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Space Race Technology and the Impact on Jobs in U.S. Cities*

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Abstract

The spatial concentration of productivity and employment is central to economic geography. Yet, how the location of frontier technology affects the location of jobs is not well studied. In this paper, we examine how the Space Race driven expansion of the high-tech sector affected labor demand in the manufacturing sector. We first use Compustat data from 1954 to 1997 to show that firms receiving Space Race contracts expanded employment, reduced labor intensity, and with little change in total factor productivity. Our analysis of MSA-level Manufacturing census data from 1947 to 1997 reveals two further results on the indirect effects of the Space Race. We find that the Space Race reduced employment and wages in firms that do not receive NASA contracts, but are colocated with those that do. We find little positive effect of the Space Race on total factor productivity of colocated firms, but a decline in labor intensity.

Keywords: Jobs, Innovation, Geography, Productivity
JEL Classifications: R11, O33, N50

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1 Introduction

The concentration of frontier technology and jobs in Silicon Valley serves as a regional development blueprint for many policymakers. Yet, because frontier firms use technology with a lower labor intensity, whether frontier firms bring more jobs to a city is far from clear.[1] While frontier firms are just a small slice of a cities labor market if cities serve as a conduat for technology transfer, frontier firms may reduce labor demand in other sectors. In this paper we ask, does the high-tech sector create or destroy other jobs in a city?

The effects of the high-tech sector on the demand for labor depend crucially on the nature of frontier technology. Transferring factor-neutral technology from leading to following sectors enhances the productivity of labor, increasing local labor demand. When frontier technology is not factor neutral however, the effects of the high tech sector on labor demand are less clear. When labors' share falls sufficiently fast the transfer of frontier technology may reduce labor demand.

Identifying the effects of the high-tech sector effects on labor demand at other firms is not straightforward. Important challenges arise because high-tech firms may locate where where highly educated workers or scientific infrastructure are also located. In addition, knowledge transfer may occur with a substantial lag, requiring a long-term series of high-quality data to estimate.

By examining the effects of the Space Race – one of the largest investments in high-technology of the 20^{th} century – we are able to address these challenges. We propose that the Space Race serves as a source of exogenous variation in the size of the high-tech sectors in a city. Because the Space Race was launched in response to Sputnik in 1957 and high technology Space Race sectors were located based on pre-existing, often obsolete, fundamentals (e.g., warm weather drew North American Aviation to produce Air Force training planes in southern California in the 1930s before pilots cockpit were enclosed; Boeing located in Seattle to access the spruce needed to build World War I-era aircraft), the Space

[1] Recent evidence indicates that labor's share is declining, though the exact source of this decline remain subject to debate. (Karabarbounis and Neiman (2014), Piketty and Zucman (2014), Oberfield and Raval (2014), and Acemoglu and Restrepo (2015).

Race created a positive shock to local high-tech employment virtually independent of local economic conditions. While President Obama has called for another "Sputnik moment" to create millions of jobs, little is known about whether the original Sputnik Moment created or destroyed jobs.

Space science in the late 1950s and 1960s was mission oriented, focused on sending a man to the moon, not to generate new consumer products. The fact that it is hard to pinpoint key blockbuster products reflects this fact. Yet, NASA research did lead to a number of discoveries in telemetry, integrated circuits, cryogenics, and computer simulation that had real economic value. Even more important than the NASA-related discoveries themselves were the indirect effects. NASA-funded research provided an invaluable opportunity for a generation of scientists, engineers and managers to gain first hand experience with rapidly developing computer technology. Summing up the changes in products, processes and instrumentation, Scranton (2007, 123) concludes, "NASA projects added critical momentum and capability to nascent innovations, providing essential test-beds for them (and the funding for revision and redesign), and to explore projects where the complexity of NASA-posed problems galvanized cross-disciplinary amalgams of technique and materials, with implications for the industrial world outside."

We first examine how the surge in NASA spending during the Space Race affected firms that received the contracts. While census data on the universe of firms does not exist for this period as most of the NASA contracts were allocated to large firms that were listed on stock markets we can use Compustat data to gauge the direct effects of NASA spending. We look at how employment, total factor productivity and capital intensity differentials respond to the exogenous increase in space race funding.

Our analysis reveals that the Space Race increased employment in the directly affected firms during and after it occurred. We find little increase in TFP in the short run, but small increases after the Space Race is over. Similarly, we find notable increases in capital intensity during the Space Race. Importantly no 'effects' are present in trends before the space race and are robust to controlling for defense industry effects.

We next turn to examining the effects of the Spare Race on cities with a larger Space Sector. Our analysis examines how manufacturing labor demand is affected using newly digitized Manufacturing Census data at the MSA-Industry level. Our approach by controlling for flexible industry trends and by examining firms on non-space sectors allows us to estimate the local external affects of space sector activity. We also control for time invariant city characteristics to obtain an estimate with a causal interpretation.

Our first analysis of the affects of the space sector on local labor demand shows that employment falls in local non-space sectors when the space race takes off. The effects manifest after the space race is 5 years old in 1963 and persist until 1997. Importantly we find little evidence that local wages increase, suggesting these effects do not simply reflect reallocation between sectors in response to local sectoral labor demand shock.

That the employment effects persist long after the Space Race has ended and spatial equilibrium is likely to hold suggests technology may have changed. We pursue two analyses to examine this possibility. We first examine whether there are local external TFP effects of Space Sector activity. We find little evidence of a positive effect. Next, we examine the external effects of the local Space Sector on labor intensity. Here we find clear evidence that capital per worker declined, particularly over the longer term. We see this pattern of results as consistent with the IT-intense Space Sector providing local technological spillovers that reduce labor demand.

Our paper contributes to two literatures. A first literature is the role of government policies in place-making. Some such as Porter (1990) argue that policymakers could engineer a productive cluster by supporting and growing the right mix of industries in a single location. Others are less optimistic. Even though Moretti (2012) sees a strong role for innovation in regional job growth, he echos Lerner (2013) in stressing that governments have a poor record in picking firms that will be successful. In a similar vein, Kerr and Glaeser (2014) argue that entrepreneurs lead regional growth, leaving little role for governments to create a cluster. Our work in contrast demonstrates that public investments in innovative sectors can affect employment, but the direction of technology is central to their effects.

We contribute to the debate about the role of government in stimulating productivity growth over the long term. Historians have argued that the massive public investments in science and technology after World War II can explain why the high technology sector first took off in the United States (Nelson and Wright 1992). Mowery and Rosenberg (2000, 878) term this the Electronics Revolution and state that "The electronics revolution can be traced to two key innovations - the transistor and the computer. Both appeared in the late 1940s, and exploitation of both was spurred by cold war concerns over national security." Other economists see American high tech leadership as attributable to the lucky event of U.S. firms being first to discover a new general purpose technology - the digital computer - rather than public investment (Gordon 2012). Contemporaries like Bell Laboratories president James Fisk in 1965 expressed doubts that public investments in space research would translate into long terms gains in productivity: "We believe that it would be inaccurate and probably dangerous to persist in the presumption that this was the way to start and maintain important industrial innovation" (Cited in Leslie 2000, 66). Our results indicate that public investments in science and technology did not lead to productivity improvements, but reduced employment in manufacturing.

2 Historical Background

Space Race. The Space Race began with the launch of Sputnik on October 4, 1957. President Eisenr was not surprised by Sputnik; he had been forewarned by information derived from U2 spy plane overflight photos, as well as signals and telemetry intercepts.[2] Eisenhower initially played down the importance of Sputnik, but after the high profile failure of the U.S.'s initial satellite effort – Project Vanguard – on live TV on December 6, 1957, public fear grew (Divine 1993). It was clear to many how important missile, space, and satellite technology was to surviving a potential nuclear war with the Soviet Union.[3] It was

[2]Logson (1995, 329) summarizes a July 5, 1957, memo from Allen W. Dulles, Director of Central Intelligence, to Donald Quarles, Deputy Secretary of Defense,"By 1957, the Central Intelligence Agency was aware that the Soviet Union had an active ballistic missile program and was preparing to launch a satellite. But the exact date of the launch was still uncertain. This memorandum from Director of Central Intelligence Allen Dulles to Deputy Secretary of Defense Donald Quarles indicates that American intelligence knew a Soviet space launch was imminent, but, as of early July 1957, was still unsure of the exact date of the launch."

[3]Satellites allowed Cold War adversaries to see over the Iron Curtain and accurately assess the strength

this technological anxiety that fueled the Cold War.

This growing fear led to the formation of the National Aeronautics and Space Administration (NASA) in 1958 with a budget of $ 89 Million. NASA began by taking over the X-15 experimental rocket-powered aircraft from the National Advisory Committee for Aeronautics (NACA) and Project Vanguard from the Navel Research Laboratory (NRL), but soon envisioned launching a person into space through Project Mercury. On May 5, 1961, astronaut Alan Shepard completed three orbits of the Earth and became the first American in space aboard Freedom 7. Following this success President Kennedy announced on May 25, 1961: "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth."

President Kennedy's commitment to send a manned crew to the moon and returning them to earth by the end of the decade required a massive investment in space technology. NASA's budget grew accordingly, from from $744 million (or about 0.9% of all federal spending) in 1961 to a peak of $5.933 billion (4.4 % of the federal budget) in 1966. With the rapid escalation in public funds devoted to space exploration, the Space Race was very much a race. NASA's spending did decline after the landing on the moon was successfully completed in 1969, but still accounted for 1.92% of federal spending in 1970. Subsequently, the level of spending fluctuated between 0.75% to 1% of the federal budget from 1975 until the end of the 20^{th} century.

Growth and Organization. The Space Race is the canonical example of mission-oriented research and development spending where the mission was to land astronauts on the moon and safely return them to Earth. The Space Act of 1958 gave NASA broad powers to develop, test, and operate space vehicles and to make contracts for its work with individuals, corporations, government agencies, and others (Rosholt 1966, 61). Early on NASA made the decision to contract out much of the R&D work to private contractors.[4]

of their opponent's intercontinental ballistic missile (ICBM) arsenal. They also allowed the targeting of the precise locations where the ICBMS were located – crucial information in the event of nuclear war. In an era of very limited information, satellites provided a major advantage.

[4]T. Keith Glennan, the first administrator of NASA, was an advocate for contracting out. He wrote of his early decisions in 1958: "First, having the conviction that our government operations were growing too larger, I determined to avoid excessive additions to the Federal payroll. ... I was convinced that a major

This emphasis is reflected in the growth in personnel. While in-house NASA employees grew from 10,200 in 1960 to a peak of 34,300 in 1965, employment by NASA contractors increased from 30,500 in 1960 to 376,700 in 1965 (Van Nimmen, Bruno, and Rosholt 1976, 106). This massive increase in NASA employment outside of NASA was concentrated in private sector contractors, which accounted for 81% of total NASA employment in 1965. Universities, on the other hand, accounted for 3.1 % of total NASA employment in 1965.

Space Race spending was highly concentrated in relatively few sectors and firms. According to an input-output table constructed for NASA expenditures for fiscal year 1967 (Orr and Jones 1969), the top five manufacturing sectors accounted for about half of NASA expenditures.[5] Similarly, relatively few firms served as primary NASA contractors. In 1965, the top 10 contractors alone received nearly 70% of the spending. Leading technology companies receiving NASA projects included: North American Aviation, Boeing, Grumman Aircraft Engineering, Douglas Aircraft, General Electric, McDonnell Aircraft, International Business Machines, and Radio Corporation of America (Van Nimmen, Bruno, and Rosholt 1976, 197).

Technology Impacts. What did NASA scientists discover? How did NASA spending affect productivity? From the beginning NASA officials recognized that the transfer of technology to commercial applications was vital in securing public support. They sought partnerships with universities and established information distribution centers where private sector firms could access information on their latest discoveries.

Despite the prominence of the Space Race as one of the largest ever public investments in innovation, pinpointing a blockbuster consumer product solely attributable to NASA spending is hard. Indeed, many space-associated consumer products were already developed and the Space Race simply diffused them more broadly (e.g., Tang (Scranton 2006, 122)). Yet, the Space Race did have broader impacts on technological change.

Robbins, Kelly and Elliot (1972) identify 109 major developments in a field's technology

portion of our funds must be spent with industry, education and other institutions." (Hunley 1993, 5)

[5] The five of our SIC 3 digit industries with the largest share of NASA spending are: Aircraft and Parts (SIC=372), Electrical Equipment (SIC=361-366), Computer And Office Equipment (SIC=357), Industrial Inorganic Chemicals (SIC=281), and Instruments (including Professional and Scientific) for Measuring, Testing, Analyzing, and Controlling (SIC=381-387).

over the last decade through interviewing 161 recognized technological leaders. For each breakthrough they classify NASA's role in the technology's development: (1) an entirely new technology - 6.3% of developments, (2) an incremental advance in a technology - 64.8 % of developments, and (3) a consolidation of existing knowledge about a technology - 23.3 % of developments. Their findings echo an earlier analysis that concluded that Space Race research largely sped up progress with existing technologies rather than developed entirely new technologies (Denver Research Institute 1971).

The areas where Robbins, Kelly and Elliot (1972) identify entirely new technologies from NASA spending are: Cryogenics, Energy Conservation, Ceramics, Metals, Integrated Circuits, Gas Dynamics, Non-Destructive Testing, and Telemetry. Telemetry, Integrated Circuits, Cryogenics, and Simulation are the areas with the greatest fraction of development that would not have occurred without NASA contributions. A few examples include the development of powdered metallurgy techniques in the field of high temperature metals, the computer enhancement of radiographs, high frequency power transistors, and the simulation of lunar landings (Robbins, Kelly and Elliot 1972, 18-21).

While the direct economic effects of space research were of modest magnitude, many argued that the harder to estimate indirect effects that occurred over a much longer time horizon were substantially larger. These later studies focus on some technologies where NASA's contribution became clearer over time. For example, NASA played a important role in the development of integrated circuits, first launching them into space in 1962 (Mathematica 1976, p. 101), structural simulation software - Nastran - between 1965 and 1970 (Mathematica 1976, p. 119), and digital communications, including the use of error-correcting codes and data compression in processing digital signals for modern-day digital communication and data storage (Midwest Research Institute 1988). Mazlish (1965) draws the comparison between the indirect effects of space science and the development of the railroad.

Summing up the contributions of NASA spending, Scranton (1996) concludes, "Contrary to consumer expectations, virtually all these contributions have been indirect, as a Denver Research Institute (DRI) study explained in the early 1960s, and hence imperceptible to most observers.” Scranton (1996, 129) notes, however, that many innovations were directly applicable to manufacturing: “on the manufacturing process front, we can note innovations such as chemical milling and high-energy forming . . . as well as electron-beam, thermal, numerical control, ultra-cold, and electrical discharge machining; electrolytic grinding; plasma and induced magnetic field welding; plus stretch, magnetic, and shear forming.” On instrumentation: “The rise of reliable, precise, and speedy instrumentation as a key dimension of technical practice preceded NASAs inauguration, but its momentum accelerated at a rapid pace once piloted spaceflight became a national priority” (Scranton 1996, 136). On management practices: “NASA projects provided test platforms or incubators for a number of managerial techniques as well: project management and team-tasking, high-level quality control, reliability analyses, and handling concurrency/redesign challenges” (Scranton 1996, 137). Others also noticed the staggering developments in computerization and automation. Describing NASA’s Performance, Evaluation and Reporting Technique, Bilstein (1996, 286) notes that ”PERT was a sophisticated and complex computerized system, with inputs beginning, literally, at the tool bench. Technicians on the floors of the contractor plants around the country monitored the progress of nearly all the the hardware items and translated the work into computer cards and tapes. The PERT network was broken down into 800 major entities and summarized 90,000 key events taking place around the country.” A major improvement in quality control was the automated checkout procedure. As Bilstein (1996, 240) describes: “manual checkout techniques for the the earliest S-IV stages; pre-checkout, acceptance firing, and post-checkout required a total of 1200 man hours per stage. Vetran “switch flippers” who had for so had been vital links in the loop ... were now replaced by ranks of grey-enameled computers . . . Although the magnitude of testing rose 40 percent per stage the new automated systems reduced checkout time to just 500 man hours total.” Indeed, if the Space Race had a significant effect on the development of the leading general purpose technology – the digital computer – the effects may have taken some time to fully manifest and may have occurred outside of the space sector. Our analysis investigates this possibility directly.

3 Measurement Framework

To examine how NASA research directly affected manufactures' over the course of 50 years, we use the launch of Sputnik as a source of exogenous variation. We estimate the equation

$$Y_{it} = \sum_{t=1954:1963}^{2007} \beta_t \text{Space Firm}_i \times \gamma_t + \theta_i + \gamma_t + \gamma_{C_{i,j}t} + \epsilon_{it}. \quad (1)$$

Y_{it} is the manufacturing outcome in firm i in years t=1954-1999. γ_t is a set of year fixed effects (1958 serves as the reference year) that flexibly control for national time series trends in manufacturing outcomes and θ_i is a set of firm fixed effects which absorb time-invariant characteristics across MSAs. θ_j is a set of industry fixed effects which absorb time-invariant characteristics across industries. $\gamma_{C_{i,j}t}$ is a dummy for a defense industry interacted with year fixed effect effects. $SpaceFirm_i$ is an indicator variable for firms that receive a contract from NASA between 1963 and 1978. ϵ_{it} is random error.

To examine how NASA research indirectly affected manufactures' over the course of 50 years we use MSA industry mix in 1958 to define space places. We estimate the equation

$$Y_{ijt} = \sum_{t=1954:1963}^{2007} \beta_t \text{Space Place}_i \times \gamma_t + \theta_i + \theta_j + \gamma_t + \gamma_{C_{i,j}t} + \epsilon_{ijt}. \quad (2)$$

Y_{ijt} is the manufacturing outcome in MSA i and industry j in manufacturing census years t=1947, 1954,1958,...,1997. γ_t is a set of year fixed effects (1958 serves as the reference year) that flexibly control for national time series trends in manufacturing outcomes and θ_i is a set of MSA fixed effects which absorb time-invariant characteristics across MSAs. θ_j is a set of industry fixed effects which absorb time-invariant characteristics across industries. $\gamma_{C_{i,j}t}$ is a set of MSA characteristics (i.e. education level, population and median in 1960 interacted with linear year trends), or industry-year fixed effect effects that may be included depending on the specification. $SpacePlace_i$ is an indicator variable for MSAs that are highly exposed to NASA spending based on the MSA's total value added in 1958 in sectors that experienced high levels of NASA spending. ϵ_{it} is random error.

The event-study specification we use describes the dynamics of the research effects flexibly. Our parameters of interest are $\beta_{1947}, ..., \beta_{2007}$ that measure how the relationship between space places and productivity differed from the reference year in 1958. If space spending generated proximity effects that persisted indefinitely, then $\beta_t \neq 0$ for all years $t > 1963$. If, on the other hand, research effects disappeared then $\beta_t = 0$ for t beyond some critical time period.

Our central outcomes of interest are employment and wages in local manufacturing. If the Space Race spending increased labor demand in other sectors, through positive localized productivity effects, we would expected β_t to be positive after 1958. On the other hand if Space Race spending reduced local labor demand then we would expect β_t to be negative after 1958. Whether any effects persist after the Space Race depends on how firms and workers adjust, and whether expertise with frontier technology accumulates locally over time.

Our empirical approach utilizes variation in research that is plausibly exogenous to local manufacturing. The Space Race started suddenly with the launch of Sputnik in October 1957, causing widespread public concern that the U.S. was falling behind in new crucial technologies. The U.S. response was to quickly and dramatically expand investments in space research, leading to the creation of NASA in 1958. Further, President Kennedy's May 1961 call for "landing a man on the Moon and returning him safely to the earth." The necessity of speed to win the Space Race caused spending to be concentrated where manufacturing capacity already existed. Many of locations of the relevant sectors were determined by geographical conditions necessary from earlier vintages of technology. To give just one example, North American Aviation - the largest NASA contractor in the Space Race period - moved to Los Angeles in the 1930s because favorable weather allowed year-round flying (http://www.centennialofflight.net/essay/Aerospace/NorthAmerican/Aero37.htm)[6]

Because Space Race spending was concentrated in pre-determined locations of relevant sectors and jumped in response to nationwide concerns about Sputnik, they created a positive shock to local research virtually independent of local economic conditions. Our central

[6]Similarly, Boeing located in Seattle to take advantage of local supplies of spruce, a key input into aircraft production before the 1930s when Boeing was founded.(see: Howe, Sam (October 2, 2010). "The tale of Boeing's high-risk flight into the jet age". The Seattle Times. Retrieved May 21, 2011.)

identifying assumption is that changes in Space Race research at "space place" locations were unrelated to changes in unobserved determinants of local manufacturing development. While it is not possible to test our identification assumption directly, estimates of β_{1947} β_{1954}, allow us to test for "effects" where none is expected.

After using this reduced form to validate our approach and research design, we estimate pooled versions of this model. Thus, we estimate the model

$$\begin{aligned} Y_{ijt} = \beta_{SpaceRaceEra}\text{Space Place}_i \times \text{Space Race Era}_t + \\ \beta_{PostSpaceRaceEra}\text{Space Place}_i \times \text{Post Space Race Era}_t + \\ \theta_i + \theta_j + \gamma_t + \gamma_{C_{i,j}t} + \epsilon_{ijt}. \end{aligned} \tag{3}$$

where Space Race Era_t takes a value of one in the years 1963 and 1967, Post Space Race Era_t takes a value of one in the years 1972, 1977, 1982, 1987, 1992 and 1997. All other variables are as defined as in equation (1) above.

In all specifications, to address the possibility of persistent autocorrelation in outcomes within a MSA, we cluster the standard errors at the MSA level.

4 Data and Descriptive Statistics

Manufacturing Firm Data. We use Compustat data to estimate the impact of NASA spending on wages, employment and technology of large manufacturing firms listed on the stock market. We obtain data on employment, sales, capital, value added for 1954 to 1999 for each form.

We obtain NASA contract data for each firm from 1963 to 1978 from the NASA historical databook. This data source reports the total amount of contract with each of the top 100 contractors in a year. The firms in the compustat data account for a significant fraction of NASA spending. The top 100 firms typically receive 85% to 90% of NASA funding, and as these are typically very large firms (Boeing, IBM, McDonald-Douglas, etc.) the are likely to be listed. Between 1963 and 1978, when we have data, the Compustat firms in our data account 83.8 to 76.8 percent of the NASA spending. The firms with NASA data reported that we are unable to locate in Compustat data are typically local construction firms and highly specialized technical consultancies.

We use this NASA data to create our $Any\ NASA\ Contract_{it}$ variable that takes a value of one for firms that receive a NASA contract from 1963 to 1978, and a value of zero otherwise.

Manufacturing Industry-MSA Data. We use the Manufacturing Census to estimate the impact of city level NASA activity on manufacturing wages, employment and technology. We obtain data at the MSA-Industry level from the census's of 1947, 1954, 1958, 1963, 1967, 1972, 1977, 1982, 1987, 1992, and 1997. We obtain data on total value added, total employment, total annual wages, and total plant and equipment additions for each Industry-MSA cell. We take SIC 3 digit industries (1972 definition) in the MSA as the unit of analysis. Because not every 3 digit industry reports in every census, we aggregate those that do not, leaving us with 54 possible 3 digit industries. Another issue is that the minimum numbers of employees required for an industry-MSA cell to report changes over time. We apply the same minimum number across all years to enhance comparability. A further issue is that not all industry-MSA cells report each census. To be included in our panel, we require that an industry-MSA cell must be reported (1) in the 1958 Manufacturing Census; and (2) at least 3 times in our sample period. We are then left with a panel containing 7,187 MSA-Industry level observations.

We estimate total factor productivity in each MSA-industry cell using the production function,

$$V_{ijt} = (K_{ijt})^{\beta_{1,j}} (LPW_{it})^{\beta_{2,j}} (LNPW_{it})^{\beta_{3,j}} e^{A_{ijt}} \tag{4}$$

where V_{ijt} is value added in MSA i, industry j and year t, K_{ijt} is the capital stock (constructed from the additions to plant and equipment under a perpetual inventory method as described in the data appendix), LPW_{ijt} is the number of production workers employed, and $LNPW_{it}$ is the number of non-production workers employed. The total factor productivity we seek to estimates is A_{ijt}. Taking logs of (3) we obtain,

$$ln(V_{ijt}) = \beta_{1,j} ln(K_{ijt}) + \beta_{2,j} ln(LPW_{ijt}) + \beta_{3,j} ln(NLPW_{ijt}) + A_{ijt} \qquad (5)$$

We obtain log TFP by first estimating equation (5) separately for each of our 3 digit industries j (following Combes, Duranton, Gobillon, Puga, and Roux 2012), and then

$$A_{ijt} = ln(V_{ijt}) - \hat{\beta}_1 ln(K_{ijt}) - \hat{\beta}_2 ln(LPW_{ijt}) - \hat{\beta}_3 ln(NLPW_{ijt}) \qquad (6)$$

We use this revenue-based measure of log total factor productivity as an outcome variable. The advantages or disadvantages of a revenue-based productivity measure depend on the determinants of price variation across producers (Syverson 2011). When price variation reflects differences in product quality, a revenue-based measure may be preferred. To the extent that the Space Race led to improved vintages of a given product, this is a strength of our measure. Alternatively, if price variation reflects market power, then changes in market integration or market structure could be confused with changes in productivity. We address this concern by examining how the effects we estimate depend on the market structure of manufacturing and conducting a separate analysis of Space Race knowledge on the market value of listed firms.

NASA Place Data. We construct industry-level NASA expenditures from two sources. First, we use national time series data on NASA spending from the NSF Survey of Federal Funds for Research and Development from 1951 to 2014. Second, Orr and Jones (1969) classified all NASA expenditures in fiscal year 1966 and 1967 to SIC 4 digit categories. We use their final demand vector for fiscal year 1967 to obtain NASA spending shares for each of our SIC 3 digit industries. The five of our SIC 3 digit industries with the largest share of NASA spending are: Aircraft and Parts (SIC=372), Electrical Equipment (SIC=361-366), Computer And Office Equipment (SIC=357), Industrial Inorganic Chemicals (SIC=281), and Instruments (including Professional and Scientific) for Measuring, Testing, Analyzing, and Controlling (SIC=381-387).

We next create annual MSA-industry level NASA expenditures for the manufacturing industries in our sample. [7] Our MSA-Industry level NASA spending can be expressed as:

$$NASA_{ijt} = \sum_{j=1}^{J} \eta_{i,1958} \times \delta_{j,1967} \times NASA_t. \tag{7}$$

Equation (7) has two components. Industry NASA spending in a year is obtained by multiplying the industries share of total NASA spending in 1967, $\delta_{j,1967}$ (from Orr and Jones, 1969), times national spending in each year $NASA_t$. Industry-MSA NASA spending is computed by allocating total industry spending to each MSA by the MSA's share of employment in that industry in 1958 $\eta_{i,1958}$. For example, if total NASA spending was \$ 1 Billion in, say, 1963, and Computer and Office Equipment had a 10% share NASA spending, then we would attribute \$ 50 Million in NASA spending on Computer And Office Equipment. To obtain an MSA allocation in 1963 we use the share of Computer and Office Equipment Employment in an MSA in 1958. If Boston had a 10% share and San Francisco had a %5 share, then NASA spending in the Computer and Office industry would be \$ 5 Million in Boston and \$ 2.5 Million in San Francisco in 1963 .

To get total NASA spending in an MSA we then compute the total NASA spending across all industries in an MSA in a year. We compute $NASA_{it} = \sum_{j=1}^{J} NASA_{ijt}$. Those MSA-industry cells above the median $NASA_{i,1958}$ have: Space $\text{Place}_i = 1$, those below have: Space $\text{Place}_i = 0$. Prominent cities that are Space Places include Los Angeles, Houston, Cleveland, and Boston. Prominent cities that are not Space Places include Atlanta, Denver, Jersey City, and San Diego.

City Data. We obtain city-level data form the Census of Population and Housing. Because MSA definitions can change and some variables are not available at the MSA level in early years of our sample we use county level data that can be aggregated to consistent 1960 MSA definitions across all the years of our sample (Haines 2005). We obtain MSA-level measures of total population, median housing value, median income and percentage of the

[7] Manufacturing industries in our sample account for 49.5% of NASA spending. Non-manufacturing industries account for the remaining share. Examples of these excluded industries include General Building Contractors, Computer Services, Architecture and Engineering Services, Nonprofit Scientific Research Agencies, R&D Laboratories, Telephone Communication, etc. (Orr and Jones, 1969).

population with a college degree from this data.

The last measure we collect is the percentage of the manufacturing work force who are research scientists. During the cold war the Federal Government collects a roster of scientists intended to cover the universe of all scientists who are members of professions scientific associations (i.e. American Chemical Society, American Statistical Association, etc.). We use this data to obtain MSA-level measures of the fraction of scientists in an MSA in 1960.

Descriptive Statistics. Table 1 provides a first look at how firms that would later receive NASA grants differed in 1958. We report 1958 statistics for the full sample and then stratify based on whether a firm receives NASA contract or not. We can see that the two kinds of firms are quite different. Space firms tend to be larger in sales and employment, less capital intensive, more research intensive, but less patent intensive. These notable differences highlight the importance of looking at within firm variation and controlling for time invariant characteristics in our analysis.

In Table 2 we look the differences between space places in 1958, before the Space Race had begun. Again we see that these places were significantly different. Manufacturing census data reveal that wages were higher, employment and capital per worker larger in space places. In panel B we see that the industry mix was also different, with space places have more worker conducting routine tasks and much higher information technology utilization. The demographic and locational characteristics also differed, with space places having higher median income, house vales, a larger fraction of the work force college graduates and more scientists. These contrasts demonstrate the importance of identifying our estimates of interest based on within-MSA variation. They also indicate that controlling for trends in outcomes that could be related to initial characteristics is worthwhile.

5 Results

Space Firms. We first examine how the surge in NASA spending during the Space Race affected firms that received the contracts. The year-by-year Space Firm dummy variables from estimating equation (1) with log(Employment) as the outcome variable are plotted on the thick red line in Figure 1. We can see before the Space Race (1955-1959) employment trended similarly in firms space and non-space firms. At the peak of the Space Race the employment is around 40% higher in Space Firm reflecting the surge in employment required to meet NASA contracts. After the Space Race is over Space Firms continue to employ more workers, perhaps due to productive expertise learned during the Space Race.

Looking at space firm differentials for Total Factor Productivity in Figure 2 we see little significant increase during the Space Race period. If anything, the point estimates suggest TFP may have fell during the peak of the Space Race. These patterns persist, with little indication of a large increase in TFP for Space Firms after the space race ends.

The capital per worker effects in Table 3 are more significant. Here we see that there was little differential trend in capital per worker between Space and Non-Space firms before the space race. When the Space Race takes off however, capital per worker increases. The increase in capital per worker – by over 30% during the Space Race – appears both statistically and economically significant. This results indicate that Space Firms changed their technology to a production process that reduced labor intensity.

We present summary measures of these dynamic effects in Table 3. The results of estimating equation (2) where the years during and after the space race are pooled generally echo those in the more flexible figures. In Table 3 we see that the Space Race led significantly expanded employment during and after the Space Race. We also see that the Space Race had a legacy of increasing TFP and capital per worker after the Space Race ended.

In sum then the Space Race expanded employment in the Space sector. It also lead space firms to change their technology to reduce labor intensity and resulted in an increase in TFP.

Space Places. We turn next to examining how other firms colocated with Space firms were affected by the Space Race. Our Space Place results are depicted visually in Figures 4 to 7. Starting with employment in Figure 3 we see that before the Space Race (1947 and 1954) employment was trending similarly in Space Places and Non-Space Places. Five years after the Space Race began we see an employment differential open up in 1963. The employment differential remains during the Space Race era and if anything grows after the end of the space. The magnitude of our estimates indicates the change in employment during the space race was economically significant, as colocated producers reduce employment by around 20% during the Space Race.

The employment results may indicate that the Space Race reduced labor demand. However, if workers face migration costs leading labor markets to not be spatially integrated the employment results could reflect reallocation of workers towards space sectors and away from other sectors. To see how to interpret these results we look at wages. If workers are simply reallocating in response to a local labor demand shock we would expect non-space firms to be need to pay higher wages.

The results in Figure 5 indicate little evidence of a positive wage effect of the Space Race. If anything wages appear to fall. While the negative point estimates in 1947 suggest caution in this wage reduction interpretation, there is little evidence of an increase in wages. Taken together the employment and wage estimates provide strong evidence for the space race reducing labor demand.

What accounts for this shift? As we noted above space race spending may have two effects on technology. First, it may shift out the production possibility frontier, increasing total factor productivity. Second, it may also result in capital biased technological change, resulting in reduced labor intensity of production. If the shift in TFP is small and but the shift in capital intensity is larger labor demand may fall.

Our space firm results above indicate a small shift in TFP and a much larger shift in capital intensity. Do we see a similar pattern for non-space firms that are right next door to them? In Figures 6 and 7 the point estimates indicate an insignificant Space Race effect on TFP, but a meaningful increase in capital intensity. The fact that these shifts are similar to those experienced by Space Firms certainly suggests that technology was transferred by colocation.

We summarize the labor market results in Table 4. The results in columns (1) and (3) echo those in the figure. Proximity to space firms led employment to fall significantly, with a decrease that persists to the present day. Similarly, wages also appear to drop with proximity to space firms, through the estimates are smaller and less persistent. When we look at only firms in non-space sectors, so that we are just capturing the external effects of space sector activity, we see similar patterns with larger point estimates. Importantly all the models control for flexible industry time trends, so national trends in industry employment do not contribute to identification of these effects.

The local external technology effects of space sector activity are summarized in Table 5. Again the results largely echo those in Figures 5 and 6. The capital per worker effects are positive, reflecting a reduction in the labor intensity of production. The external TFP effects of space activity appear negative. This could reflect adjustment costs to the adoption of new information technology or perhaps a reduction in markup in sectors that compete with the space sector. In any case there is little evidence of a positive external effect of the space sector on total factor productivity.

Heterogeneity. We next examine whether there is any evidence that the effects are heterogeneous. We first examine how the effects depend on the MSA characteristics in Table 6. Each panel of the the table presents estimates of model (2) for the dependent variable and sample indicated. The results in the first two panels show that the labor market estimates are very consistent across cities with different income, house price or skill levels. Similarly, the TFP point estimates in panel C are also very similar. The possible exception here is in columns (7) and (8) where the point estimates are positive in cities with research scientists.

In panel D of Table 6 we see that generally the space sector activity are on labor intensity are quite similar across cities. The exception is in columns (5) and (7) where we see notably larger effects when the skill level is low. This could be consistent with these new IT capital the Space Sector transferred being particularly substitutable with lower skilled workers.

How do the effects differ by industry? We examine this in Table 7. Again in Panels A and B we see very similar labor market effects across industries. This pattern is born out in the technology effects in panels C and D. Indeed the point estimates are nearly identical between industries that initially have differing capital per worker, TFP, IT intensity and routine task shares.

Recent work has demonstrated that agglomeration economies can be heterogeneous, with sectors more closely related experiencing larger knowledge spillovers (Greenstone, Hornbeck and Moretti 2010; Kantor and Whalley 2014). Do we see similar effects here? In Table 8 we examine where effects differ based on how technologically close an industry is to the Space sector. We consider four measures of technological proximity: labor market pooling (where workers transition between industries), using Space Sector inputs in production, selling output to the Space Sector, and whether an industry typically co-locates with the Space Sector.

Table 8 reveals some surprising results. In panels A and B we find larger labor market effects in columns (1), (3), (5) and (7), where industries are technologically distant from the Space Sector. While we find similar TFP effects across sectors, our capital intensity effects are all larger in sectors that are technologically distant from the Space Sector. These results may indicate that the IT technology utilized by the space sector is general purpose rather than for only similar firms. Further work is needed to better understand these results.

6 Conclusion

In this paper we study how frontier information technology intensive technology affects the demand for labor. To do so we study the expansion of the space sector during the Space Race. Our first set of results show that the space race led firms to increase employment, but reduce labor intensity, with little effect on total factor productivity.

We then ask how labor demand in other firms in the same city were affected by the space sector expansion. We find that the space race reduced employment in local non-space manufacturing sectors. That wages in non-space sectors did not increase indicates that labor demand in fact fell.

What explains this shift in local labor demand for non-space firms? We find little evidence that total factor productivity is increases in response to space race proximity. Labor intensity does drop, consistent with cities spreading capital-biased technological change.

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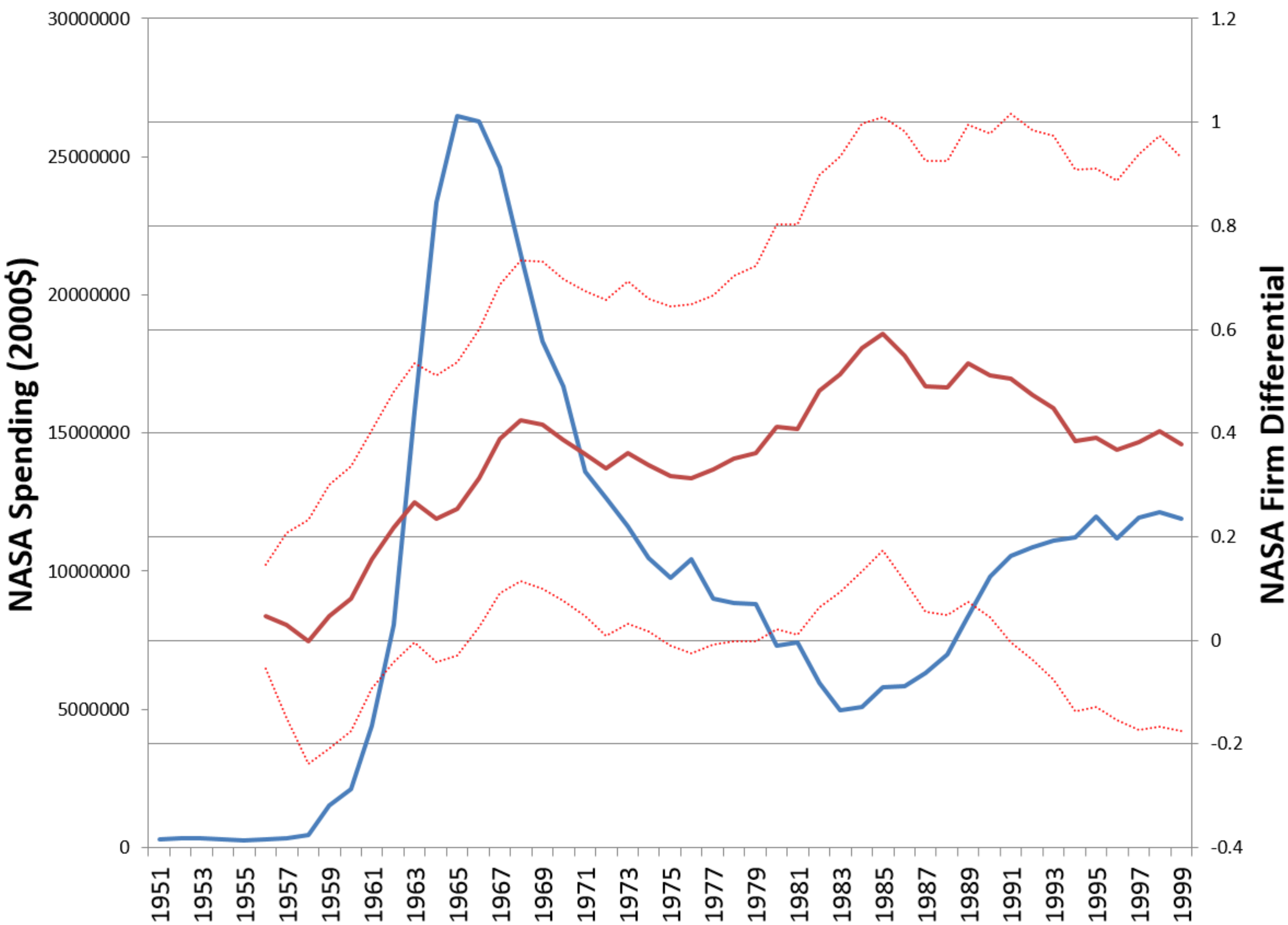
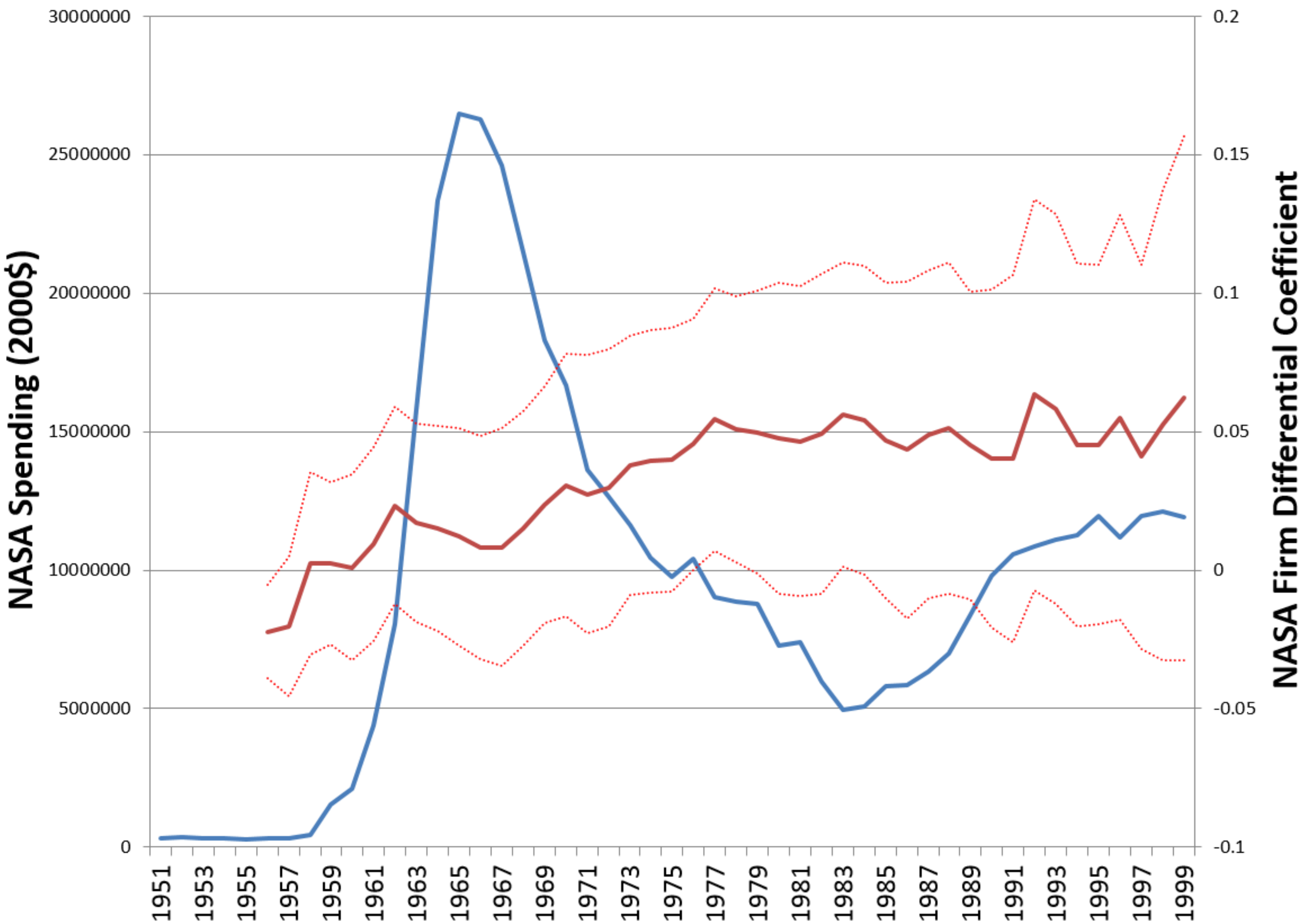
Figure 1: Log(Employment) – NASA Firms Differentials



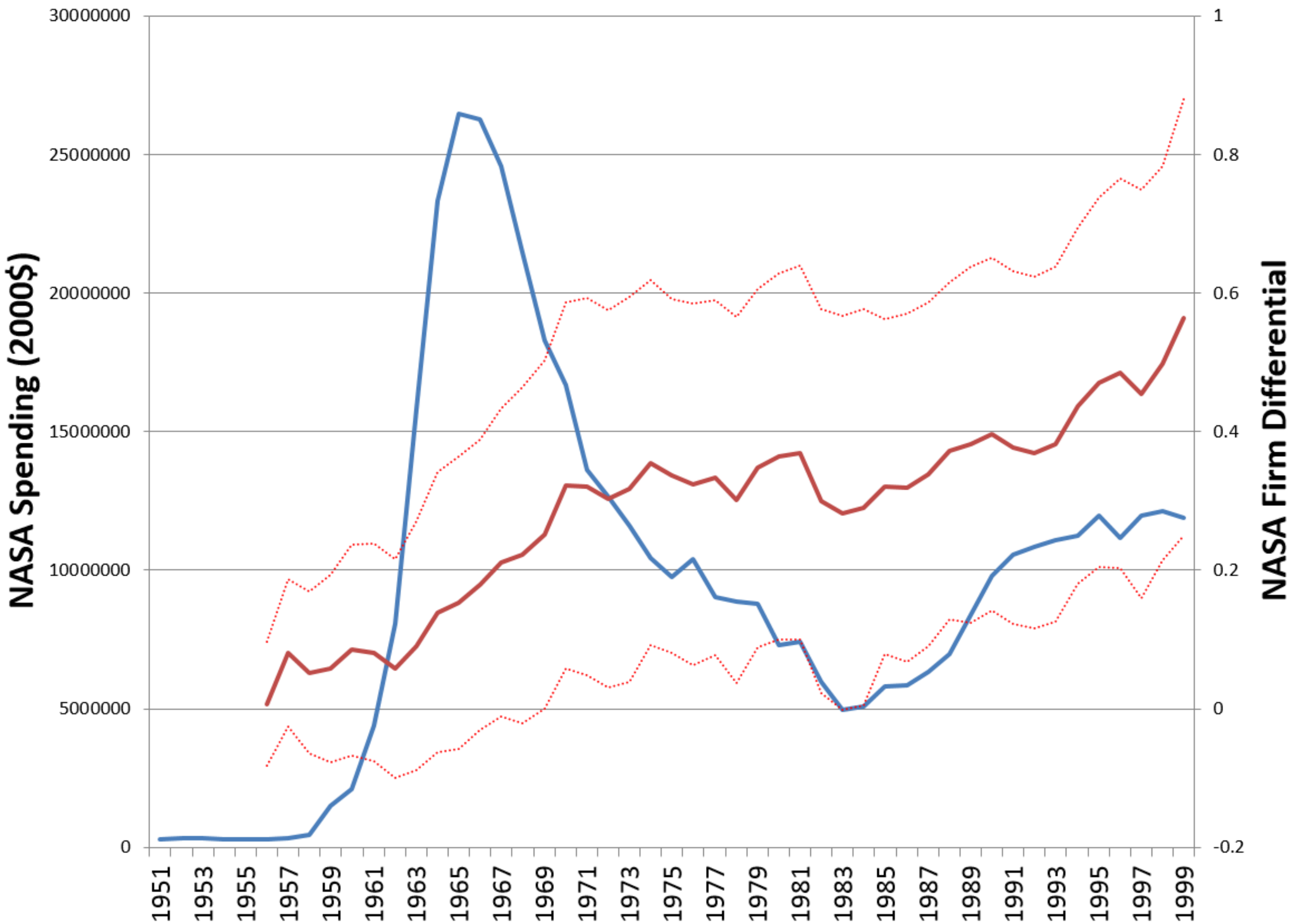
Notes: Authors' calculations with Compustat and NASA data. The solid blue line depicts the total federal NASA spending on space projects in 2000$. The solid red line depicts the year-by-year coefficient estimates from fitting equation (1) in the text. The dotted redlines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

Figure 2: Log(TFP) – NASA Firms Differentials



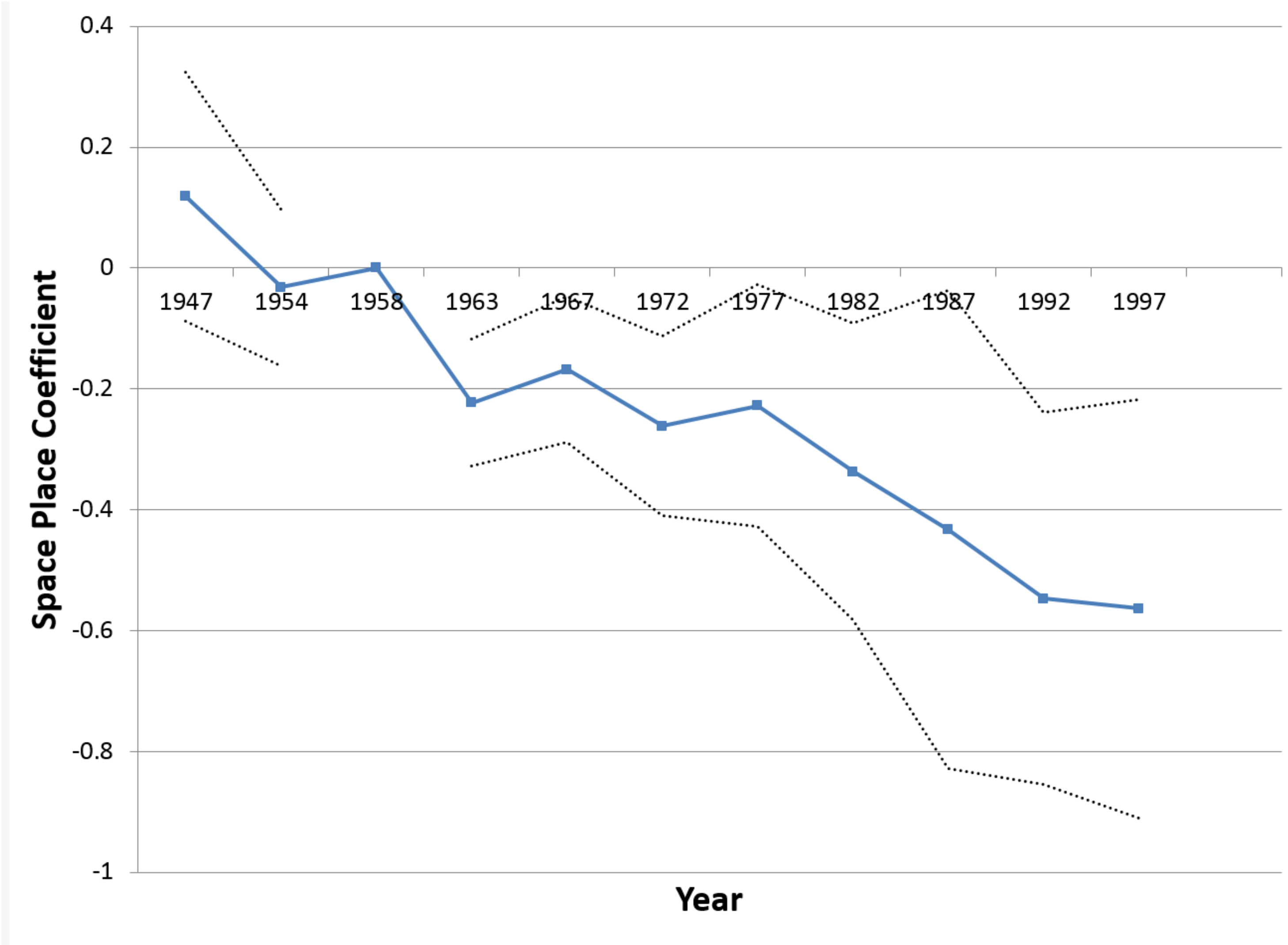
Notes: Authors' calculations with Compustat and NASA data. The solid blue line depicts the total federal NASA spending on space projects in 2000$. The solid red line depicts the year-by-year coefficient estimates from fitting equation (1) in the text. The dotted redlines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

Figure 3: Log(Capital Per Worker) – NASA Firms Differential



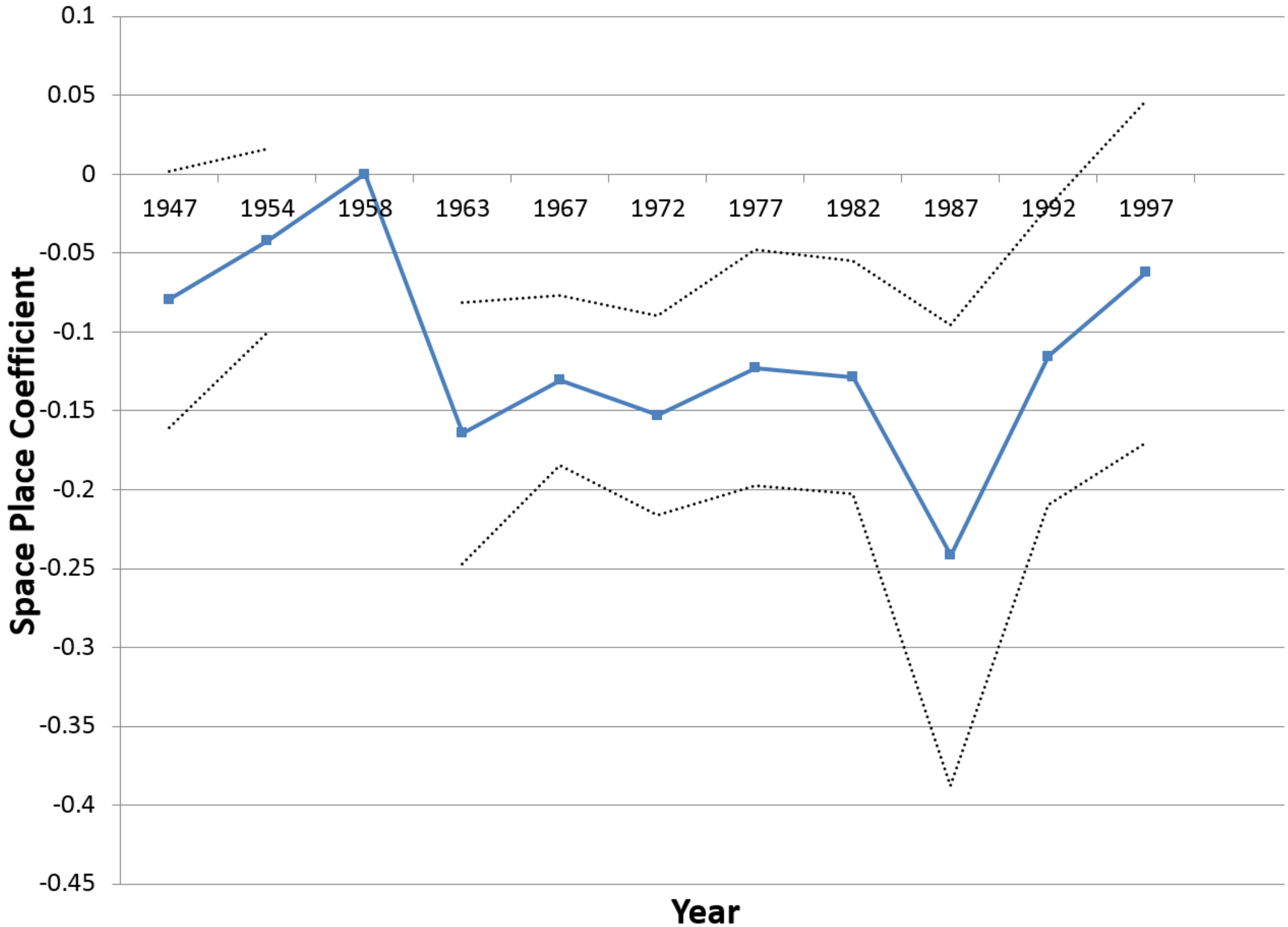
Notes: Authors' calculations with Compustat and NASA data. The solid blue line depicts the total federal NASA spending on space projects in 2000$. The solid red line depicts the year-by-year coefficient estimates from fitting equation (1) in the text. The dotted redlines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

Figure 4: Log(Employment) – NASA Place Differentials



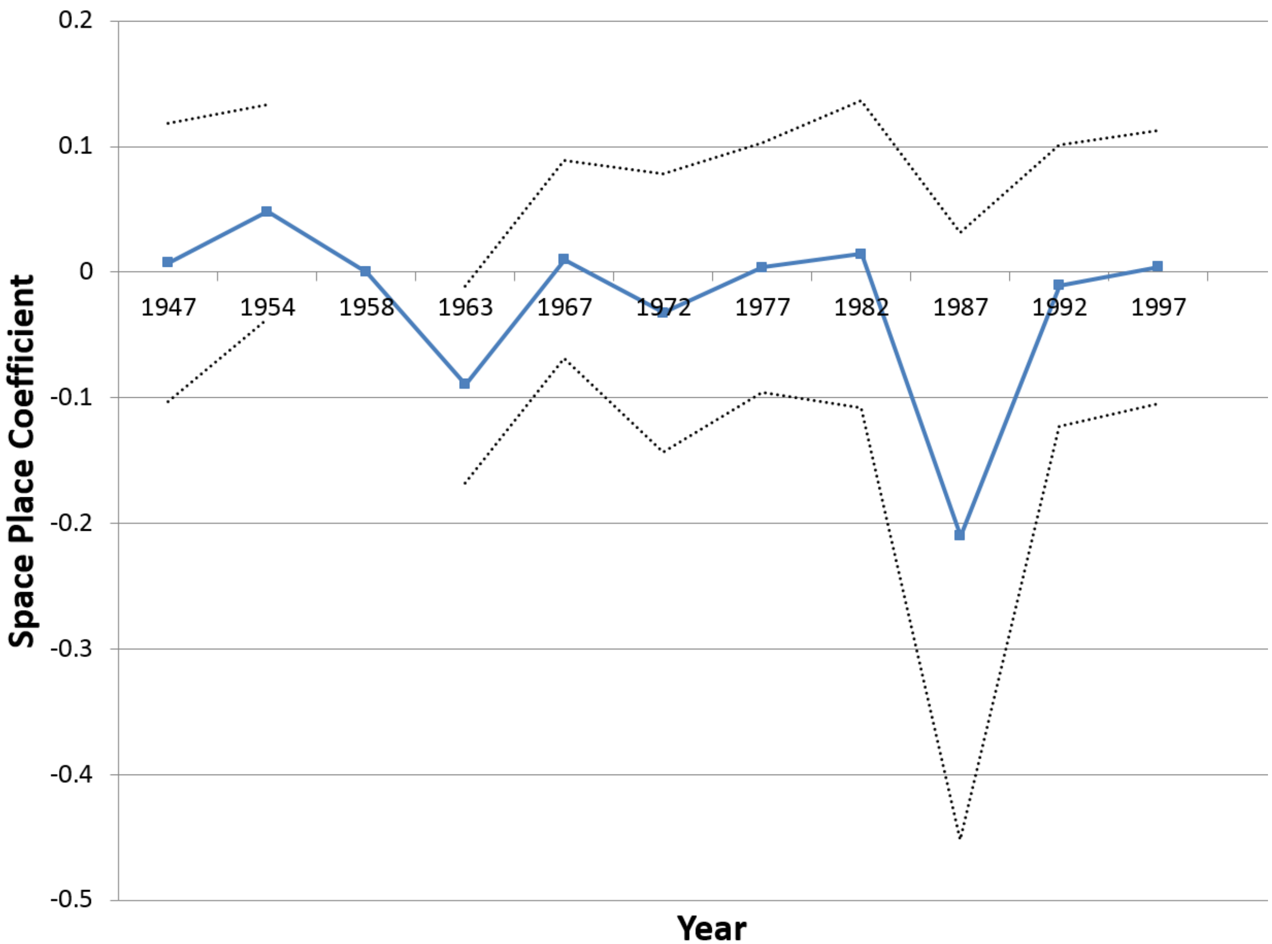
Notes: Authors' calculations with Manufacturing Census and NASA data. The solid blue line depicts the year-by-year coefficient estimates from fitting equation (2) in the text. The dotted black lines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

Figure 5: Log(Average Annual Wages) – NASA Place Differentials



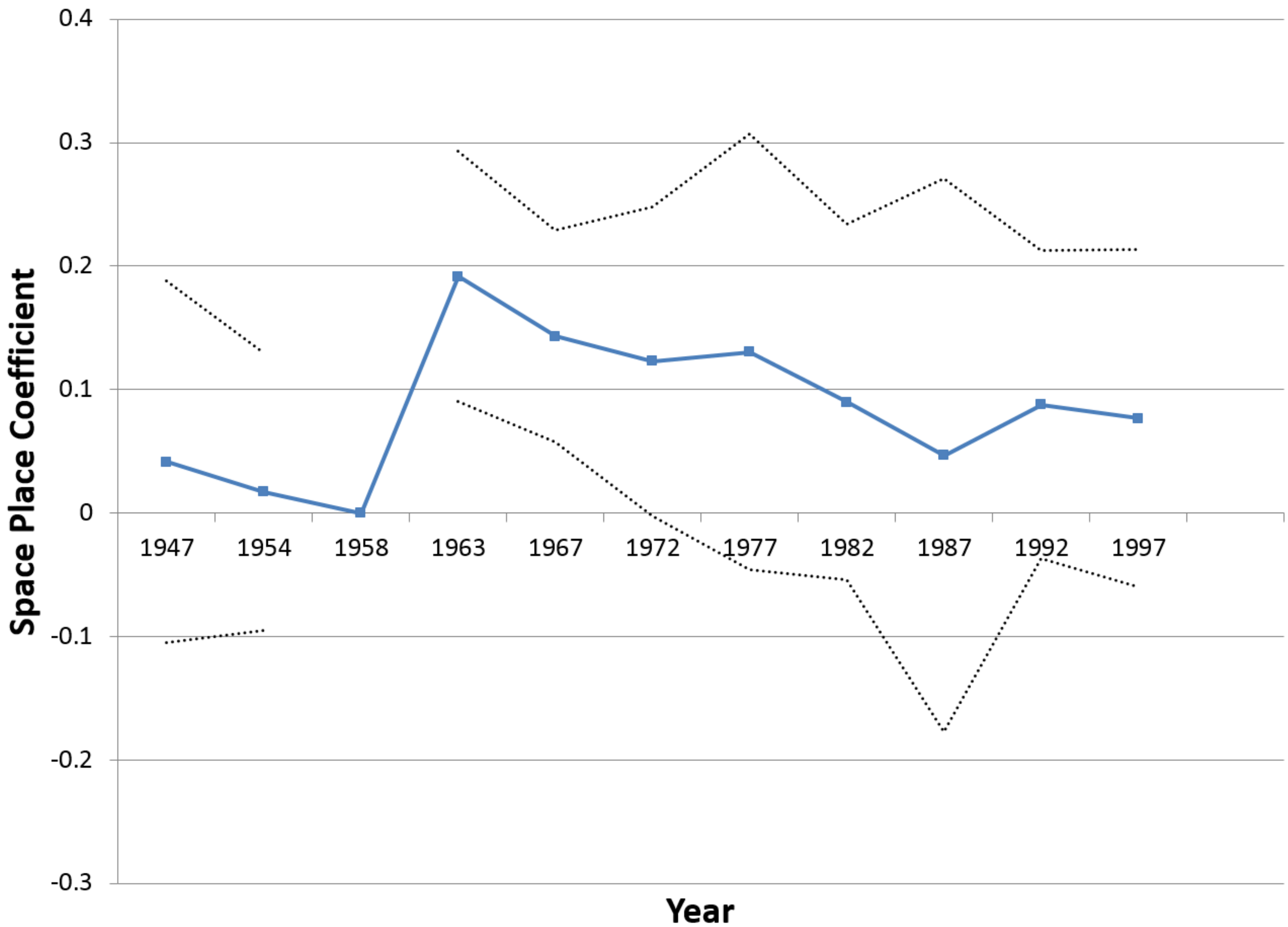
Notes: Authors' calculations with Manufacturing Census and NASA data. The solid blue line depicts the year-by-year coefficient estimates from fitting equation (2) in the text. The dotted black lines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

Figure 6: Log(TFP) – NASA Place Differentials



Notes: Authors' calculations with Manufacturing Census and NASA data. The solid blue line depicts the year-by-year coefficient estimates from fitting equation (2) in the text. The dotted black lines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

Figure 7: Log(Capital Per Worker) – NASA Place Differentials



Notes: Authors' calculations with Manufacturing Census and NASA data. The solid blue line depicts the year-by-year coefficient estimates from fitting equation (2) in the text. The dotted black lines depicts the 95% confidence interval for the coefficient estimates. The right axis presents the units for these coefficient estimates.

TABLE 1: Descriptive Statistics: Firms, 1958

		NASA Contract:		Difference
Sample=	Full	Yes	No	(2)-(3)
	(1)	(2)	(3)	(4)
Manufacturing (Firm Level 1958):				
Total Sales	289	651	242	0.000
	(735)	(1500)	(568)	
Employment	14,676	39,756	11,410	0.000
	(35,920)	(80,636)	(23,108)	
Capital Per Worker	0.81	0.38	0.86	0.012
	(1.29)	(0.42)	(1.35)	
Research Expenditure Per Sales	0.03	0.07	0.02	0.001
	(0.09)	(0.20)	(0.06)	
Patents Per Sales	0.42	0.24	0.44	0.868
	(7.99)	(1.66)	(8.48)	
n=	434	50	384	

Notes: Source authors' calculations with Compustat data. The unit of observation is a firm. Column (1) presents the mean of the indicated variable with the standard deviation in parentheses for the full sample. The main entries in column (2) presents the mean of the indicated variable with the standard deviation in parentheses for the sample of firms that receive a NASA contract between 1963 and 1978. The main entries in column (3) presents the mean of the indicated variable with the standard deviation in parentheses for the sample of firms that receive a NASA contract between 1963 and 1978. The entries in column (4) are p-values for the test of different means between columns (2) and (3).

TABLE 2: Descriptive Statistics: NASA Metro Areas, 1960

		NASA Sector 1958 Share:		Difference
Sample=	Full	High	Low	(2)-(3)
	(1)	(2)	(3)	(4)
Panel A: NASA Industry-MSAs (MSA-Industry Level 1958)				
Average Annual Wage (1958 $)	7,144	8,010	6,317	0.000
	(4,130)	(4,726)	(3,262)	
Employment	3,836	6,096	1,676	0.000
	(5,822)	(7,500)	(5,124)	
Log(Total Factor Productivity)	-0.65	-0.68	-0.63	0.008
	(0.36)	(0.35)	(0.38)	
Capital Per Worker	5.01	5.42	4.62	0.002
	(4.39)	(5.11)	(3.53)	
n=	1,203	588	615	
Panel B: NASA Industries (MSA-Industry Level 1958)				
Routine Task Employment Share (1960)	0.30	0.34	0.28	0.000
	(0.12)	(0.08)	(0.12)	
Information Technology Capital Share ×1000	2.83	7.39	0.45	0.000
	(5.81)	(7.50)	(2.35)	
Panel C:NASA Places (MSA-Level 1960)				
Total Population	1,223,953	2,657,306	594,677	0.000
	(1,664,941)	(2,464,778)	(327,254)	
Median Household Income (1960 $)	6,132	6,611	5,922	0.000
	(718)	(629)	(656)	
Average House Value (1960 $)	12,507	14,144	11,789	0.001
	(2,465)	(2,557)	(2,373)	
Fraction College Graduate	0.08	0.09	0.08	0.093
	(0.02)	(0.03)	(0.02)	
Research Scientists Manufacturing Employment	4.02	6.97	2.50	0.000
(1960) ×1000	(12.42)	(16.35)	(9.48)	
n=	59	18	41	

Notes: Source authors' calculations with Manufacturing Census, Population Census, Bureau of Economic Analysis, National Register of Scientists and NASA data. The unit of observation is a industry-MSA. Column (1) presents the mean of the indicated variable with the standard deviation in parentheses for the full sample. The main entries in column (2) presents the mean of the indicated variable with the standard deviation in parentheses for the sample of MSAs with an industry receiving NASA funding in 1966. The main entries in column (3) presents the mean of the indicated variable with the standard deviation in parentheses for the sample of MSAs without an industry receiving NASA funding in 1966. The entries in column (4) are p-values for the test of different means between columns (2) and (3).

TABLE 3: Firm NASA Spending – Employment, TFP and Capital-Labor Effects

Dependent Variable=	Log(Employment)	Log(TFP)	Log(Capital Per Worker)
	(1)	(2)	(3)
Any NASA Contract (1963-1978) × Space Race Era	0.25***	0.02	0.10
	(0.08)	(0.01)	(0.07)
Any NASA Contract (1963-1978) × Post Space Race Era	0.39***	0.05**	0.32***
	(0.16)	(0.02)	(0.10)
R^2	0.87	0.99	0.93
Observations	14,902	14,587	14,902
Year Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Year × Defense Industry Fixed Effects	Yes	Yes	Yes

Notes: Source authors' calculations with Compustat and NASA data. The unit of observation is firm-year. Each column presents estimates from equation (NUM) in the text for the dependent variable indicated. The main entries in each column are the coefficient estimates with standard errors clustered at the firm level presented in parentheses. The *Space Race Era* is defined as encompassing the years 1960 – 1969. The *Post Space Race* Era is defined as encompassing the years 1970 – 1999.

TABLE 4: City NASA Spending - Employment and Wage Effects

Dependent Variable=	Log(Employment)		Log(Average Annual Wages)	
	(1)	(2)	(3)	(4)
High NASA Sector 1958 Share ×	-0.16***	-0.21***	-0.10***	-0.09***
Space Race Era	(0.05)	(0.06)	(0.02)	(0.02)
High NASA Sector 1958 Share ×	-0.30***	-0.34***	-0.04	-0.05**
Post Space Race Era	(0.10)	(0.10)	(0.02)	(0.03)
R^2	0.56	0.55	0.90	0.90
Observations	10,181	6,751	10,181	6,751
Year Fixed Effects	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes
Sample Industries	All	Non-NASA	All	Non-NASA

Notes: Source authors' calculations with Manufacturing Census and NASA data. The unit of observation is MSA-Industry-Year. Each column presents estimates from equation (NUM) in the text for the dependent variable indicated. The main entries in each column are the coefficient estimates with standard errors clustered at the firm level presented in parentheses. The *Space Race Era* is defined as encompassing the Manufacturing Census years 1963 and 1967. The *Post Space Race* Era is defined as encompassing the Manufacturing Census years 1972, 1977, 1982, 1987, 1992, and 1997. The sample in columns (1) and (3) are all 3 digit Manufacturing industries. The sample in columns (2) and (4) are 3 digit manufacturing industries that do not receive NASA contracts.

TABLE 5: City NASA Spending - Total Factor Productivity and Capital Per Worker Effects

Dependent Variable=	Log(TFP)		Log(Capital Per Worker)	
	(1)	(2)	(3)	(4)
High NASA Sector 1958 Share ×	-0.06***	-0.07***	0.11***	0.13***
Space Race Era	(0.02)	(0.03)	(0.04)	(0.04)
High NASA Sector 1958 Share ×	-0.06**	-0.08**	0.11**	0.13**
Post Space Race Era	(0.03)	(0.04)	(0.05)	(0.05)
R^2	0.59	0.69	0.64	0.67
Observations	10,064	6,664	10,181	6,751
Year Fixed Effects	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes
Sample Industries	All	Non-NASA	All	Non-NASA

Notes: Source authors' calculations with Manufacturing Census and NASA data. The unit of observation is MSA-Industry-Year. Each column presents estimates from equation (NUM) in the text for the dependent variable indicated. The main entries in each column are the coefficient estimates with standard errors clustered at the firm level presented in parentheses. The *Space Race Era* is defined as encompassing the Manufacturing Census years 1963 and 1967. The *Post Space Race* Era is defined as encompassing the Manufacturing Census years 1972, 1977, 1982, 1987, 1992, and 1997. The sample in columns (1) and (3) are all 3 digit Manufacturing industries. The sample in columns (2) and (4) are 3 digit manufacturing industries that do not receive NASA contracts.

TABLE 6: City NASA Spending Effects: By Industry Characteristics

Stratify by:	Capital Per Worker 1958		TFP 1958		Capital Information Technology Share 1958		Routine Task Occupation Share 1960	
Category:	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: *Dependent Variable* = Log(Employment)							
High NASA Sector 1958 Share ×	-0.19***	-0.19***	-0.23***	-0.18***	-0.19***	-0.18***	-0.16**	-0.20**
Space Race Era	(0.07)	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)	(0.08)	(0.07)
High NASA Sector 1958 Share ×	-0.28**	-0.30***	-0.32**	-0.33***	-0.28**	-0.37***	-0.27**	-0.34***
Post Space Race Era	(0.11)	(0.11)	(0.12)	(0.10)	(0.11)	(0.10)	(0.12)	(0.10)
Observations	3,081	3,369	3,045	3,405	4,462	2,289	2,710	2,640
	Panel B: *Dependent Variable* = Log(Average Annual Wages)							
High NASA Sector 1958 Share ×	-0.10***	-0.10***	-0.12***	-0.07**	-0.11***	0.01	-0.09***	-0.13***
Space Race Era	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.03)
High NASA Sector 1958 Share ×	-0.09***	-0.01	-0.07*	-0.02	-0.06*	0.07**	-0.06	-0.04
Post Space Race Era	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)
Observations	3,081	3,369	3,045	3,405	4,462	2,289	2,710	2,640
	Panel C: *Dependent Variable* = Log(TFP)							
High NASA Sector 1958 Share ×	-0.06	-0.11***	-0.12***	-0.08**	-0.05*	-0.01	-0.07*	-0.04
Space Race Era	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)
High NASA Sector 1958 Share ×	-0.04	-0.12***	-0.18***	-0.09**	-0.03	-0.07	-0.10	-0.02
Post Space Race Era	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.07)	(0.06)	(0.05)
Observations	3,020	3,352	3,022	3,350	4,382	2,282	2,669	2,625
	Panel D: *Dependent Variable* = Log(Capital Per Worker)							
High NASA Sector 1958 Share ×	0.09*	0.21***	0.20***	0.13***	0.15***	0.06	0.10	0.16***
Space Race Era	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.06)	(0.06)
High NASA Sector 1958 Share ×	0.15***	0.14**	0.14*	0.25***	0.10	0.16**	0.11	0.10**
Post Space Race Era	(0.06)	(0.06)	(0.08)	(0.07)	(0.06)	(0.07)	(0.07)	(0.05)
Observations	3,081	3,369	3,045	3,405	4,462	2,289	2,710	2,640
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Source authors' calculations with Manufacturing Census and NASA data. The unit of observation is MSA-Industry-Year. Each column presents estimates from equation (NUM) in the text for the dependent variable indicated. The main entries in each column are the coefficient estimates with standard errors clustered at the firm level presented in parentheses. The *Space Race Era* is defined as encompassing the Manufacturing Census years 1963 and 1967. The *Post Space Race* Era is defined as encompassing the Manufacturing Census years 1972, 1977, 1982, 1987, 1992, and 1997. The sample is 3 digit manufacturing industries that do not receive NASA contracts, for the stratification indicated. The low stratification category is for the observations that are below median for the stratification variable indicated. The high stratification category contains the observations at or above the median for the stratification variable indicated.

TABLE 7: City NASA Spending Effects: By Industry-NASA Linkages

Stratify by:	Labor Market Pooling with NASA Sectors		Industry NASA Input Share		Industry NASA Output Share		Colocation With NASA Sectors	
Category:	Low	High	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: *Dependent Variable* = Log(Employment)								
High NASA Sector 1958 Share ×	-0.27***	-0.16***	-0.48***	-0.11	-0.36***	-0.21***	-0.27***	-0.13**
Space Race	(0.06)	(0.06)	(0.12)	(0.07)	(0.16)	(0.06)	(0.07)	(0.05)
High NASA Sector 1958 Share ×	-0.27**	-0.34***	-0.41***	-0.29***	-0.41***	-0.33***	-0.30**	-0.32***
Post Space Race	(0.13)	(0.09)	(0.14)	(0.13)	(0.20)	(0.11)	(0.12)	(0.10)
Observations	2,436	4,315	1,417	3,060	838	3,639	3,066	3,685
Panel B: *Dependent Variable* = Log(Average Annual Wages)								
High NASA Sector 1958 Share ×	-0.15***	-0.06***	-0.16***	-0.11***	-0.05	-0.17***	-0.10***	-0.08***
Space Race	(0.04)	(0.02)	(0.05)	(0.03)	(0.05)	(0.03)	(0.03)	(0.02)
High NASA Sector 1958 Share ×	-0.10**	-0.01	-0.05	-0.09**	-0.11	-0.12***	-0.05	-0.03
Post Space Race	(0.05)	(0.03)	(0.05)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)
Observations	2,436	4,315	1,417	3,060	838	3,639	3.066	3,685
Panel C: *Dependent Variable* = Log(TFP)								
High NASA Sector 1958 Share ×	-0.06	-0.06*	-0.11*	-0.04	0.05	-0.07*	-0.03	-0.05
Space Race	(0.06)	(0.03)	(0.06)	(0.04)	(0.08)	(0.04)	(0.04)	(0.04)
High NASA Sector 1958 Share ×	-0.03	-0.10**	-0.03	-0.04	0.09	-0.03	0.02	-0.08
Post Space Race	(0.07)	(0.05)	(0.07)	(0.04)	(0.10)	(0.04)	(0.04)	(0.05)
Observations	2,408	4,256	1,395	3,016	836	3,575	3.009	3,655
Panel D: *Dependent Variable* = Log(Capital Per Worker)								
High NASA Sector 1958 Share ×	0.16**	0.09**	0.17*	0.15***	-0.06	0.19***	0.16**	0.07
Space Race	(0.07)	(0.04)	(0.10)	(0.06)	(0.15)	(0.05)	(0.07)	(0.05)
High NASA Sector 1958 Share ×	-0.04	0.24***	0.11	0.11	0.02	0.09	0.10	0.12*
Post Space Race	(0.09)	(0.05)	(0.10)	(0.08)	(0.15)	(0.07)	(0.07)	(0.06)
Observations	2,436	4,315	1,417	3,060	838	3,639	3,066	3,685
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Source authors' calculations with Manufacturing Census, BEA and NASA data. The unit of observation is MSA-Industry-Year. Each column presents estimates from equation (NUM) in the text for the dependent variable indicated. The main entries in each column are the coefficient estimates with standard errors clustered at the firm level presented in parentheses. The *Space Race Era* is defined as encompassing the Manufacturing Census years 1963 and 1967. The *Post Space Race* Era is defined as encompassing the Manufacturing Census years 1972, 1977, 1982, 1987, 1992, and 1997. The sample is 3 digit manufacturing industries that do not receive NASA contracts, for the stratification indicated. The low stratification category is for the observations that are below median for the stratification variable indicated. The high stratification category contains the observations at or above the median for the stratification variable indicated.

Table 8: City NASA Spending Effects, By MSA Characteristics

Stratify by:	Median Per Capita Income 1960		Average House Value 1960		Percentage College Graduate 1960		Percentage Scientist 1960	
Category:	Low (1)	High (2)	Low (3)	High (4)	Low (5)	High (6)	Low (7)	High (8)
Panel A: *Dependent Variable* = Log(Employment)								
High NASA Sector 1958 Share ×	-0.16**	-0.27***	-0.21**	-0.21**	-0.25***	-0.15*	-0.23***	-0.11
Space Race	(0.08)	(0.08)	(0.09)	(0.10)	(0.07)	(0.08)	(0.05)	(0.13)
High NASA Sector 1958 Share ×	-0.28*	-0.29**	-0.21	-0.25	-0.30***	-0.36**	-0.34***	-0.16
Post Space Race	(0.16)	(0.14)	(0.21)	(0.17)	(0.10)	(0.15)	(0.09)	(0.20)
Observations	3,494	3,257	3,431	3,320	3,437	3,314	5,875	778
Panel B: *Dependent Variable* = Log(Average Annual Wages)								
High NASA Sector 1958 Share ×	-0.06*	-0.10***	-0.08**	-0.06*	-0.09**	-0.08**	-0.08***	-0.16**
Space Race	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.02)	(0.06)
High NASA Sector 1958 Share ×	-0.05	0.00	-0.04	0.02	-0.05	-0.04	-0.03	-0.14**
Post Space Race	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.03)	(0.06)
Observations	3,494	3,257	3,431	3,320	3,437	3,314	5,875	778
Panel C: *Dependent Variable* = Log(TFP)								
High NASA Sector 1958 Share ×	-0.08*	-0.04	-0.09	-0.03	-0.10**	-0.04	-0.09***	0.10
Space Race	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)	(0.04)	(0.03)	(0.09)
High NASA Sector 1958 Share ×	-0.12**	-0.02	-0.14***	0.02	-0.10*	-0.07	-0.10**	0.04
Post Space Race	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.10)
Observations	3,438	3,226	3,371	3,293	3,381	3,238	5,798	775
Panel D: *Dependent Variable* = Log(Capital Per Worker)								
High NASA Sector 1958 Share ×	0.09	0.17**	0.06	0.14	0.17***	0.08	0.15***	-0.05
Space Race	(0.06)	(0.07)	(0.10)	(0.09)	(0.05)	(0.07)	(0.04)	(0.13)
High NASA Sector 1958 Share ×	0.11	0.14*	0.11	0.10	0.16**	0.10	0.15***	-0.07
Post Space Race	(0.09)	(0.08)	(0.12)	(0.10)	(0.06)	(0.08)	(0.05)	(0.16)
Observations	3,494	3,257	3,431	3,320	3,437	3,314	5,875	778
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MSA Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Source authors' calculations with Manufacturing Census, Population Census and NASA data. The unit of observation is MSA-Industry-Year. Each column presents estimates from equation (NUM) in the text for the dependent variable indicated. The main entries in each column are the coefficient estimates with standard errors clustered at the firm level presented in parentheses. The *Space Race Era* is defined as encompassing the Manufacturing Census years 1963 and 1967. The *Post Space Race* Era is defined as encompassing the Manufacturing Census years 1972, 1977, 1982, 1987, 1992, and 1997. The sample is 3 digit manufacturing industries that do not receive NASA contracts, for the stratification indicated. The low stratification category is for the observations that are below median for the stratification variable indicated. The high stratification category contains the observations at or above the median for the stratification variable indicated.