Larry E. Westphal and Yung W. Rhee

*Choices of Technology in Industry*

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This article discusses questions of appropriate technology in a particular case. The case study shows that ill-advised government price policies can lead to inappropriate choices that have a substantial impact on employment generation and hence on economic welfare. The generality of this finding is then discussed, with the conclusion that proper price policies are a sufficient condition for appropriate choices only if there is an adequate infrastructure of market and non-market institutions to provide the technical information and assistance needed for those choices.

Shaping economic development in such a way that its rewards are more equitably distributed involves many questions of technological choice. Are inappropriate technological choices partly responsible for the failure of the industrial sector in many developing countries to generate sufficient employment at an adequate wage? Is there any scope for choosing different factor proportions in the production process? If so, how is the appropriate technological choice to be determined in a particular circumstance? Does the socially appropriate choice correspond to that made by the producer? Why do producers often appear to choose inappropriate techniques? Is it because of ill-advised government policies? If so, is it possible to frame policies that will influence producers' decisions in the desired directions?

The research community has devoted much effort to analysing these issues, particularly those concerning the scope for choosing different factor proportions and the means of determining appropriate technological choices. Nearly all relevant research suggests substantial scope for choosing among different factor proportions in production. But the techniques producers choose frequently are not the most appropriate from a social point of view. Although little research on the question has been conclusive, it is widely believed that ill-advised government policies affecting the prices producers pay and receive are responsible—at least in part—for inappropriate choices. For this to be true, different constellations of relative prices must operate systematically to induce different choices, which requires that producer behaviour be at least roughly consistent with profit maximisation.

This paper provides an overview of some recent research at the World Bank on these questions. It is in two parts. The first summarises a case study showing that prices indeed matter and that government price policy can be ill-advised. The discussion also conveys some idea of the complexity of technological choices in industry. The second part relies upon a survey of other case studies, most of them conducted outside the World Bank, to amplify on the general relevance of the case study's findings.

HOW GOVERNMENT PRICE POLICIES AFFECT THE CHOICE OF TECHNOLOGY

The case study summarised here is an examination of the choice between imported looms and locally made looms for cotton textile weaving in Korea. During the late 1960s and early 1970s, the period covered by the study, indigenous looms sold for less than a third of the price of imported looms, yet the imported looms were purchased in large numbers. Why? Casual empiricism would suggest a number of reasons for some producers to
have purchased costly imported machines while others bought less expensive indigenous equipment—or more generally, for different producers to use different machines for the same task.

Although appearing on the surface to be similar, machines may differ in many respects: that is, they may embody different techniques of production (or technologies). As a result, similar machines often cannot produce an identical range of products; nor are they always equally suited to make each of the products they can produce. The width of a loom, for instance, determines the maximum width of the cloth it can weave. In addition, some looms have comparative advantages for producing certain grades of cloth, distinguished by the fineness of the yarn or the density of the weave; and given certain specifications of the product, one machine may produce output of a higher quality than another. Furthermore, similar machines need not have the same input requirements—for skills, power, or raw materials. Maintenance requirements also differ, as do expected economic lifetimes.

The differences affecting the choice of a machine extend beyond the machine’s physical characteristics. The terms under which machinery can be purchased from different suppliers often are not the same. Imported machinery, for example, can often be financed by suppliers’ credits, which carry lower interest rates and more liberal repayment terms than the medium-term domestic currency credit needed to finance the purchase of indigenous machinery. Because of investment licensing or credit rationing, producers may not have equal access to different sources of finance. In addition, market segmentation and government policies may lead different producers to pay different prices for ostensibly identical inputs. For example, wages paid to the same category of labour may vary by region or by the size and type of establishment; certain raw materials may be more readily available at cheaper prices for some producers than for others. Market segmentation and differential government policies can also lead to different ex-factory prices for the same product, depending on who produces it and where it is produced and sold.

In general, the choice of product mix and the choice of machine specifications are inextricably intertwined, and profit maximisation is not simply a matter of selecting the cost minimising technique to produce a given product. The profit motive may lead producers to choose different machine specifications to produce identical products. It may also lead them to produce distinct products for which each model of machine has particular comparative advantages. Some producers, in turn, may select their models on grounds other than profit maximisation, grounds which can also explain the use of different machines.

Under the assumption that producers seek to maximise their long-term profits or net worth, economic theory states that they will compare the benefit associated with each combination of machine and product mix against its cost in order to select the combination with the highest benefit-cost ratio: that is, they will compare the discounted present value of the expected income stream—gross receipts from sales less operating expenses and taxes—against the purchase price of the machine. To investigate how various elements influence the choice of machine, it is necessary to estimate their impact on the benefit-cost ratios associated with the available models. If these estimates are to have meaning, they must incorporate a great deal of detail about the characteristics of the complementary inputs required. Just as firms may differ in important respects—for example, in their size and managerial ability—so do the factors determining the prices each firm pays for its inputs and receives for its outputs. Impinging on these factors are such things as the organisation of markets and the effects of government policy.

Are Choices Made to Maximise Profits? The detailed information needed to evaluate producers’ choices were obtained through a survey—conducted in 1972—of thirty-seven cotton-textile- weaving firms. We will first summarise the findings concerning the differences between imported and indigenous looms and the associated differences between firms using each. Then we will present our estimates of benefit-cost ratios derived from the data. All the imported looms considered here are automatic; all the domestic looms are semiautomatic. The distinction between the two types depends on whether the shuttle is changed automatically or manually when its yarn is exhausted. On all looms investigated, the shuttle was passed from side to side mechanically.

Much of the cotton fabric produced was exported. There were strong government incentives for exports, so that differences in destination were associated with differences in prices paid and received. The share of exports in total output was greater by far in firms using imported automatic looms. This was partly due to the availability of in-
digenuous looms in widths up to only 60 inches, whereas imported looms could be obtained in widths up to 103 inches and much of the export demand was for the wider varieties of cloth. Nonetheless, the narrower exported varieties were produced by indigenous and imported looms alike.

As long as loom widths were the same, the indigenously produced semi-automatic looms could produce export-grade cloth of the same specifications and quality as that produced on the imported automatic looms. The imported looms did have a comparative advantage in producing superior varieties—that is, finer, more densely woven varieties—but this advantage was not the same as absolute cost advantage. For example, there was no indirect tax on yarn used to produce for export, but there was a minimum tax rate of 10 per cent on yarn going into production for domestic sale. The business activity tax (a turnover tax charged at a maximum rate of 0.5 per cent of gross sales) was not levied on exports or on inputs used to produce exports. The schedule of income tax rates was progressive, with lower rates on corporate income. More to the point, income derived from export sales was taxed at half the rate otherwise applicable. Furthermore, exporters were allowed a somewhat higher rate of depreciation in calculating their business expenses.

To summarise: Korea’s cotton-textile-weaving sector at the time of the survey might be characterised as having had a dual structure. Firms that paid high wages and benefited from low interest rates typically used the more expensive, automatic looms and tended to produce superior varieties, mostly for export; firms paying low wages and high interest rates characteristically used the less expensive, semi-automatic looms and tended to produce inferior varieties, mostly for the domestic market. This pattern is consistent with the notion that differences in economic environments led to the selection of different technologies. But a rigorous test of this notion requires the estimation and comparison of benefit-cost ratio for the alternative technologies.

For each model of loom in the sample, several benefit-cost ratios were estimated, one for each principal variety of fabric produced on that loom. The number of loom models observed for each technology and the number of loom and fabric combinations for which benefit-cost ratios were estimated are shown in the Table 1, which summarises our numerical results.

The estimated ‘private’ benefit-cost ratios are based on prices producers paid and received. The estimates thus reflect all the differences in circumstances associated with the purchase and use of different looms, including those attributable to government price policies. They also incorporate technological changes (through learning-by-doing) from the date of a loom’s purchase to the estimated date of its being scrapped. And they embody reasonable forecasts of changes in relative prices—such as rising real wages—just as they embody observed changes over the period following the purchase of the looms.

Although the average private benefit-cost ratio
is different for the two technologies, the difference is not statistically significant. On average, no producer could have realised higher profits by changing either his circumstances or his choices to make them more like those of any other producer. In this respect, the estimates are consistent with the hypothesis that the producers chose loom models on the basis of profit maximisation. That is, it appears that differences in prices paid and received, as well as in the varieties produced, led to the choice of different technologies.

### Table 1

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<th>Items</th>
<th>Domestic Semi-Automatic Looms</th>
<th>Imported Automatic Looms</th>
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<tr>
<td>Sample size</td>
<td>26</td>
<td>32</td>
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<tr>
<td>Loom models</td>
<td>65</td>
<td>73</td>
</tr>
<tr>
<td>Average Benefit-Cost Ratio</td>
<td>4.14</td>
<td>4.39</td>
</tr>
<tr>
<td>Social</td>
<td>5.48</td>
<td>1.49</td>
</tr>
<tr>
<td>Average subsidy rates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage increase in benefit due to policies affecting:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rates</td>
<td>-67.8</td>
<td>76.8</td>
</tr>
<tr>
<td>Direct and indirect taxes</td>
<td>-36.5</td>
<td>19.4</td>
</tr>
<tr>
<td>Input and output prices</td>
<td>128.8</td>
<td>53.7</td>
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<tr>
<td>Percentage decrease in cost due to policies affecting lom purchase price</td>
<td>0.0</td>
<td>21.3</td>
</tr>
</tbody>
</table>

**Note:** Averages are simple averages over all the loom-fabric combinations for which estimates were made under each technology.

**Sources:** Rhee and Westphal, "A Micro, Econometric Investigation of Choice of Technology," Table 1.

### What Are the Effects of Government Policies?

We now turn to evaluate the technologies at uniform prices. Our purpose in doing so is to remove distortions caused by government price policies. The procedure for estimating 'social' benefit-cost ratios is the same as that used to obtain estimates in the private case. The loom-fabric combinations for which benefit-cost ratios were estimated are also the same. But the following changes were introduced to impose uniform prices:

- To remove the effect of differences in interest rates, all loom purchases were assumed to have been financed on identical terms.
- To remove the effect of differences in direct and indirect tax treatment, all indirect tax rates were set at zero, the average actual direct tax rate was imposed uniformly and depreciation deductions were calculated everywhere on the same basis.
- To remove the effect of trade policies that protected domestic producers selling in the local market by affecting the prices of intermediate inputs and of outputs, the prices of all varieties of yarn and fabric were set equal to their respective world prices converted at an appropriate exchange rate and tariff rates were set at zero.
- To remove the effect of an inappropriate exchange rate that artificially reduced the cost of imported machinery, the purchase prices of imported looms were increased in proportion to the degree of exchange-rate overvaluation.

It was assumed that there were no differences in treatment of production for the domestic and export markets and that fabrics were sold domestically at the same prices prevailing in the world market. The resulting estimates are the social benefit-cost ratios shown in the Table.

Social benefit-cost ratios exhibit far greater differences than do private benefit-cost ratios. Moreover, the average social benefit-cost ratio for the domestic semiautomatic technology is much greater than that for the imported automatic technology and statistically the difference is highly significant. It therefore appears that few, if any, imported automatic looms would have been purchased in the absence of preferential government policy, except where required to produce fabrics wider than could be produced using indigenous looms. But of eighty-nine directly observed loom-fabric combinations using the imported automatic technology, in only twenty-two did the fabric widths exceed the production capability of indigenous looms.

It can be concluded that the indigenous semiautomatic technology was the socially optimal choice to produce fabrics less than 60 inches wide. For the same initial investment, use of the domestic semiautomatic technology would have generated more than ten times the jobs associated with the imported automatic technology. Thus in this case inappropriate choices had a substantial impact on employment generation in the industry.

By estimating benefit-cost ratios under alternative sets of assumptions, it is possible to decompose the difference between the private and social benefit-cost ratios for a particular loom-fabric combination into components attributable to different policy elements. As with any such decomposition, there is a degree of arbitrariness in determining the separate contribution of each element, but the results are nonetheless instructive. The Table shows the average subsidy rates associated with removing each of the distortions in going
from private to social benefit-cost ratios. These rates indicate the percentages by which the social benefits and costs were increased or decreased as a result of government policies affecting the indicated prices.

Not all the subsidies considered here were explicitly tied to the purchase of technology. Nonetheless, those tied to the purchase of imported automatic looms—that is, access to preferential credit and the overvalued exchange rate—on average were sufficient to increase its benefit-cost ratio 125 per cent. Subsidies originating in tax differences and import protection, the latter affecting prices paid for inputs and received for outputs, were not tied to particular technologies but were realised through producers' choices of the varieties of fabric to produce and the markets in which to sell them. On average, all producers benefited from protection in the domestic market, but only those using the imported automatic technology benefited from preferential tax rates associated with concentrating their sales in export markets.

Without estimates of demand relations for different fabrics, we could not analyse the quantities of various fabrics that would have been produced under different circumstances—analysis needed for closing the circle between product demand and technology choice. Nonetheless, the foregoing discussion shows that government incentive policies were not neutral. In particular, export incentives in combination with cross subsidisation between domestic and export markets appear to have elicited a large volume of production of superior fabric varieties than would otherwise have been so. (Higher prices on the domestic market, sanctioned by measures to protect domestic products in that market, enabled lower prices on the export market). In turn, the choice of the imported automatic technology was generally associated with the production and export of these superior varieties. It bears emphasising that one effect of the underlying policies was to increase prices for domestic consumers, because some producers chose socially inappropriate techniques, which meant higher production costs though not higher profits.

To summarise: Producers' choices generally seem to have been consistent with profit-maximising behaviour. That the choices were also socially inappropriate is explained by the constellation of government price policies favouring the use of imported technology. Particularly important among these policies were access to credit on preferential terms and exemption of machinery imports from tariffs, together with an overvalued exchange rate. Except for the production of cloth more than 60 inches wide, the indigenous semi-automatic technology would have been the socially optimal choice of technology. And beyond the qualification just noted, there is every reason to expect that producers would have chosen this technology under a more appropriate set of policies. The policies encouraging the use of imported technology simultaneously discriminated against domestic textile-machinery manufacturers, and thus inappropriately retarded the development of the domestic engineering industry.

**GENERAL RELEVANCE OF THE FINDINGS**

Care is needed in drawing general conclusions from any case study, including this one. But three conclusions are possible:

- Semi-automatic looms embody THE appropriate weaving technology for less developed countries.
- Inappropriate technological choices have a substantial impact on employment generation.
- The right government price policies will lead producers to make appropriate choices.

The general relevance of each of these possible conclusions is discussed below.

Are semi-automatic looms THE appropriate technology for weaving in less developed countries? Obviously not, for as the case study demonstrates, they are not the appropriate technology to produce all varieties of cloth. Indeed, it is generally true that there is no such thing as THE appropriate technology which is right irrespective of specific product characteristics and economic circumstances.

Are semi-automatic looms then THE appropriate technology for producing inferior varieties of cloth? This question has been thoroughly analysed in other research at the World Bank and the answer is clear. It is again no, but for a different reason. In achieving their economic potential, semi-automatic looms require more highly skilled and dedicated operators and managers than do automatic looms. The requisite skills and dedication are not everywhere equally abundant and they are nearly impossible to develop in the absence of conducive market conditions. Moreover, there is some evidence to indicate that
the skills and dedication cannot be developed without five to ten years of accumulated indigenous experience in weaving. Thus semi-automatic looms often are not the appropriate weaving technology in countries less developed than Korea was in the early 1970s. All that can be concluded is that the determinants of appropriate technological choices are not only many and complex, they are also highly variable across economic environments, with the result that THE appropriate technology can only be determined in light of the specifics of individual cases.

No: Do inappropriate technological choices always have a substantial impact on employment generation? The answer obviously depends on the industry and the technologies compared. In this regard, a pertinent answer comes from an extensive survey of the case study literature that Howard Pack conducted for the World Bank. Based on the data contained in this literature, he compares the, labour intensities of two technologies. One is the technology that would typically yield maximum profits at market prices in a less developed economy. The other is the 'conventional technology, the one typically chosen for "a turnkey plant designed by a consulting engineering firm or a diversified equipment producer, though LDC producers may themselves design such a plant, ... [which] is not as mechanized as an advanced factory in a developed country ... [and thus reflects] some adjustment of factor proportions to local endowments, ... but] is not necessarily the most labour-intensive [technology available]." In other words, he compares the profit maximising technology with the alternative most likely to be chosen if the profit maximising technology is not.

For a mix of industries representative of the composition of industrial output in the less developed economies, Pack finds that profit maximising technologies on average generate more than three times as much employment as conventional technologies for the same amount of investment. In turn, because the typical configuration of market prices does not reflect the true scarcity of capital relative to labour, appropriate technologies are typically more labour-intensive than profit maximising technologies (Pack does not estimate the difference). It, therefore, appears that inappropriate technological choices will generally reduce employment generation substantially.

Finally: Will the right government price policies lead producers to make appropriate technological choices? Here the answer is in two parts: no, not unless producers are profit maximising; and then yes, but only if producers have sufficient information about alternative technologies and the techno-economic ability to assess them.

Case study research has uncovered instances in which producers have chosen technologies that are considerably less labour-intensive than readily available alternatives that would have led to higher profits, at least in the estimation of the researchers. Such instances often involve producers in highly concentrated industries or producers having quasi-monopoly positions owing to product differentiation. Some researchers conclude from this evidence that producers, particularly those not subject to intensive competition, often pursue engineering objectives rather than economic objectives and hence do not choose technologies on the basis of profit maximisation. But as Pack notes in his survey, one need not substitute 'engineering man' for 'economic man,' to rationalise the choice of technologies that are not profit maximising in the eyes of an outside observer whose attention is focused on but one dimension of business management.

The act of choosing is not costless, particularly in a less developed economy where relevant information is often absent and the ability to make adequate techno-economic assessments is frequently limited. Moreover, businessmen confront many competing claims on their decision-making resources—profits are affected by the choice of capital-embodied technology and by the host of other factors that determine sales revenues and the margin of gross receipts over operating expenses and taxes. Thus managers also have to pay attention to such things as marketing, labour practices, inventory control and—too often—securing favourable government treatment. In short: "the choice of technique may be subordinated simply because alternative use of the businessman's time are more profitable than carefully searching for the optimal [profit-maximizing] technique." Development banks and other institutions can affect producers' behaviour in this regard by supporting actions that reduce the producer's costs of searching for information about alternative technologies and assessing them. Such actions include providing relevant technical information and assistance as well as encouraging market forces and institutions that would have the same effect. An associated benefit of these actions is that they avoid needless duplication of the collection and assessment of technical information by many competing producers. Moreover, to the
degree that producers would otherwise choose conventional rather than profit maximising technologies, there are clear gains not only to society, in employment generation, but to the producers and their bankers and stockholders as well. This is seen in Pack's estimate that profit maximising technologies on average yield 51 per cent more non-wage income than conventional technologies.

It does not follow, however, that development bankers and others concerned with practical development issues should be content simply to do what is useful within the confines of existing market prices. They should also be concerned with government policy. As the Korean case study demonstrates, ill-adviced government policies retard employment generation by affecting the behaviour of profit maximising producers. The fact that some producers are not profit maximising is not relevant—because the profit maximising producers, as the ones most able to survive and prosper in an environment conducive to growth, will eventually come to dominate their industries. Thus "getting the prices right" is very important even though it is not always sufficient.

NOTES
3. The number of looms in the sample was slightly greater than a third of the population of more than 30,000 looms then in Korea.
4. Semiautomatic looms are often referred to elsewhere as ordinary, power, or nonautomatic power looms.
5. Differences between loom models reflect differences in suppliers, vintages and specific characteristics.
6. Our imposition of uniform prices is akin to using shadow prices to calculate the benefit-cost ratios. Overvaluation of the currency is taken into account by using the appropriate shadow exchange rate, while tradeable goods are valued at border prices. But labour is not shadow-priced and the uniform discount rate is simply taken to be the average of the real interest rates paid to finance loom purchases in the sample. On the other hand, most observers would agree that market wages in Korea are not very different from shadow wages, so that it is principally in underestimating the discount rate that our approach markedly differs from the use of shadow prices.
7. Through payments to banks, the government explicitly subsidised domestic credit made available on preferential terms. On the other hand, government licensing merely controlled access to foreign suppliers' credits. Nonetheless, with respect to the latter, the government could have imposed an interest equalisation tax but did not, so that access to the lower interest rate must be considered as an implicit subsidy.
8. Because of incomplete information in some cases, the number of loom-fabric combinations for which benefit-cost ratios were estimated is less than the total number that were actually observed.
9. Extensive sensitivity analysis showed that the semiautomatic technology retains its superiority over the automatic technology in a wide range of circumstances. Our conclusion can therefore be considered robust.
10. Refer to the figures shown in the Table and note that \[
\frac{(1.0 + 0.768)/(1.0 - 0.213) - 1.0}{1.0}
\]
yields 124.7 per cent.
11. Korean government policy changed very soon after the time of our study. In particular, imports of capital goods are no longer favoured through tariff exemptions or access to credit on softer terms; in some cases, there are even import restrictions on competing imports of equipment. Income derived from exporting is no longer taxed at a preferential rate and other export incentives have been substantially reduced. Many of the differential policies have thus been changed or removed. And it appears that export prices for most fabrics now are equal to or higher than domestic prices, once allowance is made for the remaining export subsidies. As a result of the engineering industry's increasing maturity, wider looms are now produced domestically, so that the imported technology no longer has an absolute advantage on this score.
Equally significant is the fact that more than two-thirds of the new looms purchased by cotton-textile producers in 1973 and 1974 were locally manufactured, though some of these looms were automatic.


13. Pack, Howard, *World Bank Staff Working Paper*, No. 377, p. 16. For weaving, the conventional and profit maximising technologies are different models of automatic loom; the ratio of employment generated to investment required for the former is more than four times for the latter.


15. Capital-embodied technology refers to the technology embodied in the machines chosen at the time of investment. Decision-making with respect to many of the other factors involves a number of distinct techno-economic considerations. In subsequent research for the World Bank, Pack has been investigating in the context of analysing the productivity with which capital-embodied technologies are employed in practice. For a summary of the findings, see Pack, Howard, "Productivity and Technical Choice: Applications to the Textile Industry," *Journal of Development Economics*, forthcoming in 1984 (copies of the manuscript are available from the Productivity Division, Development Research Department, World Bank).


17. The actions that are possible are better known and appreciated by development bankers than by economists, who have only recently come to understand their importance. Hence our reluctance to go into more detail here.


No. 312. Bela Balassa, "Adjustment Policies in Developing Countries: A Reassessment," *World Development*


No. 315. Bela Balassa and Carol Balassa, "Industrial Protection in the Developed Countries," *The World Economy*


No. 318. Sweder van Wijnbergen, "Credit Policy, Inflation, and Growth in a Financially Repressed Economy," *Journal of Development Economics*

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