STATE-DIRECTED DIFFUSION OF TECHNOLOGY: 
THE MECHANIZATION OF COTTON-HARVESTING 
IN SOVIET CENTRAL ASIA

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ABSTRACT

Mechanization of cotton harvesting began in earnest in the Soviet Union in 1958 and was expected to proceed more rapidly than the market-driven process which had begun in the USA a decade earlier. Despite high output of cotton-picking machines, the share of the crop harvested mechanically grew more slowly than in the USA. Mechanical picking was resisted at the farm level on the basis of distorted prices and incentives, but after the end of central planning mechanization also appeared unprofitable at market-based prices in the labor-abundant Central Asian economies. Thus, planners could enforce introduction of the new technology, but the investment in cotton harvesting machines was largely a waste of resources. The costs of premature introduction waste are estimated at over one billion US dollars in 1960s prices.

JEL Classifications: O33, N55, O13, P32, Q16

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State-directed diffusion of technology:
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The relative merit of market-based and state-directed approaches is a recurring theme in the literature on the diffusion of new technology. This paper addresses the issue in the context of technology embodied in a machine, the mechanical cotton harvester. It contrasts the market-driven diffusion process in the USA with the state-directed diffusion in the USSR.

In market economies the speed of diffusion depends on the technical characteristics of the machine (including improvements and variations on the basic design), relative factor prices, and in some cases scale effects due to indivisibilities or complementarities.\(^1\) Competition can be effective in prompting continuous improvements, inducing institutional innovation to overcome obstacles to diffusion, and filling missing markets. Competition may, however, lead to inefficient use of resources, pursuing too many alternative technological variants or having too many models produced in sub-optimally scaled factories. Public policy may be superior to market forces in setting standards and providing other public goods such as secure intellectual property rights. If indivisibilities matter, the state can encourage small producers to consolidate into supra-threshold units or can organize shared use of machines. In the USSR the state played all of these roles, consolidating both production of the capital equipment and potential adopters of the new technology.

Technical problems in developing economical cotton harvesting machines were overcome in the 1930s and 1940s. The mechanically picked share of the cotton harvest in the USA increased in a classic S-shaped diffusion pattern between 1949 and the late 1960s, starting in high wage California and occurring later in low-wage areas of the southeastern USA, especially the less geographically suited coastal areas of South Carolina (Musoke and Olmstead, 1982; Grove, 1997). By the end of the 1960s, 96% of the US cotton crop was being harvested mechanically (Whatley, 1991, 199). Mechanization of the Soviet cotton harvest got seriously under way about a decade later than in the USA, but with the government giving high priority to the process after 1958 it was expected that the centrally-planned diffusion would be rapid.\(^2\)

The outcome was, however, not a steep diffusion path to more or less complete mechanization. The Soviet diffusion path was flatter than that in the USA, and even turned down after 1981 (Figure 1). Three quarters of the cotton crop was mechanically harvested by 1959 in California, by 1962 in Texas, by 1965 in Mississippi and by 1968 in South Carolina (Musoke and Olmstead, 1982, 405-6), but no major cotton-producing Soviet republic ever reached this share.\(^3\) Despite rapid build-up of machine production in the early 1960s to a peak

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\(^1\) Rosenberg (1982) emphasizes the importance of technical improvements (the D in R&D) and of informational gaps and interdependencies. Griliches (1957) is the classic account of the S-shaped diffusion path of new technology. The threshold model (David, 1966) introduces indivisibilities, and combined with the size distribution of potential adopters generates an S-shaped diffusion path (Pomfret, 1976). Initially applied to the diffusion of mechanical reapers and later to tractor adoption (eg. Ankli, 1980; Lew, 2000), the threshold model has been criticized by Olmstead (1975; 1979; 1995). Musoke (1981) and Whatley (1985) analyse the diffusion of tractors among US cotton farmers.

\(^2\) Priority was given to replacement of back-breaking work by modern machines in part because it provided good publicity when, at the peak of Soviet prestige in the Third World, Soviet Central Asia was held up as a model, contrasted to southern neighbors both in the satisfaction of basic needs and in economic dynamism. Western economists also accepted this image; Nove and Newth (1966), Conolly (1967, 55-241) and Wilber (1969).

\(^3\) The minor exception was Kazakhstan, where the reported share of the harvest picked by machine exceeded
in 1965 and an increasing share of machine-harvested cotton in the 1960s and 1970s, machine use was below capacity from the start and by the 1980s the share of machine-picked cotton was declining in the Soviet Union.

How to explain this phenomenon? A picture is often painted of bungling politicians and planners failing to maintain production of mechanical harvesters or of complementary inputs, or failing to appreciate the importance of model variations to suit differing conditions or of repair and maintenance services. Some authors even see a plot to delay diffusion in order to keep Central Asian peasants on the land and prevent the social disruption associated with rural-urban migration. In this view, the state-directed approach was not itself at fault, but rather poor implementation by planners or political leaders explains the slow and incomplete diffusion. This paper argues that the source of failure to mechanize was exactly the opposite, i.e. at the level of the users rather than the planners. The authorities were pushing for too rapid diffusion, and by the 1980s they failed to maintain even the diffusion levels achieved in the 1960s and 1970s due to farm-level resistance.

How do we know that intended diffusion was too rapid? One sign is that when the Soviet successor states shifted to greater market orientation in the 1990s, there was no recovery from the declining rates of mechanization in the 1980s. Although reliable data on the share of machine-picked cotton in post-Soviet Central Asia are hard to come by, anecdotal evidence and casual observation suggest that hand-picking became more prevalent in the 1990s. By the end of the decade new machine production had collapsed. Another indication of too rapid diffusion is the phenomenon of idle machinery. The value put on cotton-harvesting machines by farmers was very low, and yet real resources went into their manufacture. The self-evident benefits of mechanization seen by central planners ignored the costs, as well as the

75% in 1986 and 1988, although the spikes in 1985 and 1988 look implausible in the long-term context (Table 3). Less than 5% of Soviet land under cotton in the late 1980s was in Kazakhstan (Table 1b).
distribution of costs and benefits at the farm level.

The paper’s next section sets the scene by providing technical background material, and discusses the role of political leaders and central planners at the innovation stage, where some of the USSR’s latecomer advantage in copying technology developed in the USA was dissipated by political intervention. Section 2 discusses arguments that neo-colonial political leaders hampered the diffusion process. The hypothesis that farmers were starved of machines is belied by the machine production data and by evidence of idle machines. Section 3 posits an alternative hypothesis that resistance to mechanization was at the farm level where, for the majority of adult male members of collective farms, the costs exceeded the benefits. Section 4 assesses the outcome in terms of social costs and benefits, and argues that, although the interests of Soviet farmers were determined within the framework of collectivized agriculture, their actions reflected the economic unsuitability of mechanical harvesting in labor-abundant Soviet Central Asia. A lower bound valuation of the resources wasted in premature diffusion is one billion US dollars at 1960s prices. The final section draws some conclusions, emphasising that while public intervention can accelerate the pace of technological diffusion, this may not be a desirable outcome.

1. Politicization, Rigid Central Planning and Innovation.

Cotton harvesting was one of the agricultural processes to be most slowly mechanized even in high-wage countries. Although the first patent had been taken out in 1850 and cotton mechanization was always “just around the corner” (Hon, 1937, 384), general adoption of mechanical cotton pickers only began in California in 1949 and in the southeastern USA in the early 1960s. The problems were both economic and technical.

Despite the labor-intensity of hand-picking, the economic incentive to replace labor by the expensive harvesting machines was insufficient even in high-wage California before the late 1940s. Mechanized picking also had a negative impact on the quantity and quality of cotton harvested. Machines missed some plants and knocked the bolls off others. The machines also compressed the soil, destroying nutrients and reducing future yields. Machine-harvested cotton is moister and contains more impurities than hand-picked cotton, and therefore harder to process, and this led to problems with the processing equipment.

The most important technical deterrent was the need for standardized conditions and for prior removal of weeds and leaves. Machine-picking requires that a high proportion of the bolls ripen at the same time, and before any rain, and at a precise distance from the ground and from other bolls, in a weed-free and leafless space. Strains of cotton with simultaneous ripening had to be developed to avoid the need for multiple passes, which posed little problem to hand pickers but were destructive of the soil with mechanical pickers. Machine picking required flat land, straight ploughed furrows and complementary use of weedkillers and chemical defoliants. In sum, although the labor-saving benefits were large, mechanization required many complementary adjustments by cotton-farmers which added to

4 Strippers, which snapped cotton bolls off at the top of the stalk and failed to distinguish ripe from unripe bolls or trash, were used in Texas and Oklahoma after 1926, but were less efficient than the later cotton pickers which picked only ripened bolls. Production of cotton pickers appears to have begun in 1946, when 107 machines were produced, and by 1951 over 3,500 machines were being produced annually in the USA (Street, 1957, 133).
the cost of displacing hand-pickers. Failure to provide equipment for planing, sufficiently powered tractors, appropriate seeds, herbicides and defoliants all reduce the effectiveness of harvesting machines.

Ever since the Russian conquest of Central Asia in the 1860s, the central government had promoted cotton production through technological borrowing and heavy investment. In the 1870s the first Russian Governor General sent two specialists to Texas to obtain new seed varieties, initiating a half century transition from short staple to long staple cotton. As with the mechanical harvester, US varieties required selection and adaptation to the climatic and topographical conditions of Central Asia, and an experimental station was established in Tashkent. Railway construction reduced transport costs to the textile mills of Russia. Irrigation projects increased the land available for cotton sowing, and here again the Soviet government drew on foreign expertise. Cotton output by 1940 was triple the Tsarist peak, and 1980 output was four and a half times that of 1940 (Table 1a). Almost all of the cotton was grown in Central Asia, with over half of the harvest from the Uzbek republic and most of the remainder from neighboring regions of the Tajik and Turkmen republics.

Soviet policymakers closely followed the development of practical cotton harvesting machinery in the USA. The USSR purchased two of the ten machines built by the Rust Brothers in the USA in 1936 and invited the inventors to the USSR in the same year. The first mass-produced Soviet cotton harvester, a vertical-spindle machine called the SkhM-48, appeared in 1949.

Politicization hampered the refinement and improvement of harvester design during the 1950s. In the early 1950s the big cotton controversies concerned row width and square clusters. The Tajik leadership advocated planting in narrow rows and square clusters to increase cotton yields. The Uzbek leadership and cotton officials in Moscow opposed this “for respectable technical reasons and in order to maintain investment momentum behind new irrigation construction” (Hodnett, 1974, 77 - italics in original). The debate was resolved by Khrushchev in favor of the Tajik position, primarily because the Tajiks were fulfilling their cotton quotas and the Uzbek were not, and because Khrushchev was not keen on more investment in irrigation. Khrushchev also supported the Tajiks in their advocacy of horizontal-spindle machines, and production of the SkhM-48 ceased in 1954. The need to design horizontal-spindle machines from scratch and, even more, the need to cater to 45-50 centimetre rows rather than the traditional 70cm rows, set the machinery industry back several years without any real test of the relative merits of narrow rows or horizontal spindles. In a market economy, there would have been technical competition and in most cases a process of converging on the superior technology. In the Soviet planned economy, the decision was ultimately taken by a poorly-qualified autocrat.

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5 Before the 1860s Central Asia supplied less than ten percent of Russia’s cotton, but by the 1930s the USSR was self-sufficient in cotton and it became an exporter in the 1950s.
6 Arthur Davis, a well-known US irrigation engineer, surveyed the feasibility of irrigating the Goldnaya Steppe in 1913. Fifteen years later his proposal was accepted and in June 1929 Davis went to the USSR, where he was given engineering responsibility for the Central Asian irrigation program. Other US, Japanese and Korean technicians worked on the Central Asian cotton economy, although most left in 1931 (Sutton, 1971, 32-43).
7 Rosenberg (1994, 87-108) identifies the ability to make such economic experiments as a key advantage of capitalism over socialism.
8 Khrushchev’s experience of agriculture was based on grain-farming regions of Ukraine and Russia. He had little sympathy for Central Asian farmers whom he considered lazy and shiftless, and procurement prices for cotton were held back after 1954 because he considered them already too high relative to grain prices. When cotton output failed to meet targets, he blamed the political leaders, and purged the leadership of each cotton-
Once production problems had been resolved in the late 1950s, both Soviet and outside observers expected mechanization to proceed as fast as possible. Annual output increased from a few hundred machines in the late 1950s to 3,200 in 1960 and a peak of 8,000 in 1965 (Table 4a). The central planners favored mass production of a limited range of standardized machines, which was less-suited to the variety of farmers’ needs than it might have been. In particular, even by 1970 no Soviet machines were suited to harvesting some varieties of long-staple cotton grown by a large part of the Turkmen and Tajik cotton sectors (Hodnett, 1974, 78).

These problems of politicization and biases of central planning, however, can only explain slight delays in the timing of the initial large-scale mechanization in the 1950s and some geographical limitations on the spread of mechanical harvesters. They cannot explain the slow diffusion of mechanical harvesting, and the reversal of mechanization after the 1970s.

2. Politicization and Diffusion.

Gleason (1990) provides the most sustained analysis of the lack of progress in mechanization of the Central Asian cotton harvest. He focuses on the labor market effects of mechanization, arguing that it would free the native population from the land and create a potential source of unrest in the towns of the region or in other parts of the USSR as they relocated in search of work. Moreover, shifting the rural/urban balance of Central Asia’s workforce would be associated with inflows of skilled labor from elsewhere in the USSR. Neither politicians in Moscow nor the leadership in the Central Asian republics welcomed these consequences, and in the Brezhnev era they conspired to discourage mechanization in order to forestall its social consequences.9 Gleason (1990, 80) concludes that “Moscow officials failed to order the agricultural machinery industry to produce that which was required for full mechanization”, and he predicted this would change with perestroika when market forces would push farm managers to mechanize in order to cut costs and be competitive.

The idea that cotton farmers were starved of machinery is belied by the production record. The stock of machines continued to increase through the 1980s (Table 4b), even after the share of cotton harvested by machine had begun to decline in every cotton-growing Soviet republic (Table 3). Moreover, from early in the mechanization drive there is evidence of the share of cotton harvested by machine being far below the potential share, given the stock of machines. In the Uzbek republic 2% of cotton was harvested by machine in 1958 and 11% in 1962, even though the stock of machines produced by 1958 should have been sufficient to harvest a third of the Uzbek crop (Hodnett, 1974, 79). In 1977, two International Labour Organization economists visiting five collective farms in the Uzbek and Tajik republics were surprised at how little of the harvest was mechanically picked, even on a showpiece collective which had forty percent more mechanical harvesters per acre than the average for the Uzbek growing republic between December 1958 and May 1961. Under Brezhnev, the political leadership was remarkably stable in Central Asia, and the outcome of the row and spindle debate might have differed.

9 Gleason sees evidence of this complicity in the longevity of Central Asian leaders between 1961 and 1982, when there was only one change in the top official of the five republics. He also sees local farm managers condoning the anti-mechanization strategy, because their influence was related to the number of workers on the farm.
In contrast to the public relations pictures of massed cotton harvesters bringing in the crop, there are frequent references in the less official literature to idle machinery. Over 800 machines were reported idle during the 1970 cotton harvest in the Turkmen republic (Hodnett, 1974, 74), when the stock of machines in the Turkmen republic was 3500 (Table 4b). Craumer (1992, 161) cites a figure of 19% of machines being idle during the 1982 harvest in the Turkmen republic, i.e. around 2000 machines.

The counterpart to unused machines is strong folk memories of masses of people picking cotton by hand in the 1970s and 1980s. Few outside observers made it to rural Central Asia during the cotton harvest, but in 1977 Khan and Ghai (1979, 110n26) “witnessed a great deal of cotton picking by hand”, even though the five farms they visited were showpiece collectives in locations relatively well-suited to mechanization. Visiting Uzbekistan in the 1990s, I came across many people who had picked cotton in the 1970s and 1980s when they were students and, as for Khan and Ghai, their recalled images are of large numbers of people picking cotton by hand. In view of the prevailing pro-modernization ideology, the official data on the share of cotton picked by machine are likely to overstate the actual share, and the diffusion path is likely to have been flatter than that presented in Figure 1.

The idle machines are usually explained by the low priority given to repair shops in Soviet Central Asia, or more generally to central planners’ focus on production and neglect of maintenance and upkeep. Cotton-harvesting machinery is everywhere subject to breakdown and needs constant maintenance. There is, however, a choice. If mechanization were such a dominant technology with huge benefits, then surely local resources would have been devoted to repair. Admittedly, maintaining the machines required skills that were scarce in Central Asia, but over the decades they could have been acquired if farmers wanted to avoid hand-picking of cotton. Central Asian farms chose to leave machines idle, and do not seem to have been too bothered by the fact.

3. The Microeconomics of Mechanization

The explanation for the slow diffusion of cotton harvesters and resistance to mechanical-picking lies in the incentive structure at the farm level. For the farm, mechanization is profitable if the annual cost of a machine (C) is less than the value of the labor saved by mechanization:

\[ C < L_s \cdot w \cdot Q \]

where \( L_s \) = days of labor saved per ton picked, \( w \) = daily labor cost of hand pickers, and \( Q \) = the amount in tons that a machine can harvest in a year. In the Soviet era prices were

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10 The tone of Khan and Ghai’s footnote is clearly one of the “numbers do not add up”. Elsewhere in their report, they refer to being “told that there were technical problems of designing harvesters that would pick high quality cotton without waste” (110, n26). This is a polite excuse rather than an explanation, because such problems are an inherent feature of mechanical cotton harvesters and conditions around Samarkand, where the comment was made, are about as favorable as they can get for mechanical harvesting in Central Asia.

11 Hodnett (1974, 113, n69) compares an Australian cotton farm which he visited in 1971, where four specialized mechanics were employed full-time to look after fifty cotton harvesters, with the situation in Soviet Central Asian where many farms had no repair shop and the provision of centralized repair services was minimal after the 1958 reform of the Machine Tractor Station system.
distorted and the distribution of resources did not depend solely on profitability, but these economic and technological variables still mattered. In this section, I argue that the costs of hand-picking as perceived by collective farm decision-makers were low, and outweighed by C.

Before 1958 mechanization decisions were made by central planners, and the machines were allocated to farms via machine tractor stations (MTS). After the 1958 MTS reform, however, purchase of a machine was a cost to a farm, which would affect the incomes of kolkhoz (collective farm) members. The actual capital costs are difficult to calculate given the soft budget constraint faced by collective farms; C may have been low because debts incurred in their purchase were not enforced, but it is plausible that farm managers perceived their debts to be real. The operating costs (fuel, lubricants, repairs and so forth) were borne by the kolkhoz. Labor inputs for mechanized picking were very low, but there was a trade-off between labor-saving and crop wastage, and wastage was always greater with machine picking than with hand-picking. Mechanization also reduced farm income because of the poorer quality output, for which the producers received lower procurement prices. Thus, C should include the fixed and variable costs plus indirect costs of wastage and lower quality.

The decision-makers clearly saw the labor costs of hand-picking as being sufficiently low relative to the costs of machines that mechanization was resisted despite high values of L_s and Q. In the USA the labor required for cotton harvesting was reduced by 95-98% by mechanization (Street, 1957, 170; Whatley, 1991, 201), depending on climate and other field conditions, and this appears to have been true of Central Asia too. The value of Q also varies by location. In Soviet Central Asia, the degree of resistance to mechanization varied, depending on the technical conditions reflected in L_s and Q; for example, machine design was such that L_s and Q were lower and diffusion was slower in the Tajik republic. Nevertheless, the phenomenon of idle machines suggests a fairly ubiquitous tendency not to consider costs worth incurring in order to bring marginal machines into service.

The labor costs of hand-picking, as seen by kolkhoz decision-makers, were depressed by the varying status of kolkhoz members and by the state’s ability to organize levies of students and urban workers. The main benefit from mechanization, the saving of back-breaking labor, was not shared equally. Despite the mass mobilization at harvest time, many kolkhoz members did not participate. Hodnett cites a figure of 400,000 non-participants in the 1962 harvest in the Uzbek republic, when the total kolkhoz population in the republic was about a million (Craumer, 1992, 154). The kolkhoz members who did participate in the cotton harvest were mainly women, and a plausible presumption is that kolkhoz managers perceived their female workers as having a lower opportunity cost than most male members of the kolkhoz.

12 Whatley (1991, 201) reports that in the USA between 1949 and 1964 wastage with mechanical harvesting was fairly constant at 9%. Over the same period wastage with hand-picking was between 2.5 and 5%, rising over time as the average age of pickers increased.
13 The difference was about ten percent in 1963, according to Hodnett (1974, 115 n93).
14 In 1999 in Uzbekistan cotton harvester drivers were paid 100-200 sums per tonne picked while hand pickers were paid 8-9 sums per kilogram, so that the reduction in labor costs from mechanization was at least 97.5%.
15 Annual use of cotton harvesting machines in the USA in the 1950s and 1960s varied from 225 hours in the southeast, to 350 hours in the Mississippi Delta, to 500 in the west (Whatley, 1991, 215). The main reason was the drier and more reliable climate in the west compared to the mud and morning mist of the southeast coastal regions. Musoke and Olmstead (1982) emphasize larger farm size and climate as reasons why Californian cotton farms were best-suited to mechanical harvesting in the USA. Similar features in the core cotton-growing areas of Central Asia suggest that neither physical conditions nor farm fragmentation are plausible explanations for the slow diffusion of machine-picking.
Soviet Central Asia was often described as a surplus labor region, in contrast to the labor shortages in European parts of the USSR. Although there was by definition no unemployment, western estimates found substantial underemployment.\textsuperscript{16} One complication is the seasonality of agricultural work, and especially the heavy demands during the cotton harvest. In the mid-1980s over half of Uzbek cotton and three quarters of Tajik cotton was hand-picked, and students and industrial workers were commandeered for one and a half to two months. In 1986 and 1987, 650,000 to 700,000 schoolchildren, 140,000 college and vocational school students, and an unreported number of urban workers harvested cotton in the Uzbek republic (Craumer, 1992, 162). In the Tajik republic over 300,000 students and industrial workers were commandeered during harvest seasons in the mid-1980s for one and a half to two months cotton picking (Dienes, 1987, 130). The main social cost of these levies was the disruption of the outsiders’ primary employment or their education, but the direct cost to the kolchoz was small. In 1972 the casual workers were paid 5 kopeks per kilogram picked.

Mechanization would also have other effects on farm organization. As well as implying the need for complementary inputs which would be less critical with hand-picking, mechanization would make more economic sense if greater acreage were devoted to cotton and plantings devised to ease mechanical harvesting. Such changes in sowing patterns were resisted by kolchoz members because they threatened to upset the established division between collective land and private plots.

The private plots provided insurance against sudden policy changes and other negative shocks to living standards. Although hard evidence on the value of private plots in Central Asia is difficult to come by, Hodnett (1974, 85-6) claims that they probably accounted for at least a third of average family income in the 1960s. Lubin (1984, 181-2 and 188) estimated that private plots accounted for a fifth of Central Asian agricultural output and a quarter of collective farm families’ income circa 1980. Marnie (1992, 223) shows a big range by republic and by family income in 1989, eg. in the Uzbek republic for the poorest families (with per capita monthly income below 75 rubles) private plots accounted for 19-20\% of family income but for families with per capita income above 200 rubles private plots accounted for 32\% of income.\textsuperscript{17} Thus, in the biggest cotton-producing republic, all collective farm families might resist any threat to their private plots, but the wealthier and presumably more influential families had most to lose.

4. Cost-Benefit Analysis

\textsuperscript{16} Dienes (1987, 131) reviews some of this literature, concluding that surplus labor in 1979 was about 1.1 million in the Kyrgyz, Tajik, Turkmen and Uzbek republics combined and around 315,000 in the Kazakh republic. Marnie (1992, 203-5) estimates that in 1984 over a million people were voluntarily or involuntarily unemployed in the Uzbek republic, the core of the Soviet cotton economy, and the non-employed amounted to 14\% of the working age population, compared to 5.5\% in the Russian republic, although Klugman (1998, 34) points out that large regional variations exist in Uzbekistan between cotton-growing areas such as the labor-scarce Dzijak region and the surplus-labor Ferghana Valley.

\textsuperscript{17} The progressivity was more pronounced in the Tajik republic, rising from 16\% to 45\%. In the Kyrgyz and Turkmen republics, the share fell as family increase rose. The share of family income coming from private plots was much lower in the Turkmen republic (8-16\%) than in the other three republics covered by Marnie.
The previous section investigated the mechanization decision from the perspective of the most influential members of the collective farm. This section tries to make the same calculation on the basis of opportunity cost prices. Was mechanization appropriate in Soviet Central Asia given the region’s resource endowments?

One approach to this question is to assume technical parameters and capital costs from the much studied US case. According to Whatley (1991), in 1964 the total expected cost of mechanically harvesting cotton ranged from 3.1 cents per pound in California to 8.9 cents in North Carolina.\(^{18}\) If the technical characteristics of Soviet and US machines (L and Q) were similar, then the key issue is whether labor costs at a shadow wage rate were below this range.\(^{19}\) The casual harvest-time wage rate of 5 kopeks per kilogram was equivalent to around 2 US cents per pound at official exchange rates, and even less at other exchange rates preferred by Sovietologists in the 1960s.\(^{20}\) Thus, it seems probable that labor was sufficiently abundant in Soviet Central Asia for hand-picking to be the most efficient technique, even if physical conditions were as favorable to mechanization as in the least-cost US region.

This conclusion is consistent with international evidence. In the southern USA in the late 1950s, the labor costs of hand-picking cotton were over 5 cents per pound (Whatley, 1991, 211).\(^{21}\) Australia, the other high wage cotton-growing country, also mechanized harvesting. Major producers such as India, China and Pakistan, however, continue to harvest by hand because their labor costs do not justify mechanization.\(^{22}\) Soviet Central Asia was between these extremes of labor costs, and closer to Egypt or Iran or Turkey, none of which has mechanized the cotton harvest.

One cannot, of course, rule out externalities. The social disruption of mechanization would have been considerable,\(^{23}\) but not necessarily negative and, as emphasized in section 2, there is little evidence of policymakers delaying mechanization for this reason. More plausibly, Soviet planners may have placed great weight on the propaganda benefits of modernization. An economic price was, however, paid for any such psychic benefits.

How high was this price? The phenomenon of idle machines suggest that their true economic value was close to zero, and this is supported by the collapse of sales after 1991. In that case the cost of premature mechanization was the resource cost of building the machines. Output was 60,000 machines in the 1960s (Table 4a) and, although I have no data on depreciation

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\(^{18}\) Whatley’s estimates draw on earlier work by Street (1957) and a 1969 University of Chicago PhD dissertation by Frank Maier.

\(^{19}\) This is not a very stringent test. Insofar as US machine-makers offered a wider range of cotton harvesters than Soviet producers, Soviet labor costs would need to have been significantly higher than 3 US cents per pound to justify widespread mechanization.

\(^{20}\) This was not a market-determined wage, but the low wage is consistent with the underemployment evidence presented in the previous section. Thirty years later, labor was still abundant enough to make mechanization uneconomic; in the 1998 harvest season in Uzbekistan cotton pickers were paid 5 sum per kilogram (Pomfret, 2000), which was just over 2 US cents per pound at the official exchange rate and less than one cent at the market exchange rate.

\(^{21}\) Labor costs consisted not just of the minimum wage payments, equal to about $3.50 per hundredweight, but also to recruitment and organizing costs (0.86 and 1.16 c/lb).

\(^{22}\) In 1999 the countries with the largest cotton production were China, USA, India, Pakistan, Uzbekistan, Turkey, Australia, Brazil, Turkmenistan and Greece (Table 2).

\(^{23}\) In the southern USA the mechanization of cotton and subsequent release of unskilled labor was arguably the major single economic and social event of the twentieth century, transforming not only the cotton sector but also the entire labor market and social structure, leading to large-scale migration to the northern USA and reinforcing demands for civil rights.
rates, the numbers in Table 4b suggest that this flow was perhaps maintained through the 1970s and declined in the 1980s, before collapsing to a few hundred per year in the late 1990s (Table 4c). Soviet prices tell us little about the resources going into each machine, because input prices, transport costs and output prices for producer goods were all meaningless in the centrally planned economy. During the 1960s the list prices for generic standard model cotton pickers in the USA ranged from $6,000 to $10,000 (Whatley, 1991, 209). Given the competitive nature of the US industry, this could be considered the “world price” of a standard machine and, if Soviet machines were of the same quality, then it provides an opportunity cost price. Thus, during the 1960s the opportunity cost of premature mechanization of cotton picking was in the range of $360-600 million. The amount may have been slightly less in the next two decades, but it is unlikely that the total (undiscounted) cost at 1960s prices was less than a billion US dollars.

5. Conclusions

Labor productivity in Soviet Central Asia was very low. Cotton output per day of labor in 1953 was even lower in the USSR than in Egypt (ECE, 1957, 60; Hodnett, 1974,73). Labor productivity increased during the 1950s and 1960s, but fell in all of the cotton-growing republics between 1970 and 1987 (Craumer, 1992, 159). Thus, despite the large expenditure on irrigation, machinery and fertilizers, the returns to both land and labor used in cotton production were diminishing in the final two decades of the USSR, and the cotton economy was imposing huge environmental costs as chemical fertilizers drained into the rivers and irrigation projects cut off the flow of water to the Aral Sea. Soviet planners recognized the low level of labor productivity and saw the need for mechanization, but low opportunity cost of labor is a reason for doubting the appropriateness of labor-saving investment.

Politicization and central planning delayed the development of the cotton machine industry in the 1950s and the rigidity and biases of central planners restricted the development of technical improvements and of repair facilities. These are, however, minor features of the story of the diffusion of mechanical harvesting in Soviet Central Asia between the 1950s and the dissolution of the USSR. The main point is that, given the technical parameters and abundance of labor in Soviet Central Asia, hand-picking was more economical than mechanical picking. Even with machines essentially free (ie. there was a stock and no second-hand market), farmers preferred to leave them idle. Planners and politicians had little

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24 In interviews at the Tashkent Institute of Engineers for Irrigation and Agricultural Mechanization (TIEIAM) in 1997 I was told that 2000 cotton picking machines were produced per year in the 1980s. Output dropped to very low levels in the early 1990s, although TIEIAM staff explained that this was due to input supply disruptions (especially steel) and technical problems which were being resolved by negotiating a joint venture with a US producer. With a total academic staff of 422, and 514 students registered in its Faculty of Agricultural Mechanization, TIEIAM clearly maintains the tradition of central advocacy of mechanization.

25 Because some machines had positive value in relatively labor-scarce areas such as Dzhijak this could be an overestimate, but in other respects it is a minimum estimate. The prices are for bottom-of-the-line US one-row pickers, and, to the extent that Soviet output included two-row pickers (which were twice as expensive as one-row pickers in the USA) or other non-standard models, are underestimates. As noted in Table 4a, data on machine production in the 1950s is scrappy, but substantial costs were incurred in the design and retooling associated with the ShkM-48 and subsequent shift to horizontal-spindle machines.

26 In March 1989 Gorbachev was reported in Pravda as complaining that over the previous twenty years in Uzbekistan 1.6 million new hectares of irrigated land had been created and productive forces in agriculture had increased six times, but gross production was up only 78% (Gleason, 1990, 72).
idea of how their strategy for increasing labor productivity was received at the farm level.\textsuperscript{27}

Writing after a decade of post-Soviet experience we have a huge advantage over writers trying to explain cotton mechanization during the Soviet era. Nevertheless, it is surprising just how universally accepted was the premise that mechanization was a source of improved efficiency. Citing the difference in labor requirements between hand-picking and machine-picking proved the point, without paying any attention to the capital costs and other factors. Since the introduction of market economies in the new independent states, there appears to have been a continuing decline in mechanical harvesting.\textsuperscript{28} The implication is that the kolkhoz members, who opposed mechanization out of a narrow self-interest created by distorted Soviet prices and other incentives, actually produced the economically efficient outcome in view of true relative factor prices in labor-abundant Central Asia. Cotton-picking remains back-breaking work, but in the market economy of the 1990s the demand for cotton-harvesting machines virtually disappeared and the supply of labor was plentiful even at the low wages.\textsuperscript{29}

The role of central planners in pushing cotton mechanization was similar to that prescribed by advocates of public policy to accelerate technical diffusion. In the long run, as incomes rise, mechanical picking will displace picking cotton by hand. That this process did not occur as smoothly or rapidly as planned was not primarily due to the incompetence of politicians or planners (and still less to Machiavellian attempts by them to undermine official policies), but rather due to resistance at farm level. The farmers resisted mechanization because it was not in their economic interests. Such interests were distorted by the Soviet system, but they reflected the lack of economic efficiency of mechanization in labor-abundant Central Asia that has deterred mechanization in the more market-oriented economy following perestroika in the late 1980s. The true cost of state-directed diffusion was not that the planners failed to speed up diffusion, but that they did it too far ahead of its time. The costs in terms of wasted resources in machine production were large, amounting to at least a billion US dollars at 1960s prices, even under conservative assumptions.

Accelerating technical diffusion, especially when it appears to be obstructed by scale barriers associated with expensive equipment, is often advanced as a reason for government intervention, and not just in centrally planned economies. In new independent states in the 1950s and 1960s, technological catch-up was one of the arguments for state-supported industrialization. Even a well-managed economy like South Korea fell into this trap with its chemicals and heavy industry drive of the late 1970s, aimed at speeding the ascent up the technical ladder, but leading to an embarrassing climb-down by policymakers. In high-income market economies a costly example was the French and British governments’ success

\textsuperscript{27} Irrigation projects, the other huge capital investment in Central Asian agriculture, also reflected an emphasis on increasing cotton output, regardless of cost or side-effects or implementation problems. Irrigation projects were generally supported by farmers, who saw private benefits from free or heavily subsidized water. Yet little attention was paid to effective use of the water or to the environmental costs. Even as late as the mid-1980s official opinion was still in denial as to the costs of desiccation of the Aral Sea and Chernenko was still considering diversion of Siberian rivers. The common feature was the grand commitment to modernization without paying attention to the complexity of the irrigation or mechanization decision.

\textsuperscript{28} At the very least, there has not been the dramatic shift to mechanical picking which Gleason (1990) predicted would be the inevitable outcome as market forces became more important under economic reforms begun by Gorbachev in the late 1980s.

\textsuperscript{29} In the 1998 harvest season the base rate in Uzbekistan was 5 sum per kilogram, or about $5 per day at the market exchange rate (Pomfret, 2000), but unlike in other unskilled occupations wages were paid promptly and in cash.
in providing their national airlines with a supersonic aircraft when the market failed to do so. British Airways and Air France, each forced to take seven Concordes, were unhappy even when the aircraft were sold to them for one franc; the premium they could charge supersonic passengers was inadequate to cover even the operating costs. Supersonic travel will surely be an economical long-haul flight mode of the future, just as Central Asian cotton will eventually be picked by machine, but anticipating the future can be a costly folly.

---

30 By the end of 1978 the British and French governments had spent $4,280 million to build two prototypes and fourteen commercial planes. The two national airlines each made operating losses on their seven Concordes, so that in 1981 both national governments were subsidizing Concorde operations (Feldman, 1985, 83-120). Public spending on Concorde is a lower-bound cost estimate because it understates the opportunity cost of many valuable resources.
Table 1a: Cotton Production in the Soviet Republics, thousand tons of raw cotton

<table>
<thead>
<tr>
<th></th>
<th>Azeri</th>
<th>Kyrgyz</th>
<th>Tajik</th>
<th>Turkmen</th>
<th>Uzbek</th>
<th>USSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1913</td>
<td>64</td>
<td>28</td>
<td>32</td>
<td>69</td>
<td>517</td>
<td>744</td>
</tr>
<tr>
<td>1940</td>
<td>154</td>
<td>95</td>
<td>172</td>
<td>211</td>
<td>1,386</td>
<td>2,237</td>
</tr>
<tr>
<td>1953</td>
<td>388</td>
<td>134</td>
<td>390</td>
<td>308</td>
<td>2,432</td>
<td>3,853</td>
</tr>
<tr>
<td>1956</td>
<td>352</td>
<td>151</td>
<td>415</td>
<td>334</td>
<td>2,857</td>
<td>4,332</td>
</tr>
<tr>
<td>1960</td>
<td>366</td>
<td>126</td>
<td>399</td>
<td>363</td>
<td>2,949</td>
<td>4,289</td>
</tr>
<tr>
<td>1965</td>
<td>355</td>
<td>167</td>
<td>609</td>
<td>553</td>
<td>3,904</td>
<td>5,662</td>
</tr>
<tr>
<td>1970</td>
<td>336</td>
<td>187</td>
<td>727</td>
<td>869</td>
<td>4,495</td>
<td>6,890</td>
</tr>
<tr>
<td>1975</td>
<td>450</td>
<td>202</td>
<td>836</td>
<td>1,079</td>
<td>5,330</td>
<td>7,864</td>
</tr>
<tr>
<td>1980</td>
<td>884</td>
<td>206</td>
<td>1,011</td>
<td>1,258</td>
<td>6,245</td>
<td>9,962</td>
</tr>
<tr>
<td>1985</td>
<td>788</td>
<td>58</td>
<td>935</td>
<td>1,287</td>
<td>5,382</td>
<td>8,755</td>
</tr>
<tr>
<td>1988</td>
<td>616</td>
<td>79</td>
<td>963</td>
<td>1,341</td>
<td>5,365</td>
<td>8,689</td>
</tr>
</tbody>
</table>

Source: Gleason (1990, 67).

Note: Kazakhstan, not identified in the source, accounts for most of the residual in the total.

Table 1b: Cotton sowings, thousand hectares, 1940-88

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uzbek</td>
<td>924</td>
<td>1,098</td>
<td>1,387</td>
<td>1,550</td>
<td>1,709</td>
<td>1,878</td>
<td>1,990</td>
<td>2,017</td>
</tr>
<tr>
<td>Turkmen</td>
<td>150</td>
<td>153</td>
<td>222</td>
<td>257</td>
<td>397</td>
<td>508</td>
<td>561</td>
<td>636</td>
</tr>
<tr>
<td>Tajik</td>
<td>106</td>
<td>126</td>
<td>172</td>
<td>228</td>
<td>254</td>
<td>309</td>
<td>311</td>
<td>320</td>
</tr>
<tr>
<td>S.Kazakh</td>
<td>102</td>
<td>97</td>
<td>106</td>
<td>112</td>
<td>118</td>
<td>127</td>
<td>131</td>
<td>128</td>
</tr>
<tr>
<td>Kyrgyz</td>
<td>64</td>
<td>65</td>
<td>71</td>
<td>73</td>
<td>75</td>
<td>76</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>1,345</td>
<td>1,539</td>
<td>1,958</td>
<td>2,220</td>
<td>2,553</td>
<td>2,897</td>
<td>3,021</td>
<td>3,133</td>
</tr>
</tbody>
</table>

Source: Craumer (1992, 144).
Table 2: Cotton Production in Central Asia and Azerbaijan, 1992-9
(thousand tons of raw cotton)

<table>
<thead>
<tr>
<th></th>
<th>Azerbaijan</th>
<th>Kazakhstan</th>
<th>Kyrgyz Republic</th>
<th>Tajikistan</th>
<th>Turkmenistan</th>
<th>Uzbekistan</th>
</tr>
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<tbody>
<tr>
<td>1992</td>
<td>336</td>
<td>246</td>
<td>52</td>
<td>515</td>
<td>1,290</td>
<td>4,129</td>
</tr>
<tr>
<td>1993</td>
<td>284</td>
<td>198</td>
<td>49</td>
<td>524</td>
<td>1,341</td>
<td>4,235</td>
</tr>
<tr>
<td>1994</td>
<td>284</td>
<td>208</td>
<td>54</td>
<td>531</td>
<td>1,283</td>
<td>3,936</td>
</tr>
<tr>
<td>1995</td>
<td>274</td>
<td>223</td>
<td>75</td>
<td>412</td>
<td>1,293</td>
<td>3,934</td>
</tr>
<tr>
<td>1996</td>
<td>274</td>
<td>183</td>
<td>73</td>
<td>318</td>
<td>436</td>
<td>3,350</td>
</tr>
<tr>
<td>1997</td>
<td>125</td>
<td>198</td>
<td>62</td>
<td>353</td>
<td>635</td>
<td>3,700</td>
</tr>
<tr>
<td>1998</td>
<td>113</td>
<td>162</td>
<td>75</td>
<td>385</td>
<td>707</td>
<td>3,220</td>
</tr>
<tr>
<td>1999</td>
<td>101</td>
<td>249</td>
<td>87</td>
<td>316</td>
<td>1,300</td>
<td>3,680</td>
</tr>
</tbody>
</table>

Source: Food and Agricultural Organization website www.fao.org

Note: Other countries producing over a million tons in 1999 were China 11,490, USA 9,517, India 6,218, Pakistan 4,486, Turkey 2,093, Australia 1,728, Brazil 1,416 and Greece 1,185.
Table 3: Percentage of cotton harvested by machine 1965-88

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uzbek</td>
<td>23</td>
<td>33</td>
<td>46</td>
<td>63</td>
<td>68</td>
<td>54</td>
</tr>
<tr>
<td>Turkmen</td>
<td>n.a.</td>
<td>32</td>
<td>47</td>
<td>52</td>
<td>49</td>
<td>41</td>
</tr>
<tr>
<td>Tajik</td>
<td>14</td>
<td>22</td>
<td>28</td>
<td>36</td>
<td>29</td>
<td>22</td>
</tr>
<tr>
<td>Kazakh</td>
<td>21</td>
<td>41</td>
<td>69</td>
<td>63</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>Kyrgyz</td>
<td>33</td>
<td>39</td>
<td>62</td>
<td>51</td>
<td>61</td>
<td>63</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uzbek</td>
<td>34</td>
<td>31</td>
<td>40</td>
<td>42</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Turkmen</td>
<td>43</td>
<td>26</td>
<td>52</td>
<td>47</td>
<td>n.a.</td>
<td>65</td>
</tr>
<tr>
<td>Tajik</td>
<td>12</td>
<td>11</td>
<td>13</td>
<td>22</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Kazakh</td>
<td>43</td>
<td>39</td>
<td>76</td>
<td>n.a.</td>
<td>57</td>
<td>78</td>
</tr>
<tr>
<td>Kyrgyz</td>
<td>49</td>
<td>60</td>
<td>23</td>
<td>69</td>
<td>69</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Source: Craumer (1992, 161).

Note: Hodnett (1974, 79) gives similar figures: at “the end of the 1960s” 33% of the entire Soviet crop was machine-harvested, with variation across republics: Kirghizia 39% (1970), Turkmen 33% (1970), Tajik 21% (1969), Azerbaijan 9% (1965), and Uzbekistan 1.7% (1955), 2% (1958), 11% (1962), 24% (1965), 29% (1969) and 34% (1970).
Table 4a: Annual Output of Cotton Harvesting Machines in the USSR, 1960-70 (thousands)

<table>
<thead>
<tr>
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<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>3.2</td>
<td>4.3</td>
<td>6.1</td>
<td>7.1</td>
<td>7.0</td>
<td>8.0</td>
<td>7.0</td>
<td>6.4</td>
<td>5.7</td>
<td>5.7</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Source: Hodnett (1974, 80). Hodnett also gives sporadic figures for the 1950s, but they do not seem to be consistent with the text. He also provides data on the stock of machines, which was 4.8 thousand in 1950 and similar to Craumer’s estimates in the following table.

Table 4b: Number of cotton harvest machines, thousands, 1960-86

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uzbek</td>
<td>8.30</td>
<td>21.80</td>
<td>26.10</td>
<td>28.70</td>
<td>36.60</td>
<td>37.90</td>
</tr>
<tr>
<td>Turkmen</td>
<td>0.68</td>
<td>3.30</td>
<td>3.50</td>
<td>6.50</td>
<td>9.30</td>
<td>10.90</td>
</tr>
<tr>
<td>Tajik</td>
<td>0.17</td>
<td>2.23</td>
<td>2.85</td>
<td>2.91</td>
<td>3.42</td>
<td>4.11</td>
</tr>
<tr>
<td>Kazakh</td>
<td>0.70</td>
<td>n.a.</td>
<td>2.80</td>
<td>n.a.</td>
<td>2.50</td>
<td>2.60</td>
</tr>
<tr>
<td>Kyrgyz</td>
<td>0.14</td>
<td>1.64</td>
<td>1.74</td>
<td>1.27</td>
<td>1.05</td>
<td>0.74</td>
</tr>
<tr>
<td>Total</td>
<td>9.99</td>
<td>n.a.</td>
<td>36.99</td>
<td>n.a.</td>
<td>52.87</td>
<td>56.25</td>
</tr>
</tbody>
</table>

Source: Craumer (1992, 161).

Table 4c: Annual Output of Cotton Harvesting Machines in Uzbekistan, 1994-9

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>651</td>
<td>1121</td>
<td>863</td>
<td>1049</td>
<td>351</td>
<td>278</td>
</tr>
</tbody>
</table>


Note: so far as I am aware no cotton harvesters were produced elsewhere in the former USSR so these figures are comparable with Table 4a.
References


