations, occasionally bursts of rapid growth, occasionally bursts of slow growth or even a slight decline"(Solow 2007). And at the same time, there is a tendency to get back, that is some degree of stability to that growth path.

²¹ We use Beatrice Cherrier's definition of MIT models. See (Cherrier 2014, 24)

²² (Solow 2007) All the quotes in this paragraph and the next are from this same source.

Solow, dismissing Harrod and Domar's fixed-proportion assumption, and stressing the possibility of substitution between capital for labor, proposed what he considered to be a "better model" (Solow 2007), a model that additionally to *overcome* Harrod and Domar "unfactual characteristic" (Solow 2007), "would actually work"—that is to say, "could be used to interpret facts, data" (Solow 2007). "It turned out to be a good thing" (Solow 2007), he stated later. After empirically implementing his model, Solow could observe that the main driving force for growth in developed economies had not been the increase in population and the accumulation of capital goods, as "everybody else" (Solow 2007) before, had "taken for granted". Solow called this main force for growth *technical progress*.

As Verena Halmayer have shown (Halmayer 2014), Solow came out with the "collapsed production functions", a major component of his model, while simplifying a dynamic input-output system in order to teach it to his MIT students. Beyond its pedagogical role, the model was also an instrument of *measurement* of technological change as well as a simplified version of the economy where causal relations could be visualized. Swiftly Solow's growth model became the epitome of the MIT approach and reinforced the self-aware sense of identity of MIT economists, a rather endogamous group.

3.3. Mastering a craft exercise in a laboratory-like context

Although Paul Samuelson's and Robert Solow's approaches to modeling were different, in the fifties the Department of Economics at MIT began to acquire an identity, associated with Samuelson, and increasingly with Solow²³. Their sustained collaboration is indeed key to understand the orientation of the department. For instance, Samuelson and Solow spent part of the fifties working on linear programming for RAND, producing a book with Robert Dorfman.

²³ Charles Kindleberger and Evsey Domar also played important roles at this point.

Light could be shed on Samuelson's influence by looking at his description of the department's building process during the late 1940s and early 1950s:

[W]hat subsequently came to happen was that this is the way it was done [...] me advising Ralph Freeman, I think we ought to try to get that guy, and we ought to avoid that guy. And I think this one is hurting. He's had some new babies and his salary ought to be increased. And the reason that could happen was that I was earning more, getting a higher salary than any of the rest of them. So, there was no competition. (Samuelson 2007)

The experience of the black students that enrolled the Ph.D. program in the context of an affirmative action project during the 1960s is also telling of the clear hierarchies of the department, and the consistence of its project:

MIT's faculty, which did not include any black faculty member (and *never* has included any black faculty member on tenure track), seems to want its black students to replicate their own interests and style of doing economics. There was little enthusiasm from black economist bringing a set of intellectual questions and perspectives to the field separated from the white mentor's interest and expertise (Darity and Kreeger 2014, 326)

Yet, internal hierarchies passed often unnoticed —the department was regularly presented, both by insiders and outsiders, as an open environment where students were encouraged to collaborate with each other²⁴. Compare to the Economics Department of the University of Chicago, infamous for its vertical hierarchical organization and competitive environment, MIT Economics Department could appear as the “happier economics department” in the United-States, as Hollis Chenery presented it after a visit in the 1950's. MIT graduate program was the antithesis of the

²⁴ As Darity and Kreeger's analysis already cited made explicit, having the “right” skin color, choosing the “right” topics, and using the “right” approach was a *sine qua non* condition to actually perceive the openness and collaborative environment of the department.

University of Chicago: while Chicago brought in large classes and flunked out 60 to 70 percent after the first year, MIT brought in smaller classes —generally a maximum of thirty students a year— with the expectation that virtually all would complete the program.

MIT's Economics Department was indeed a student focused one. This evidenced for example in the institutionalized *open-door policy* and in the importance given to teaching. Research time could not be bought off with research funds: "If you were a member of the faculty of the MIT economics department, you taught"(Solow 2007). The self-replication chain reeling in adviser-advisee relationships —where Samuelson but particularly Solow played key roles²⁵ — participate in the constitution of a mode of organization similar to the laboratories where the *right* mixture of "basic science" and "engineering applications" was put together at MIT.

This laboratory-like context both made possible and reinforced the translation of "esoteric research" into "tools". More than the result of a five steps recipe this process —as narrow and specialized as it may look like— can be assimilated to a highly specific craft, mastered after years of study and practice in an apprenticeship fashion. Conspicuously, Paul Samuelson, in the 90th Nobel Jubilee, presented economics as an "inexact science [that] along with logic and mathematics, [...] still depends on the art of judgment" (PASP. Box 4. Folder: Nobel Jubilee). MIT's Economics Department laboratory-like context was an appropriate environment for the blooming their craft translation process, and the associated judgement that both it demanded and developed.

Simultaneously this environment reinforced the connections to the concrete conditions of application. For instance, Samuel Mayers Jr., graduate student during the 1970s, his experience attending a Black College and Universities (HBCU) was critical in preparing him for MIT:

²⁵ On the adviser-advisee self-replication chain see (Svorenčík 2014).

If I had not go to Morgan, I would have never go to MIT. I think going to Morgan gave me an opportunity to focus more explicitly on using the tools and the skills of economics in order to solve the problem of minority communities.(Darity and Kreeger 2014, 325)

Likewise, Solow's, referee letter to Bernard Haley, editor of The American Economic Review, illustrates the importance that the actual conditions of application had at MIT Economics Department:

[...] the author simply brushes off any suggestion that the housing market may be too imperfect to admit simple conclusions from very simple theory. I am not an expert, and I am not asserting that the market for houses is too imperfect for the theory to apply. But the paper is written exactly as if we were talking about assigning apples of different quality to people of different income and tastes. And I know houses are different from apples. (The complete of external effects is especially surprising.) If the paper is ultimately to be published, Smith must argue the case that his conclusions may be applied with some confidence to Philadelphia. As it stands, it's too doctrinaire (RSP. Box 1. Folder 1961)

For Paul Krugman, one of the most famous alumni of the MIT Economics Department,

It [was] obvious why this approach was better suited for producing future central bank governor's chief economists, and even than an approach that elevated purity over realism (Krugman 2015).

Certainty, the fact that for Krugman it was obvious that MIT's approach was particularly well adapted to produce economist with great influence in the policymaking process is explained by the positions in the government they occupied. For instance, during the fifties Samuelson provided advise to Treasury and the Bureau

of the Budget²⁶. Nevertheless, it is equally telling of MIT economists' self-perception. Indeed, a long-term well established collective identity characterized by a pragmatic engineering approach and driven by real-world questions existed at the MIT Economics Department. As Krugman summed it up:

MIT students developed a style that was either wonderfully pragmatic or disgustingly lacking in rigor, depending on your tastes: models derived from micro foundations were always the goal, but when observed experience was clearly at odds with what the models predicted, you'd just impose realistic behavior and leave its ultimate explanation as a project for the future.²⁷

CONCLUSION

In the US-American environment, where expert knowledge is not a technocratic arm of the state itself and thus where top civil service positions have traditionally been filled with outsiders, MIT's translation of "esoteric" research into "tools" was crucial for economics to connect the academic and the practical arena. For Marion Fourcade the intervention of economics in public arenas has been shaped in the United States "not only by their own "scientific" capabilities but also by the particular expectations emanating from the institutions that request such expertise in the first place" (Fourcade 2009, 128). As Theodor M. Porter showed (Porter 1997), the suspicions towards ideological underpinnings of knowledge coming from the social sciences, that characterized US-American political culture, encouraged the use and reinforced the authority of *quantitative technologies* such as MIT models.

The context of an engineering school, MIT's Economics Department established a unique position in economics applied to practical issues. As Howard R. Bowen's report on the state of economics graduate education made it explicit during the aftermath

²⁶ A non-exhaustive list of MIT's students that became central bank presidents includes Mario Draghi (PhD MIT, 1977) European Central Bank; Stanley Fischer (PhD MIT, 1969; MIT professor, 1973-1979) FED; Ben Bernanke (PhD MIT, 1979) FED.

²⁷ Paul Krugman. 28 February 2015. The New York Times.

of World War II the discipline of economics needed to advance its frontiers into the practical arena.

It is vital to the advancement of our society that successive generations of economists be trained who would have the technical skills, the broad perspective, the judgment, the leadership, and the sense of social responsibility necessary to advance the frontiers of knowledge into practical solutions for social problem.²⁸

The particular approach developed during the year around World War II at MIT Department of economics was not created simply by the context of the engineering school close related to war and post war powers, though of course it fostered a technical approach and discourse.

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²⁸ (Bowen 1953, 38)

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