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Is Child Labor Substitutable for Adult Labor?

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The American University in Cairo

Department of Economics

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By Tammy Fayed

A Thesis Submitted to the Department of Economics
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IN ECONOMICS

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For my family—American and Egyptian...

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IS CHILD LABOR SUBSTITUTABLE FOR ADULT LABOR?

ABSTRACT

This research aims to answer the question of whether or not child and adult labor are substitutable in production. Using the motivation of child labor laws, this research will examine the effect of an exogenous shift in the supply of child workers on the employment of adult workers. Since quantities rather than prices will be taken as exogenous, a production function rather than a cost function will be estimated, and Hicks elasticities rather than Allen elasticities of factor demand will be calculated since there appears to be a consensus in the literature on substitutability that this method is the most appropriate for estimating the substitutability between factors of production when quantities are taken as exogenous. In order to determine substitutability, this research will estimate share equations for a translog production function and use the estimated coefficients to calculate Hicks elasticities. The elasticity estimates will then be used to simulate employment effects as a result of reducing the supply of child workers under alternative assumptions about the wages of adult workers. A translog production function has been chosen as the functional form for this research because of its flexibility--it places no restrictions on elasticities between different factors of production--and because of its ability to test separability restrictions. The separability of capital and labor is particularly important for studies which estimate labor-labor elasticities since many studies choose to omit capital stock measures because of inavailability of data and large measurement errors in available data. Employment data for this study will be constructed from the Household Expenditure, Income and Consumption Survey 1990-91 collected by CAPMAS, and capital and output data will be constructed from both CAPMAS and World Bank sources. The main set of data used in regressions will be constructed for industry in general rather than for a particular industry both because of data inavailability and because expansions or contractions of industries would bias the elasticity estimates.

CHAPTER 1
INTRODUCTION

Currently in Egypt, it is not difficult to observe children working. Walking down a street in Cairo, one might find children selling small packets of tissues or gum, collecting trash in carts pulled by donkeys, changing tires in garages, sweeping floors in grocery stores, or begging in front of the University gate. One study (Azer and Ramzy 1992) finds that in 1986 there were an estimated 1.4 million working children aged 6-12 in Egypt. If one includes the 12-14 year olds in this figure, the number rises to 2.2 million, 11% of Egypt's total labor force (Fergany 1993). Azer and Ramzy (1992) also cites many reasons children and parents themselves give for children working: poverty, deficient educational systems, and desire to learn a trade to name a few. These children do not work in isolation; they are part of the larger labor market. In the following pages, this research will attempt to give a description of how child laborers affect the overall labor market of which they are a part.

More specifically, this research will aim to discover if child and adult labor can be used in place of one another in production. When one type of worker can be used to replace another in production, those workers are considered substitutes. If on the other hand, workers must be used together in production, those workers are considered complements. If reducing child labor results in a decrease in adult employment, then child and adult labor must be used together in production and they are considered complements. If reducing child labor results in a increase in adult employment, then child and adult labor may be used to replace one another in production and they are considered substitutes. This research will attempt to discover if child and adult workers must be used together in production--*i.e.*, if they are complements--or if they may be used in place of one another--*i.e.*, if they are substitutes.

EGYPTIAN CHILD LABOR LEGISLATION

The current Egyptian labor law No. 137, 1981 defines a juvenile as anyone aged 12-17. It limits the number of hours juveniles may work and prohibits night and holiday work by them. It bans occupations considered harmful for this age group. It requires that all juvenile workers be examined by a physician upon their employment and have medical check-ups at least once annually. It also requires that a list of the names of all juveniles employed be posted in a visible location near the entrance of the work site. In addition, the law prohibits employment of all children under the age of 12.

Although the current legislation was enacted more than ten years ago, child labor is still pervasive in Egypt. In an effort to reduce the number of child laborers, the Egyptian parliament is considering raising the minimum legal working age from 12 to 14 as part of a "Comprehensive Children's Law" (Farag 1996). The proposed child labor law, a modification of the previous law, would increase the age of entrance to occupations not considered detrimental to health or morals from 12 to 14.

WHO WILL BE COVERED UNDER THE LAW?

Before beginning to examine what effects the proposed law might have on adult employment and production, it is important to know what kinds of child labor will be restricted by the new law. Firstly, only work performed by children which is officially classified as "child labor" will be covered under the child labor law. Some authors claim that the current definition of child labor is too narrow. Nieuwenhuys (1994) argues for the inclusion of non-wage work in the definition of child labor and argues persuasively that many children, though not receiving monetary wages, are nonetheless working. The new Egyptian law which is a modification of the previous law, continues the practice of not covering children who work without monetary wages. Therefore, these children will not be affected by the proposed law. Secondly, neither the original 1981 law nor the proposed law covers agricultural child labor. Azer (1986) found that approximately 70% of Egyptian child laborers were working in rural areas. Since agriculture is the dominant industry in rural areas and child labor is not regulated in agriculture, 70% of waged child laborers will not be covered by the new law. Excluding non-waged and agricultural child labor implies that approximately 30% of the total workers in the labor force under the age of 14, 660,000[1] child laborers, would be removed from the market if the government passed the new law and *strictly enforced* it.

OBJECTIVE

The main objective of this research is to predict what effect the proposed legislation would have on adult employment if passed and *strictly enforced.* Some people claim that reducing child labor will increase the employment of adults. In a book published by the ILO (1988) which describes the working conditions of children in several developing countries including Egypt, it is asserted that "...child labour is a cause of and may even contribute to, adult unemployment and low wages..."(p. 90). Another study (Goode 1993) which specifically addresses the Egyptian labor market conditions claims that strictly enforcing child labor laws "may help to employ more adults and raise wages for the unskilled" (p. 39). This hypothesis is one which this research aims to test. If the proposed law is passed and child laborers are removed from the work force, will more adults become employed? If so, how many adults will gain jobs, or if not, how many adults will lose jobs? These two questions form the center on which the remainder of this research will focus.

[1] Since 70% of waged child laborers work in rural areas, the remaining 30% are urban workers who will be covered by the new law. 30% of the 2.2 million child laborers aged 6-14 is 660,000.

THEORETICAL FRAMEWORK

When beginning to examine what effects the new law might have on adult unemployment and production, it is important to consider the basic theoretical framework that should be used to examine this question. Similar to the method Ehrenberg and Smith (1994) use for examining the effects of immigration on domestic workers, it is appropriate in the context of child labor to use supply and demand analysis. The new law on child labor parallels immigration policies which deport illegal immigrants. Like illegal immigrants, child laborers are illegal workers which the government wishes to remove from the market. By forcing a group of workers out of the market, both of these policies directly alter the supply of labor to the market.

Policies which aim at changing the supply of labor--reducing the supply of child labor in this case--are known in the literature as type Q-policies[2]. Type Q-policies are policies that primarily affect market quantities. Although Q-policies may have effects on the equilibrium wages of workers, their direct effect is on quantity, not price. Unlike Q-policies, P-policies are policies which primarily change relative prices of inputs. Although P-policies may effect the equilibrium level of employment for some or all workers, their primary effect is on price, not quantity. Minimum wage laws are an example of P-policies because they raise the wages of low-waged workers relative to higher-waged workers. On the other hand, child labor laws which attempt to reduce child labor by restricting the age at which a child may begin working are Q-policies; they do not attempt to reduce child labor by forcing employers to change wages (although many countries also have minimum wage laws for children--P-policies). Instead, Q-policies aim to reduce child labor by directly reducing the supply.

[2] See Hamermesh 1993, pages 164-166, 196-202 for a discussion of Q-policies.

SUBSTITUTABILITY OF CHILD AND ADULT LABOR

Will removing 660,000 child laborers from the market cause any adults to find jobs? The answer to this question depends on how child and adult workers relate to each other in production. Consider the case of a small garage in Cairo which currently employs four young boys aged 8-14. If the boys were forced to leave their jobs because of the new law, would the garage owner hire some adults to do the boys' work? Or would he close the garage because of increased costs and fire the adults who were supervising the boys? And if he did hire more adults to take their places, how many would he hire? These questions fundamentally ask how substitutable child and adult workers are. If they are highly substitutable, one would expect to see adults being hired to take the place of children. If they are complementary, one would expect to see the adults being fired with the children.

SUBSTITUTION AND SCALE EFFECTS

The previous simple example illustrates the importance of both the substitution and scale effects in production when analyzing *ex ante* the effect of a change in type Q-policies. When the supply of one or more factors is altered, as with a Q-policy, the result is changes in relative prices. However, since firms are assumed to be profit maximizers, they may substitute a relatively less expensive input in order to maintain the same level of output. Changes in employment due to changes in relative prices, holding output constant, are known as substitution effects.

Additionally, changes in relative prices change the costs for firms--increasing costs in the case of removing child labor. Since firms are assumed to be profit maximizers, it may be the case that the level of output produced before the shift in supply is no longer optimal after the shift in supply. Since a firm's technology is fixed in the short run, firms may reduce output in order to attain maximum profits. Changes in employment due to changes in output are known as scale effects. Whether or not the garage owner will hire more adults is a combination of both the substitution and scale effects. Whether the substitution or scale effect is larger is an empirical question which must be tested to determine if child and adult workers are net substitutes or net complements.

LITERATURE ON SUBSTITUTABILITY

In order to examine the substitutability of children and adults, it is important to examine the literature in this area to discover how others have approached the question of substitutability. Hamermesh and Grant (1979) present a summary of works on the substitutability of workers in order to determine if there was, at that time, a consensus in the literature about the substitutability of different classes of workers. They are critical of studies which inappropriately choose to estimate production functions rather than cost functions when prices are taken as exogenous. The reason for their criticism is because of the method used to obtain Allen elasticities of substitution as opposed to Hicks elasticities of complementarity. Allen elasticities of substitution measure how relative factor quantities respond to changes in relative factor prices. Hicks elasticities of complementarity measure how relative factor prices respond to changes in relative factor quantities. While both Allen elasticities and Hicks elasticities may be produced from either production or cost functions, an inappropriate choice may result in inaccurate elasticity estimates. For example, as stated by Hamermesh and Grant, using a cost function to estimate one Allen elasticity requires using the estimates from only one factor share equation. Using a production function to estimate the same Allen elasticity, on the other hand, requires the inversion of "...an NxN matrix of estimated coefficients, where N is the number of factors..."(p. 520). This method is more likely to lead to large standard errors because the likelihood that one or more coefficients has a large standard error is higher. The argument is reversed when one wishes to estimate Hicks elasticities; estimating a cost function may lead to large standard errors because this method requires the inversion of an NxN matrix. This knowledge is important for estimating the substitutability of child and adult labor since the exogenous shift in the supply of child labor resulting from the child labor law implies that estimation using a production function approach rather than a cost function approach is the better choice. This is consistent with Hamermesh and Grant's claim that when labor is disaggregated by age, as is the case with child and adult labor, a production function approach is the better choice.

Hamermesh and Grant (1979) also highly favor use of the translog production and cost functions because of their flexibility and because of their ability to test separability restrictions. When two factors are separable, a change in the quantity (price) of one does not effect the price (quantity) of the other. In the case that two factors are found to be separable, one may be omitted from the estimation of the other's elasticities. If a factor is omitted from the elasticity estimates, it is implicitly assumed that the factor to be measured and the omitted factor are separable. If they are not separable in reality, the own-price elasticity of the omitted variable will be underestimated while the cross-price elasticities of the other factors will be overestimated (Hamermesh and Grant 1979). Therefore, it is important to be able to test for separability restrictions rather than assuming that one variable does not affect the elasticities of other variables as many articles have done by omitting measures of capital.

Field (1988), also using a translog production function, tests her hypothesis that free and slave labor were complements and not substitutes in production, and therefore, criticizes other authors for their use of less flexible forms of production which aggregate free and slave labor. Using data from the 1860 U.S. Census for farms in the South which includes data on employment, capital, and output and dividing labor into free and slave labor, she estimates factor share equations for capital, free labor, and slave labor using the method of ordinary least squares. From those estimates she calculates the elasticities for free and slave labor and rejects the hypothesis that free and slave labor were substitutes in production in the South in the 1800's. This article is relevant for the study of child labor since child labor is not separated from adult labor in current estimations of production. The current aggregation implies that child and adult labor are perfect substitutes, but this aggregation should be tested to see if such an aggregation is valid.

Also using a translog specification, Grant and Hamermesh (1981) estimate elasticities for different subcategories of labor using employment data from the 1970 U.S. Census and output and capital data from issues of the *Census of Manufactures* and the *Annual Survey of Manufacturers*. They find various relationships among different age-sex-race classifications of labor inputs; however, more interestingly they claim that, unlike the method other studies before them followed, the inclusion of capital is necessary for accurate estimates of elasticities among various groups. Although some studies omit a measure of capital mainly because of measurement problems, Grant and Hamermesh find that they cannot accept the hypothesis that capital and subcategories of labor are separable. Therefore, they state that capital should be included in models which estimate labor-labor elasticities even when the capital measurement is unreliable. Hamermesh and Grant (1979) admit that the error in measurement of capital is greater than that of labor. Measuring capital stock of different vintages and prices in order to develop an accurate estimate of capital to include in elasticity estimates is a difficult process and is subject to much error. However, in their 1981 article, they maintain that the inclusion of capital is necessary for more accurate elasticity estimates.

Another article (Grossman 1982), particularly relevant for the study of child labor given the parallel between immigration and child labor Q-policies, examines the question of whether natives and immigrants are substitutes in production. Using a translog production function, Grossman disaggregates labor into natives; legal, foreign born immigrants; and second generation immigrants. Similar to Field (1988) and Grant and Hamermesh (1981), she estimates factor share equations for nineteen Standard Metropolitan Statistical Areas (SMSAs) for 1969 and calculates the Hicks elasticities of complementarity evaluated at the mean value of the share equations. Grossman assumes capital's share to be one minus the sum of labor's shares; she admits that this definition results in an overestimation of capital's share since fringe benefits and Social Security are not accounted for in the estimates of labor's shares. For her estimates, Grossman uses cross-sectional data from the 1970 U.S. Census for employment and income, the *County and City Data Book* for output, and the *Census of Manufacturing* and the *Annual Survey of Manufacturing* for capital in the manufacturing sectors. For the informal sector, she assumes that the total capital stock is proportional to the manufacturing sector's capital stock. In her definition of output for each SMSA, she sums "local government revenues, total value added in manufacturing, total retail sales, total service receipts and, (*sic*) total wholesale sales" (p. 598). Using Zellner's seemingly unrelated regression technique to account for correlation between equations, she estimates the share equations using the 19 observations from SMSA level data and finds new immigrants to be complements rather than substitutes with native workers. She also rejects the hypothesis that the three coefficients that account for capital's interaction with labor subcategories are simultaneously zero. Rejection of this hypothesis implies that capital is not separable from labor; therefore, she includes it in her estimates of elasticities. This work is important for measuring the substitutability of child and adult labor because it gives an empirical framework for an issue--immigration policies--which theoretically parallels child labor policies.

There appears to be a consensus in the literature that a translog specification is the most appropriate specification for estimating elasticities and for determining the effect of either P or Q-policies. Because of their flexibility and ability to test separability restrictions, many models are based on this type of specification when there is sufficient data to allow for estimation of the extensive number of parameters. There also appears to be a consensus that estimation of share equations derived from translog production functions is the most appropriate method for calculating Hicks elasticities.

MODEL AND DATA REQUIREMENTS FOR THIS STUDY

Like other recent studies that examine the question of substitutability between factors of production, this research will use a translog production function and estimate factor share equations in order to obtain aggregate production coefficient estimates. These estimates will be substituted into formulas for Hicks elasticities in order to calculate elasticities between adult males, adult females, and children in order to determine if adults and children are substitutes in production in Egypt.

In order to estimate the parameters of the share equations, cross-sectional data for different governorates, rather than SMSAs, in Egypt will be used since, unlike the U.S., Egypt is not divided into SMSAs. For each governorate, data on output (GDP per governorate), employment for each labor subgroup, capital stock, and shares of total output for each type of labor will be used in regression analysis. In order to construct data for employment of each labor subgroup and data for labor's shares of total output to use for regressions, a sample of individual level data, including data on age, sex, governorate of employment, and wages, will be used to disaggregate labor according to the desired subcategories. Sample employment relative to sample size for each subgroup in each governorate will form a weight to estimate the employment of each subgroup per governorate to be used in regressions. Also from the sample individual data, the sample mean wages paid to each labor subgroup per governorate will be calculated. From the sample mean wages, total estimated wages paid to each subgroup may be determined for each governorate and then used to calculate each subgroup's share in producing the output for each governorate.

The most recent data set on individuals available at this time is the 1990-91 Households Income, Expenditure, and Consumption Survey collected by CAPMAS which includes observations on approximately 16,000 individuals of all ages living in all 26 governorates in Egypt. Since this survey includes workers aged six and above, this data will cover the groups of interest: children aged 6-14 and men and women above the age of 14. However, since this data is individual data, rather than firm data, it will not provide estimates for capital or output; these must be gathered from other sources.

AIM OF THIS RESEARCH

The media is filled with horror stories about child labor from all over the world. Stories about children who are abused and exploited are everywhere. This research does not attempt to reiterate the shocking details of those stories. There is no question that children in many countries work long hours for little pay. Rather, the aim of this research is use the Egyptian case to test the hypothesis that child laborers take jobs from adults. In the following pages, this research will attempt to answer the following two questions related to this hypothesis: 1) If child laborers are removed from the market, will adults be hired to take their places? and 2) At the new steady state equilibrium, how much higher or lower will adult employment be? In order to answer these questions, this research will examine the new child labor law as a Q-policy, similar to immigration Q-policies, to discover what effects an exogenous shift in supply will have on the labor market. It may be the case that removing child laborers from the market will have no effect on adult employment. Or the scale effect might dominate the substitution effect so that fewer, not more, adults will be employed. It might also be that reducing child labor causes household income to fall so that more women are forced to enter the labor force--shifting out the labor supply curve. There are a number of possibilities, but an empirical examination is necessary to determine what the net effect will be. The net result is important for policy makers who are considering new child labor laws. If it is true that adult unemployment is worsened by a high incidence of child labor, then a policy to reduce child labor will also increase adult employment in the short run. If however, the opposite is true and reducing child labor also leads to a reduction in adult employment then policies to reduce child labor will also reduce adult employment in the short run. While firms have the option of choosing a technology which relies less heavily on child labor in the long run, they do not have this option in the short run. For this reason, the results of the question of substitutability of children and adults may have important short run effects which must be considered by policy makers who wish to formulate optimal policies.

CHAPER 2

BACKGROUND INFORMATION

Although child labor has been the focus of much attention during this century, it is not a new phenomenon. Children have worked for centuries in various capacities--both as waged and non-waged labor. However, the attitudes at various points in history about the appropriateness of child labor have depended on the prevailing attitudes about childhood, including attitudes about the length of childhood, the role of children in society, and the basic characteristics of children--whether children were generally perceived as innocent or devious. Before the Industrial Revolution, child labor legislation was rare. Child labor laws were generally viewed by the public as government interference in private matters. During the period immediately preceding the Industrial Revolution as well as during the Industrial Revolution, however, those attitudes began to change and governments started to take a more active role in the regulation of child labor.

BRITISH CHILD LABOR AND THE INDUSTRIAL REVOLUTION

Horn (1994) states that during the late eighteenth and early nineteenth centuries in Britain, child labor was not only accepted by many but was also encouraged as a method of keeping children occupied and off the streets. During this period, children were generally viewed as evil, and children of the lower classes were encouraged to work so that they would not have time to engage in mischief. It was believed that if children's time were not occupied, they would be roaming the streets and committing crimes. According to Horn, child labor at the beginning of the Industrial Revolution was not limited to the well-known chimney sweeps and textile factory workers. During this period, children could be found working in industries such as textiles, metalworking, and mining as well as working in domestic service, agriculture, or chimney sweeping.

The first piece of legislation aimed at regulating child labor in Britain was the 1802 Health and Morals of Apprentices Act (Horn 1994); however, since the law affected only a small number of children, it was largely ineffective in regulating child labor. During the century that followed the introduction of this Act, a variety of legislation was passed in Britain with varying degrees of applicability. Some legislation targeted very specific groups such as apprentices, textile workers, or chimney sweeps while others attempted to deal with issues such as education or religious teaching for child workers. Included in this legislation were the Factory Acts of 1833, 1844, and 1853 which regulated the hours and conditions under which child textile workers were allowed to work. These Acts also required the provision of part-time education for children working in textile factories.

However, there were problems with this legislation. Initially, inspectors were few but were given the authority to impose fines immediately during inspections where violations of the Factory Acts were discovered. This authority, however, lead to corruption since inspectors were subject to bribery. After several years of unsatisfactory results, the system was modified so that violators were sent to court rather than being fined directly by inspectors (McCord 1991).

Additionally, there were problems in enforcing the letter of the laws. Although the Factory Act of 1933 prohibited work for all children under the age of 9 and required two hours of daily education for children under the age of 13, the enforcement of these standards was difficult. At that time in Britain, registration of births was not mandatory; therefore, many children did not possess formal evidence of their ages. For this reason, inspectors were required to estimate the age of children to determine if they should be allowed to work or should be provided with part-time education (McCord 1991). This method was not only subject to error on the part of the inspectors, but also allowed parents and employers the opportunity to convince inspectors that the children were above the minimum ages set forth in the Factory Act.

By the mid-eighteen hundreds, part-time education had become a popular strategy for reducing child labor. By applying a system of part-time education, it was believed that the children would be removed from work for a period of time everyday--thus reducing the quantity of child labor--and would, in addition, be receiving valuable education (Horn 1994). However, during the 1870 and 1880's the concept of part-time education was abandoned in favor of compulsory education for all children. Despite the numerous laws passed during the 1880's in Britain, in 1878 the minimum age required to become employed in factories and workshops was only ten--with certain occupations banned for all children. By the time extensive regulation was passed and enforced, however, much child labor demand had already been eliminated. Because of advances in technology and the added expense of providing the compulsory education to children, many employers chose to substitute away from child labor either in favor of adults or machines.

THE UNITED STATES AND CHILD LABOR

In the United States during this period, child labor was also prevalent. According to Garraty (1968), children frequently worked outside on farms prior to the Industrial Revolution. During the late 1800's, he also states that it was common for entire families to be hired to work in textile mills. He states that many Americans, like the British citizens Horn describes, believed work to be beneficial for children because it taught discipline and kept them off the streets and out of trouble.

As attitudes about child labor began to change, however, the abolition of child labor began to be included in the politcal demands of US workers. During the 1840's the New England Working Men's Association began to circulate petitions calling for a ten-hour work day and the removal of child labor (Rayback 1959). The petitions were signed and then sent to state legislatures where in 1847, the legislatures began to pass child labor legislation.

The earliest attempts at legislation were largely unsuccessful because the laws allowed for exceptions to the ten-hour work day upon agreement of the workers and for child employment with the written permission of parents (Rayback 1959). Although most workers maintained that they would not sign contracts which included such exceptions, companies resorted to black-listing men who refused to sign. Therefore, the legislation was rendered ineffective.

In the years that followed, legislation restricting child labor was passed in a variety of states (Rayback 1959). In 1848, Pennsylvania enacted a law which, among other things, prohibited child labor in textile factories. In 1851, New Jersey forbade employment of children under 10 in all factories and mills. In 1852, Ohio passed a law prohibiting child labor under the age of 14. However, by 1880, only 7 states had laws regulating the minimum age of employment of children. By 1900, the number of states which had passed such laws had risen to 26.

Enacting legislation, however, was only part of the battle. Even when states attempted to regulate child labor, they were often unsuccessful, depending on the state in which the laws were proposed and on the particular judges on the State Supreme Courts where the laws which managed to pass through their state legislatures were challenged. For instance, a law in Massachusetts in 1874 which limited the working hours of women and children to 10 hours was allowed to stand by the Massachusetts courts; however, a similar law passed in Illinois in 1893 was declared unconstitutional by the Illinois court (Garraty 1968). And not only were the state laws to be challenged. In 1916 when the United States Congress passed a law regulating child labor, it was declared unconstitutional by the United

States Supreme Court. Another child labor law (1919) as well as a proposed Constitutional Amendment (1924) regarding child labor were also defeated. Not until 1934 did Congress manage to pass a law--the National Industrial Recovery Act (NIA)--containing child labor provisions that was not declared unconstitutional. The NIA contained provisions to prohibit child labor in the textile industries. Finally, in 1938 the Fair Standard Act formally declared child labor to be illegal (Garraty 1968).

INTERNATIONAL CHILD LABOR REGULATION

International concern for the problem of child labor became apparent in 1919 after the formation of the International Labour Organisation (ILO). The ILO, from its inception, has been involved in developing international standards for regulating child labor--especially regarding the minimum age at which a child is eligible to begin working. In 1921, the ILO formulated Agreement No. 5 which prohibited night work for children under the age of 18 in industrial production and set the minimum legal working age for industrial production at 14 (Azer 1988, p.7). However, application of this agreement was limited to industrial production, and therefore, excluded many forms of employment in which children were engaged such as "shops and offices, hotels, cafes, and places of entertainment" (Johnson 1970, p. 221). In 1932, the scope of the Agreement was broadened to prohibit non-industrial employment for children under 14 with the provision that children 12-14 could engage in non-strenuous work when not in school.

Later in 1937, the minimum age was increased to 15 with the age for light work increased to either 13 or 14 depending on the occupation. In 1948, Agreement No. 90 was drafted, requiring all workers less than 18 to work no more than seven hours daily and prohibiting night work in all occupations for the same age group. In 1973, the minimum age was increased further to 16 for developed countries while keeping the minimum at 15 for developing countries.

EGYPTIAN CHILD LABOR LAWS

In Egypt, the international standards have not always been met. Although Egypt began regulating child labor in 1909 by prohibiting child labor under the age of nine years old, the current Egyptian labor law No. 137, 1981 sets the minimum age of entrance for occupations not considered harmful to health or morals at 12, not 15 as set forth by the ILO in 1973. If Egypt raises the minimum age as proposed to 14, it will still be below the ILO's standard.

In addition to setting a minimum age for entering the labor force the current Egyptian labor law No. 137, 1981 also sets forth other provisions aimed at protecting child laborers. For instance, child workers are to be examined by a physician upon their employment to determine whether or not they are healthy enough to be working and then are to be examined at least once annually. Additionally, the names of all child workers are to be posted in a visible location near the entrance of the work site and all children are to be given an identification card. Children are not permitted to work on weekends or holidays as well as at night and are to be given rest periods and a one hour lunch break on the days they work. Also, children are to receive one glass of milk everyday to be provided by the employer (Azer and Ramzy 1992).

CURRENT STATE OF CHILD LABOR IN THE WORLD

Despite numerous laws countries regulating child labor, in many countries, especially in the third world, child labor is still prevalent. How many working children are there in the world? The answer to this question is unclear. There are problems associated with trying to estimate the number of working children in the world. Different countries not only use different definitions of the length of childhood but also use different definitions of work. While some countries may count children working at home for their parents in agricultural fields as workers, others may only count children who earn monetary wages as workers and still others may only count children who work full-time (as opposed to seasonal or part-time work) and earn monetary wages as workers. Despite the difficulties in estimating the number of child workers, the ILO estimates the number of working children less than 15 years old in 1979 to be 52 million worldwide (Azer and Ramzy 1992). UNICEF however, estimates the number to be much higher at 75 million aged 8-15 in the third world alone (Azer and Ramzy 1992). By 1988 it is estimated that the number of children less than 15 years old who worked on a regular basis (does not include seasonal work) to have risen to 100 million (Azer and Ramzy 1992). Currently, the ILO estimates there to be as many as 200 million working children in the world (ILO 1996).

STATE OF EGYPTIAN CHILD LABOR

Over the past two decades, the number of working children in Egypt has steadily increased. In 1974 there were 256,000 working children aged 6-12 in Egypt and in 1984 there were 1,014,300 (Azer and Ramzy 1992). By 1988 that number had risen to 1.4 million children aged 6-12 and 2.2 million aged 6-14 (Fergany 1993).

Child labor in Egypt is concentrated in rural areas. Azer (1986) found that 70% of children were working in rural areas. Although children in Egypt work in various industries such as leather tanning, weaving, and textile manufacturing as well as in supporting jobs such as cleaning and errand running, agriculture is by far the most dominant area of employment for Egyptian children.

IMPORTANCE OF CHILD LABOR SUBSTITUTABILITY STUDIES

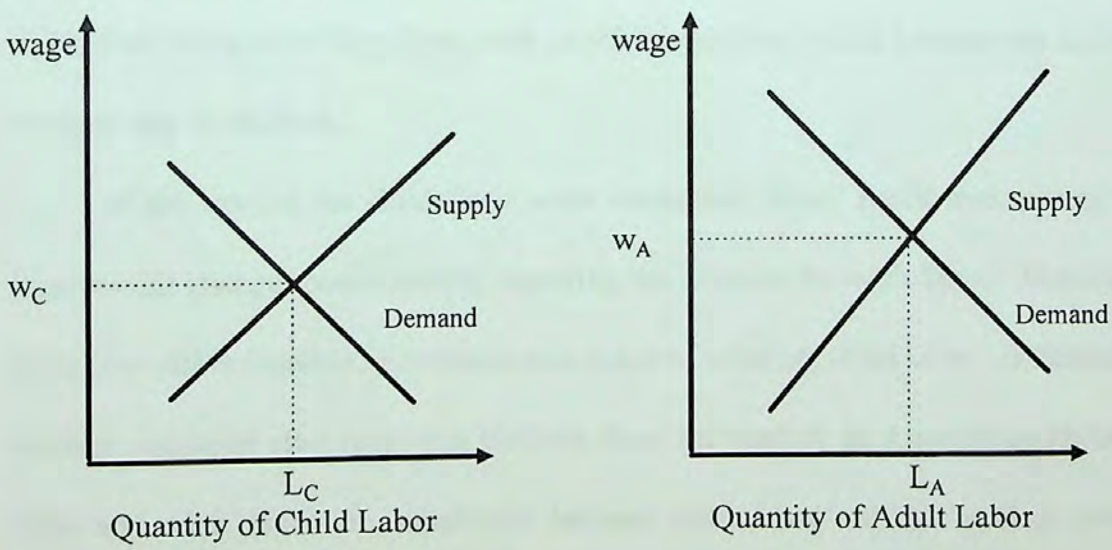
It is possible that with such high numbers of children working, policies aimed at reducing child labor may have strong effects on the market for other kinds of labor besides child labor. For this reason, studies about the substitutability of child and adult labor are important. While it may be the case that in the long run, firms will change their technology in response to policies which restrict the use of child labor, in the short run, a firm's capital and, therefore, technology is fixed so that reducing the supply of child labor may have effects which need to be considered before implementing a policy to reduce child labor. In Egypt, for instance, the number of child workers in 1986 aged 6-14 represented 11% of Egypt's total labor force (Fergany 1993). Removing such a large percentage of the labor force could potentially have a large impact on the employment of other workers. This impact is important information to know before making and implementing child labor legislation.

CHAPTER 3

THEORY OF CHILD LABOR LAWS

As Azer & Ramzy (1992) have found, there are many reasons children work. However, the fact that children wish to supply their labor does not necessarily imply that employers will hire them. If there were no demand for child labor at any wage for which children are willing to work, there would be no children working in the market. However, it is very easy to find children working in Egypt, so it must be the case that there is demand for child labor in Egypt at wages for which children are willing to work.[3] Since there is supply and demand for child labor in Egypt, we may graphically represent the market for labor, including child labor, if the labor market is in equilibrium as follows:

Figure 3.1 Initial Market Equilibrium



Where: w_C: equilibrium child wage
L_C: employment equilibrium of children
w_A: equilibrium adult wage
L_A: employment equilibrium of adults

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[3] The term "willing" is used here loosely. It implies that children have been observed by researchers (Azer and Ramzy, ILO, Nieuwenhuys, *etc.*) working for very low wages and are, therefore, assumed to have made this choice as a result of maximizing their preferences. It does not imply that parents or employers never force children to work against their wills.

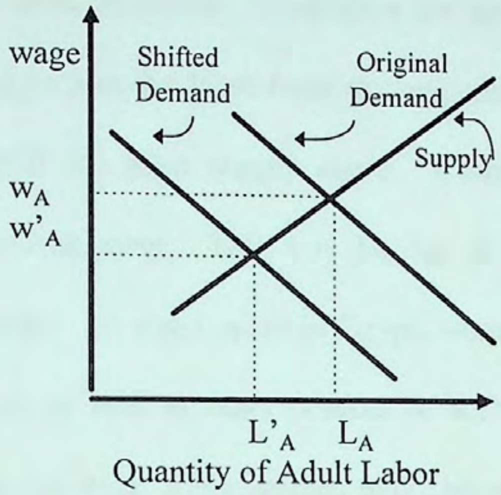
REMOVAL OF CHILDREN FROM THE LABOR MARKET

If the new law is passed and child workers are removed from the market, however, the initial equilibrium will change. Since the initial labor markets consist of all workers, including children, who are participating in the labor market, removing some workers will have an effect on the wages and/or employment of the remaining workers by shifting the labor supply curve--thus altering the market equilibrium.

Assume that the government will *strictly enforce* the new law and all under-aged workers will be removed from the market. Perhaps, thousands of police officers would walk door to door and drag away any child under the age of 14 who was found working. The method of enforcement is not of concern here; its effect is. If the government were able to reduce the supply of child labor, this would constitute an exogenous shift in the supply of child labor--the goal of Q-policies such as child labor laws which increase the minimum legal working age of children.

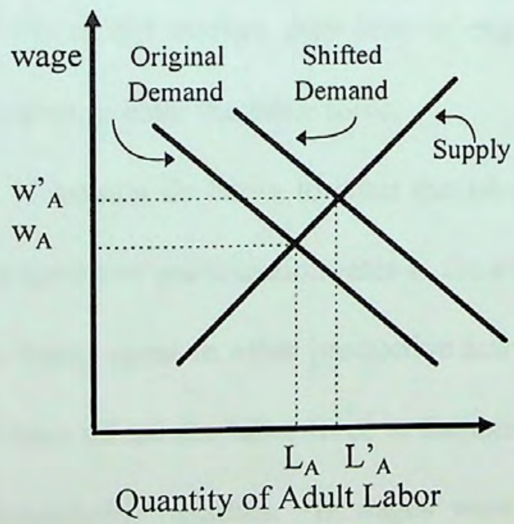
If the market for child labor were eradicated, firms' profit maximizing choices of labor would change, consequently, changing the demand for adult labor. Demand for adult labor may either increase or decrease as a result of reducing child labor. If demand for adult workers increases after removing children from the market, as depicted in Figure 3.2, then child and adult labor are substitutes because adult labor will be used in production to compensate for the lost children. On the other hand, if demand for adult labor decreases, as in Figure 3.3, then child and adult labor are complements because child and adult labor tend to be used together in production.

Figure 3.2 Decreased Demand for Adult Labor



Where: w_A: initial equilibrium adult wage
w'_A: new equilibrium adult wage
L_A: employment equilibrium of adults
L'_A: new employment equilibrium of adults

Figure 3.3 Increased Demand for Adult Labor



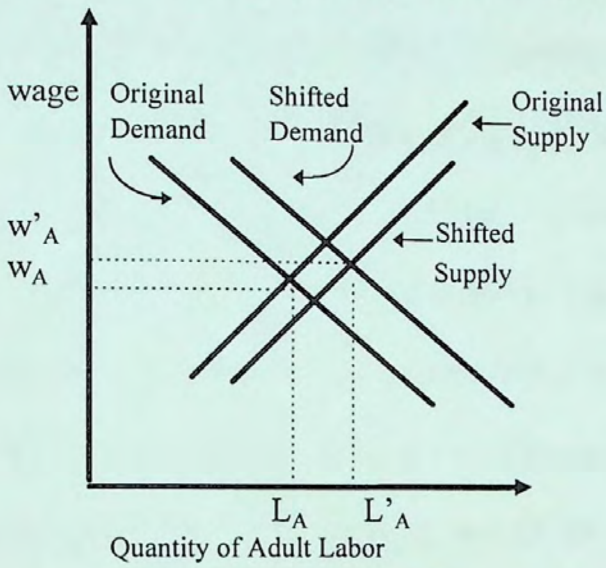
Where: w_A : initial equilibrium adult wage
w'_A : new equilibrium adult wage
L_A : employment equilibrium of adults
L'_A : new employment equilibrium of adults

INCREASE IN FEMALE LABOR SUPPLY

To complicate matters, it is important to note that according to Azer and Ramzy (1992, pp. 36-7), 30% of family income in their study came from child labor. Removing children from the labor force in some families constitutes a significant reduction in family income. In this case, it is important to remember that children are part of a household which makes joint decisions. If children are no longer allowed to work, some women may be induced to join the labor force to compensate for the reduction in household income. This may shift the adult supply curve. Currently in Egypt, women have low labor market participation rates. This may be due to their families' reliance on women's household production. In some areas in Egypt, women work in agricultural fields, make bread, raise children, as well as other productive activities. If children were forced out of the labor market, however, some women may choose to join the labor market either because market wages increase above their reservation wages or becasue the loss of children's wages lowers their reservation wages. It may be the case that in some families women and children will exchange market and household production responsibilities so that when the children are forced out of the market, they start to engage in unregulated household production while women start to enter the labor force.

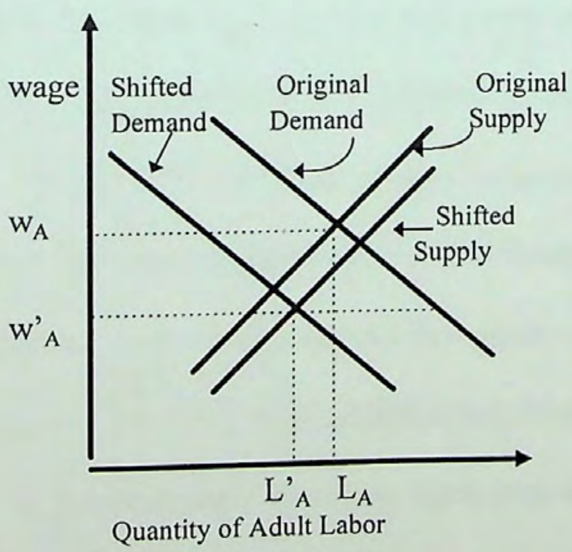
If women do begin to enter the labor force, this will shift the supply curve. Since women have low participation rates at the existing wage, it is reasonable to assume that their time is better spent in other productive activities outside of the labor force; otherwise, they would have joined the labor force at the existing wage in order to maximize their utilities or their households' utilities. If wages were to increase, however, the opportunity cost of household production would also increase. Some women who were not previously in the labor force may choose to join the labor force, shifting out the supply curve as in Figures 3.4 and 3.5. It is obvious from Figures 3.4 and 3.5 that the net effect of removing child labor will depend on the magnitude of supply and demand shifts. It may be the case that the reservation wage supply of females in Egypt is so high that even if the market wage increases because of the removal of children from the market, the effect on women's labor force participation is negligible; however, the possibility must be considered.

<u>Figure 3.4</u> Entrance of Women with Increased Demand for Adult Labor



Where: w_A : initial equilibrium adult wage
w'_A : new equilibrium adult wage
L_A : employment equilibrium of adults
L'_A : new employment equilibrium of adults

<u>Figure 3.5</u> Entrance of Women with Decreased Demand for Adult Labor



Where: w_A : initial equilibrium adult wage
w'_A : new equilibrium adult wage
L_A : employment equilibrium of adults
L'_A : new employment equilibrium of adults

THEORY VERSUS EMPIRICAL ESTIMATION

Although theoretical analysis sheds some light on the possible results of the proposed child labor law in supply and demand context, it is not without problems. As Grant and Hamermesh (1981) point out, estimating a system of equations which include both supply and demand equations will result in collinearity. Ideally, a set of instruments would then be chosen to correct the problem. However, given the difficulty in specifying a system containing both supply and demand equations as well as the difficulty in choosing an appropriate set of instruments, they claim that either price or quantity should be assumed to be fixed. In an earlier article (Grant and Hamermesh 1979), they state that when labor is disaggregated by age, as this research does for the case of child labor, it is more appropriate to assume factor quantities rather than factor prices to be fixed. They state that although some labor supply curves may be responsive to changes in wages others are likely to be unresponsive to changes, "so that on the net the age structure of the work force is better treated as exogenous"(p. 521). For this reason, when labor is disaggregated by age they argue for assuming that quantity rather than price is constant.

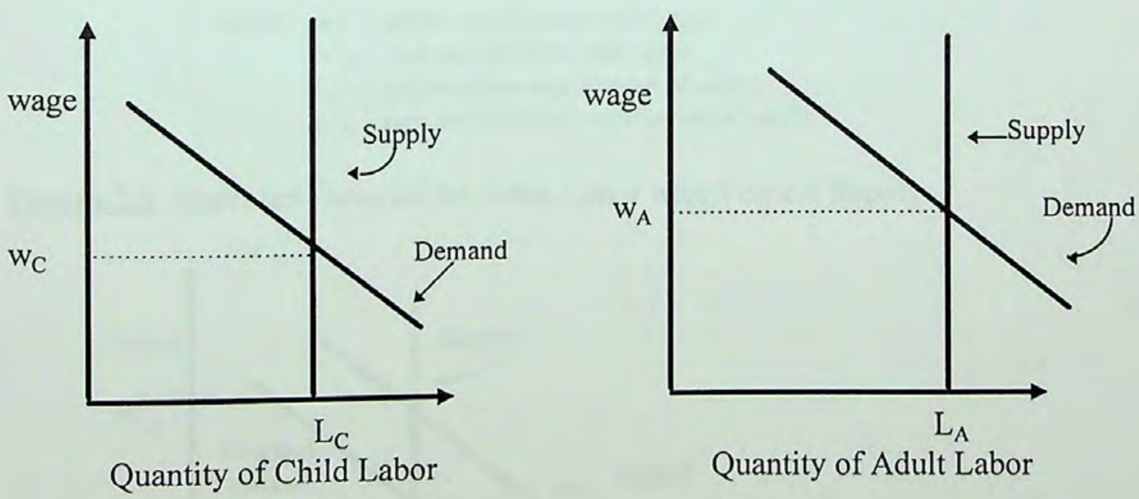
Additionally, when data is highly aggregated--as in this study, it is more appropriate to assume that factor quantities rather than factor prices are fixed. In their 1979 article, they are critical of studies which assume that prices rather than quantities are fixed when data are either divided according to geographical locations or highly aggregated.

If this study were estimating elasticities for one industry where the industry must take the prices set in the remainder of the economy as given, it might be reasonable to assume that prices, not quantities were fixed. Since this research estimates elasticities for the entire Egyptian labor market rather than for a particular Egyptian industry, it is more realistic to assume that prices within the economy are flexible than to assume the number of workers to be flexible. At any point in time, the number of workers in the labor force is constrained by the number of people in the economy who are capable of work. Since the supply of domestic workers has an upper bound and since Egypt requires working permission for non-Egyptians to enter the labor force, the total supply of workers in the labor force is better assumed to be fixed than flexible. Since this study disaggregates labor by age, chooses points of observations across geographical regions, and uses highly aggregated data, it will follow the method outlined by Grant and Hamermesh and assume factor quantities rather than factor prices to be fixed.

MODIFICATION OF GRAPHS USING INELASTIC SUPPLY

If the previous graphical representations using upward sloping supply curves to examine the labor market are adjusted using an inelastic supply curve, the initial equilibrium may be depicted as shown in Figure 3.6.

Figure 3.6 Initial Equilibrium with Vertical Supply

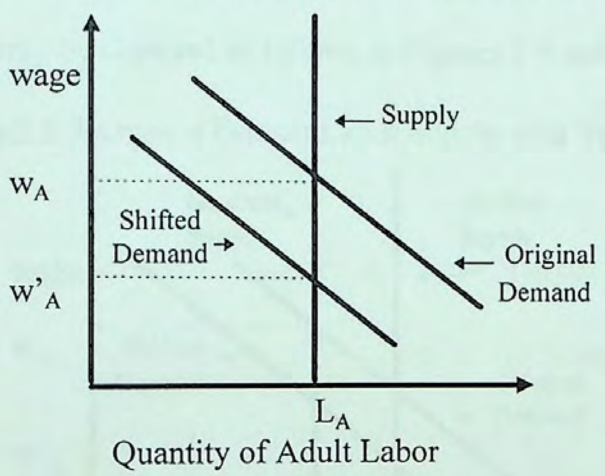


Where: w_C: equilibrium child wage
L_C: employment equilibrium of children
w_A: equilibrium adult wage
L_A: employment equilibrium of adults

SHIFT IN ADULT DEMAND WITH VERTICAL SUPPLY CURVE

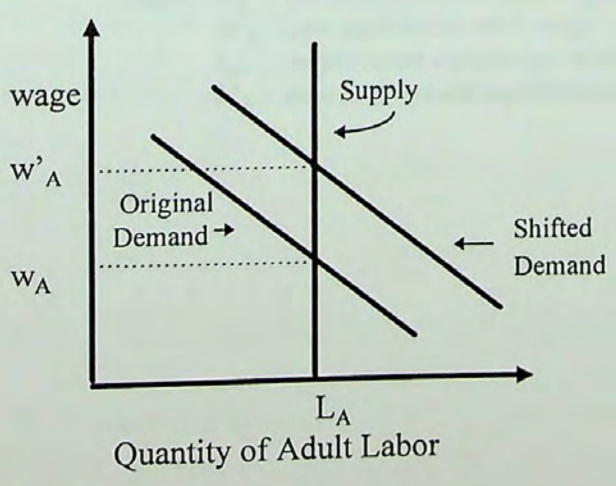
As in the former case, if child laborers are removed from the labor force, there will be an inward shift in the labor supply curve. This will cause a shift in the demand curve for adult labor. As with the case of an upward sloping curve, an outward shift in demand implies that child and adult labor are substitutes while an inward shift implies they are complements as Figures 3.7 and 3.8 illustrate.

Figure 3.7 Decreased Demand for Adult Labor with Vertical Supply



Where: w_A : initial equilibrium adult wage
w'_A : new equilibrium adult wage
L_A : employment equilibrium of adults
L'_A : new employment equilibrium of adults

Figure 3.8 Increased Demand for Adult Labor with Vertical Supply



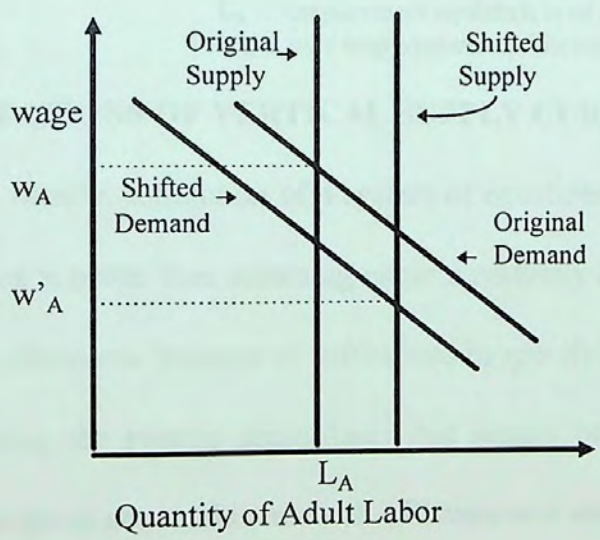
Where: w_C: equilibrium child wage
L_C: employment equilibrium of children
w_A: equilibrium adult wage
L_A: employment equilibrium of adults

Unlike the previous case in Figure 3.2 where the decrease in child labor caused an change in the employment of adults, the entire result of the shift in supply here is observed as a change in wages, not employment. This is due to the assumption of a vertical supply curve. Since factor quantities are assumed to be fixed, the employment of adults will not change.

INCREASE IN FEMALE LABOR SUPPLY WITH VERTICAL SUPPLY CURVE

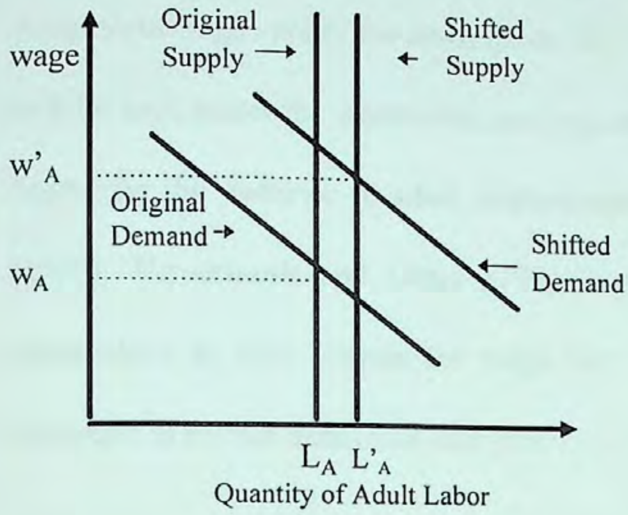
Similarly, the effect of an increase in female labor supply using a vertical supply curve may be depicted as follows in Figures 3.9 and 3.10:

Figure 3.9 Increased Female Labor Supply with Vertical Supply and Decreased Demand



Where: w_A : initial equilibrium adult wage
w'_A : new equilibrium adult wage
L_A : employment equilibrium of adults
L'_A : new employment equilibrium of adults

Figure 3.10 Increased Female Labor Supply with Vertical Supply and Increased Demand



Where: w_A : initial equilibrium adult wage
w'_A : new equilibrium adult wage
L_A : employment equilibrium of adults
L'_A : new employment equilibrium of adults

LIMITATIONS OF VERTICAL SUPPLY CURVE

Ideally, estimation of a system of equations which includes both supply and demand relations is better than assuming either a perfectly elastic or a perfectly inelastic labor supply curve. However, because of difficulties in specifying such a system as well as difficulties in estimating the system necessitates that supply be assumed to vertical or horizontal. For reasons given above, this research will assume a vertical supply curve.

There are limitations to this approach, however. Since the aim of this research is to discover whether or not child labor is substitutable for adult labor and to determine by how much, if any, adult labor will increase or decrease as a result of decreasing child labor, assuming a vertical supply curve is problematic. By assuming a vertical supply curve, one assumes that decreasing child labor has ***no*** effect on adult employment (without female entrance) and that the entire effect will be observed as increased or decreased wages. This may not be the case. Therefore, in an attempt to gather some meaningful information from the estimation, initially a vertical supply curve will be assumed to obtain parameter estimates and to calculate elasticities, and these estimates will be used to determine the bounds for the decrease in wages under the assumption of a vertical supply curve. Then the same estimates will be used under the alternative assumption of a horizontal supply curve to determine the bound for the decrease in adult employment. This exercise follows the work of Johnson (1980), Hamermesh and Grant (1981), and Grossman (1982) who performed similar calculations to find bounds for wage and employment changes. This exercise will be discussed in further detail in a later chapter.

CHAPTER 4
MODEL SPECIFICATION

Since the objectives of this research are to determine if adult employment will increase if child laborers are removed from the market and to estimate how many adults will gain or lose jobs as a result of removing child labor, this research must specify a model which will be able to answer these questions. In order to determine the effect on adult employment, it is necessary to have a measure of how changes in the employment of one group of workers affect the employment of other workers. Demand elasticities provide such a measure. Therefore, this research will estimate demand elasticities for adult and child workers in order to determine the affect on adult employment of decreasing the supply of child laborers to the market.

CHOICE OF PRODUCTION FUNCTION

As far as the choice of a production function is concerned, there are several options; however, each has its benefits and drawbacks. The Cobb-Douglas production function which has been used in some research in the past has the benefit that it is easily linearized and the coefficients are simply shares of each factor in production. However, the Cobb-Douglas production function also constrains both Hicks elasticities of complementarity and Allen elasticities of substitution between all pairs of factors to be equal to one. Therefore, an initial choice of this production function is inappropriate for this research since the goal of this research is to estimate elasticities rather than to assume they are equal to one. It may be the case that once the parameters of a more general function have been estimated, the hypothesis that the production function is a Cobb-Douglas may be accepted; however, this is a restriction which must be tested rather than assumed.

On the other hand, some researchers have chosen the Constant Elasticity of Substitution (CES) production function, a generalization of the Cobb-Douglas production function. This production function, however, also has drawbacks. In addition to the fact that, in general, it may not be linearized but must rather be approximated in order to be estimated, the CES constrains all elasticities to be equal to one another. Unlike the Cobb-Douglas, the CES does not necessitate that all elasticities be equal to one and therefore is more flexible than the Cobb-Douglas; however, the CES is also too restrictive for this research since there is no reason to initially assume that the elasticities to be estimated are equal to one another. This restriction must be tested not assumed.

In attempt to be less restrictive, some authors have chosen to estimate a multilevel CES, a further generalization of the Cobb-Douglas. Although this specification is less restrictive than the Cobb-Douglas or the CES because it allows for different elasticities between different subgroupings of factors, it is still too restrictive for this research. By choosing the multilevel CES, one is forced to decide which factors will be grouped together and therefore which elasticities will be constrained to equal one another. Although it may sometimes be appropriate to group certain factors together, it is not easy to determine which factors will be assumed to have the same elasticities. In addition, this grouping cannot be tested using the multifactor CES, so imposing the restriction that groups have the same elasticities adds an untestable constraint to the system of equations.

The translog function, another Cobb-Douglas generalization, which has been used by many authors in recent years, has the same problem as the CES in that it may not directly be linearized and therefore must be approximated using a second order Taylor expansion. However, unlike the Cobb-Douglas, CES, or multilevel CES production functions, the translog places no restrictions on the elasticities between factors. In addition, the translog function may also be used to test separability restrictions to discover whether one or more factors may be omitted from the others' elasticities without affecting the estimates. For these two reasons--the less restricted elasticity estimates and the ability to test separability restrictions, this research will use a translog production specification in an attempt to obtain more accurate results than from using either the Cobb-Douglas, CES, or multilevel CES production functions.

CHOICE OF VARIABLES

After determining what production function is the most appropriate for the problem at hand, it becomes necessary to decide which variables to include in the specification. Since this research aims to test the substitutability of adults and children, it is necessary to include measures of both adult and child labor in a model specification. Because changing the law on child labor will affect household labor supply, it is important not only to include male labor and child labor in the specification but to also include female labor since it may be the case that removing children from the labor force will force some women to enter the labor force out of economic necessity. In addition, capital must also be considered in the specification. As stated before, omitting capital assumes separability of capital and all labor inputs; however, this assumption may not be valid; therefore, capital should be included in the specification. Given that the translog production function is the most appropriate function to use in this case and that child, male, and female labor as well as capital should be included in the specification, this research will use a model derived from a translog production fuction to estimate labor-labor elasticities. In general, a production function which includes capital and child, male, and female labor may be shown as follows:

$$Q = F(X_C, X_M, X_F, X_K) \qquad \textbf{Equation (4.1)}$$

where Q : *output* $\quad X_C$: *child workers*

X_M : *male workers* $\quad X_F$: *female workers*

X_K : *capital*

As stated previously, the translog production function may be approximated by a Taylor series expansion. Using the specific case of capital and child, male and female labor, the production function in Equation (4.1) may be approximated as follows:

$$\ln Q = \ln a_0 + \sum_i a_i \ln X_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln X_i \ln X_j \qquad \textbf{Equation (4.2)}$$

where a_0, a_i, γ_{ij} *are technological parameters*

$i, j = \{C, M, F, K\}$

Hamermesh (1993) states that whenever possible, production functions should not be estimated directly. Therefore, Equation (4.2) should be modified to obtain a better estimable form. In order to modify this equation to estimate parameters, it is necessary to examine this equation in a profit maximization context. By differentiating the profit function, it is found that profit is maximized at the point where the marginal products of all factor inputs are equal to their prices.[1] Mathematically, this may be represented as:

$$\frac{\delta Q}{\delta X_i} = P_i \qquad i = \{C, M, F, K\} \qquad \textbf{Equation (4.3)}$$

By using the result that the marginal product of a factor equals its wage, the initial production function in Equation (4.2) may be modified to obtain factor share equations which, unlike the former production function, are more appropriate to estimate. Differentiating the production function (Equation (4.2)) with respect to the natural logarithm of factor inputs and substituting Equation (4.3) into the resulting first order conditions gives the following system of equations which may then be estimated[2]:

---

[1] See the Mathematical Appendix A for the derivation of these conditions.

[2] See the Mathematical Appendix B for the derivation of these conditions.

$$S_i = \frac{X_i \; P_i}{Q} = \frac{\delta \ln Q}{\delta \ln X_i} = a_i + \sum_j \gamma_{ij} \ln X_j \qquad \textbf{Equation (4.4)}$$
$$i = \{C, M, F, K\}$$

More explicitly, this research will estimate the following system of share equations:

System (4. 1)

$$S_C = a_C + \gamma_{CC} \ln X_C + \gamma_{CM} \ln X_M + \gamma_{CF} \ln X_F + \gamma_{CK} \ln X_K$$
$$S_M = a_M + \gamma_{MC} \ln X_C + \gamma_{MM} \ln X_M + \gamma_{MF} \ln X_F + \gamma_{MK} \ln X_K$$
$$S_F = a_F + \gamma_{FC} \ln X_C + \gamma_{FM} \ln X_M + \gamma_{FF} \ln X_F + \gamma_{FK} \ln X_K$$
$$S_K = a_K + \gamma_{KC} \ln X_C + \gamma_{KM} \ln X_M + \gamma_{KF} \ln X_F + \gamma_{KK} \ln X_K$$

where S_c: *share of child labor in total revenue*

S_M: *share of male labor in total revenue*

S_F: *share of female labor in total revenue*

S_K: *share of captial in total revenue*

Subject to the constraints:

1) $\gamma_{CM} = \gamma_{MC} \quad \gamma_{CF} = \gamma_{FC} \quad \gamma_{CK} = \gamma_{KC}$ **Constraint (4.1)**

$\gamma_{MF} = \gamma_{FM} \quad \gamma_{MK} = \gamma_{KM} \quad \gamma_{FK} = \gamma_{KF}$

2) $\sum_i a_i = 1 \qquad i = \{C, M, F, K\}$ **Constraint (4.2)**

$\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$

Like past research, this research also imposes the above restrictions of 1) symmetry and 2) homogeneity on the system of equations. Imposing symmetry implies that factors related to each other in the same whether the share of factor i or factor j is being considered. Imposing homogeneity implies that the production technology exhibits constant returns to scale. That is, increasing all inputs by a factor, λ, increases output by a factor, λ.

From System (4.1), Hicks partial elasticities of complementarity may be calculated. The definitions of Hicks elasticities are as follows (Grant and Hamermesh 1979):

$$c_{ij} = \frac{f\, f_{ij}}{f_i\, f_j} \quad i \neq j$$ **Equation (4.5)**

where c_{ij}: *elasticity of factor i with respect to factor j*

$f = \ln Q$

f_j : *partial derivative of f with respect to factor j*

f_i : *partial derivative of f with respect to factor i*

f_{ij} :*2nd partial derivative of f with respect to factors i and j*

For the translog productions function, however, these elasticities may be reduced to the following (Grant and Hamermesh 1979):

$$c_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j}$$ **Equation (4.6)**

$$c_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2}$$ **Equation (4.7)**

where S_i *is the share of factor i in total revenue*

S_j *is the share of factor j in total revenue*

Given the above definition of Hicks elasticities for the translog case, it is clear that in order to estimate the elasticities, γ_{ij} must be obtained. To obtain γ_{ij} this research will use the method other research (Hamermesh and Grant 1981, Field 1988, Grossman 1982) has used--estimation of a system of share equations.

DATA REQUIREMENTS

In order to estimate this system of equations, it is necessary to have different observations for all variables in the system. The difficulty in estimating this system is in the choice of points of observation. For U.S. studies, observations were collected from different Standard Metropolitan Statistical Areas (SMSAs) (Hamermesh and Grant 1981, Grossman 1982); however, since Egypt is not divided into SMSAs as the U.S. is, this research will use data from Egyptian governorates. Governorates instead of firms in a particular industry in Egypt are chosen both because of the difficulty in obtaining detailed industry level data and because when industry level data is used, elasticity estimates may pick up employment changes due to expansion or contraction of an industry rather than employment changes due to changes in relative supplies of factors (Hamermesh 1993). By using different geographical locations-- governorates--across different industries, this research avoids the problem of attributing employment changes to expansion or contraction of a particular industry--at the cost of estimating an aggregate production function which implicitly assumes all industries in all governorates are producing a homogeneous product. Although production of a homogeneous product is an unrealistic assumption, because of data difficulties as well as improper attribution of employment changes to changes in relative labor supplies rather than to expansion or contraction of an industry, this research will use governorate level data rather than industry level data. Therefore, this system will be estimated to obtain overall elasticity estimates for Egypt using one observation per variable for each governorate. There are 26 governorates in Egypt, and although this small number of observations is not ideal, published research in this area (Grossman 1982) has used 19 observations to estimate the same number of share equations (four) with the same number of variables (four).

The right hand side of each share equation includes observations on child, male, and female labor and capital. These will be defined for each governorate as follows:

X_C: Total workers aged 6-14 in each governorate
X_M: Total male workers over age 14 in each governorate
X_F: Total female workers over age 14 in each governorate
X_K: Total capital stock in each governorate

The additional observations need for each governorate are as follows:

S_C: Share of child labor costs in total revenue.
S_M: Share of male labor in total revenue
S_F: Share of female labor in total revenue
S_K: Share of capital in total revenue

The share of capital, S_K, will be defined as one minus the sum of labor's shares:

$$S_K = 1 - (S_C + S_M + S_F) \qquad \textbf{Equation (4.8)}$$

DEFINITION OF SHARES

Shares will be calculated for each governorate by using a sample of each group of workers and averaging the wages for the group in order to obtain the group's sample mean wage. The group's sample mean wage will then be multiplied by the total number of workers in each group in the population to obtain the estimated total wages per group in each governorate. Then by dividing the total wages by total revenues in each governorate, estimated $S_i \; i = \{C, M, F\}$ may be obtained. Mathematically these calculations may be represented:

$$\overline{w}_i = \frac{\sum_j w_j}{n} \quad i = \{C, M, F\} \qquad \textbf{Equation (4.9)}$$

$$T_i = \overline{w}_i * X_i \quad i = \{C, M, F\} \qquad \textbf{Equation (4.10)}$$

$$S_i = \frac{T_i}{Q} \qquad \textbf{Equation (4.11)}$$

where $\overline{w}_i$: *sample wage of group i for each governorate*

n : *number of workers per group in sample for each governorate*

T_i : *total wages paid to each group for each governorate*

X_i : *total population of each group for each governorate*

S_i : *share of group i in total revenue for each governorate*

Q : *total revenue per governorate*

In summary, this research will use data from the 26 governorates in Egypt to estimate parameters in a system of share equations and will substitute those parameter values into elasticity formulas to determine if child and adult labor are substitutable in production in Egypt.

CHAPTER 5

DATA CONSTRUCTION

MODIFICATION OF ORIGINAL STUDY

Initially, this study was designed to measure the overall substitutability of child, male, and female labor in Egypt. Once the data needed to obtain the desired estimates were sought, however, it became clear that a modification of the scope of the study would be necessary. In Egypt, as in many other developing countries, data inavailability is a serious obstacle to research. In addition, it is common for different governmental agencies to report different figures for the same variable during the same year.

When the initial study was designed, it was determined that measures of GDP and capital stock per governorate would be needed; however, no officially published figures are currently available for these two quantities. While several attempts were made to estimate the GDP and capital stock per governorate, these figures may not be considered reliable. For this reason, the main results of this study have been limited to the question of the substitutability of child and adult workers in industry. Since officially published numbers are available for industrial production, capital stock, and overall industrial employment per governorate, this data will be used to estimate the desired elasticities.

While the parameter estimates arising from other types of data constructions may not be considered reliable, they are nonetheless interesting. Although they do not provide definitive answers about the question of overall substitutability of child and adult workers in Egypt, they do provide some insight into what sorts of elasticity estimates might be obtained if a better data set were available. For this reason, parameter and elasticity estimates using different data sets as well as a discussion about their similarities and differences will be included in the following chapter which discusses the main results of this study.

DATA SOURCES

The data for this research were taken from a variety of sources. The sample data for labor force estimates and wages were taken from the 1991 *Household Income, Expenditure, and Consumption Survey* (HIECS) conducted by the Central Agency for Public Mobilisation and Statistics (CAPMAS). Industrial value added, capital stock, and employment figures were taken from the *Bulletin of Annual Industrial Production Statistics for the Public Sector 1990/91* and the *Bulletin of Annual Industrial Production Statistics for the Private Sector 1990/91* published by CAPMAS. In addition, for the alternative methods of data construction, overall employment data were constructed from the *Census of Population, Housing, and Establishments* published by CAPMAS. GDP and investment figures were taken from *World Tables* compiled by the World Bank. Agricultural value added per governorate was taken from *Bulletin of Income Estimates of the Agricultural Sector, Year 1991.* Population data for aggregate and governorate level data were taken from *The Statistical Yearbook* compiled by CAPMAS.

To clarify, the main estimates for this study will be obtained using industrial data since it offers the best available matching of output, employment, and capital stock. In addition, other estimates will be obtained using a variety of other sources and construction techniques in order to compare their results to determine if any tentative conclusions may be drawn about the overall substitutability of child and adult labor in Egypt.

REPRESENTATIVENESS OF THE HIECS

Since the HIECS is a *sample* of Egyptian households rather than a census of Egyptian households, it is necessary to use this sample to estimate the size of the total labor force for each type of worker (children, males, and females) and the total wages for each type of worker for each governorate since both of these will be used in regression estimates. It has been assumed for data construction and regression analysis that the HIECS is representative of the population. According to Cardiff (1996), the "quality of HIECS survey data from CAPMAS can be judged 'better than average' " (p. 9). Cardiff also states that the size of the survey is large enough to draw tentative conclusions about groups of the population as detailed as at the governorate level. In addition, he states that since the sample households were chosen based on the 1986 Census, the sample may be considered self-weighted by population.

The average percentage of women in the sample data from industry is 7%. Given that 10.2% of the labor force (including the unemployed) is women (World Bank 1995) and the unemployment rate of women in Egypt is 25% while the overall unemployment rate in Egypt is approximately 10% (Institute of National Planning 1994), an average percentage of 7% female workers in the sample supports the assumption that the sample is representative of the population. On the other hand, approximately 4% of the sample workers in industry are children. While this number appears at first inspection to be much lower than the 11% of the overall labor force Fergany (1993) claims, it was mentioned in Chapter 1 of the current research that 70% of child workers are employed in rural areas with a high concentration of agriculture (Azer 1986). Therefore, 70% of the children who make up 11% of the total labor force are in agriculture. Since only 35% of the total labor force is employed in agriculture (Institute of National Planning 1994) but 70% of child workers are employed in agriculture, the percentage workers outside of agriculture who are children should be much lower than 11%--as the HIECS indicates. This fact also supports the assumption that the HIECS is representative of the population.

CONSTRUCTION OF EMPLOYMENT DATA FOR INDUSTRY

In order to estimate the number of each type of worker and their wages, the individual data of the HIECS were first sorted by employment status and all observations classified as persons unemployed for a short period of time, persons unemployed for a longer period of time, and non-participants in the labor force were removed from the sample. The data were then sorted by age, sex, and governorate so that observations on children, adult males, and adult females from different governorates could be separated. Once the observations were separated by category and location, all workers employed outside of industry were removed from the sample and each category was totaled to obtain the number, $\overline{X}_i$, of children, men, and women employed in industry and earning wages in each governorate in the sample.

$\overline{X}_i$: *number of observations of type i industrial workers for each governorate* **Equation (5.1)**

$i = \{C,\ M,\ F\}$ $\quad$ C: *Child* $\quad$ M: *Adult Male* $\quad$ F: *Adult Female*

By dividing the sample number of workers in each category in each governorate by the sample size of employed workers in its respective governorate, the estimated proportion of the governorate's employed population in each category was obtained.

$$\Phi_i = \frac{\overline{X}_i}{N} \qquad i = \{C,\ M,\ F\}$$ **Equation (5.2)**

where $\overline{X}_i$: *number of type i industrial workers surveyed in each governorate*

N : *total number of industrial workers surveyed in each governorate*

For example, if 10 children were found to be employed in Giza ($\overline{X}_C = 10$) and 1000 industrial workers were surveyed in Giza ($N = 1000$), then .01 of the industrial *sample* in

Giza are working children ($\Phi_C = .01$); therefore, .01 of the industrial *population* in Giza is assumed to be working children.

$$\overline{X}_C = 10 \;; \qquad N = 1000$$

$$\Phi_C = \frac{\overline{X}_C}{N} = \frac{10}{1000} = .01$$ **Equation (5.3)**

Once the proportion of each worker type, Φ_i, was found for each governorate, the proportion was multiplied by the total industrial population in each governorate. To calculate the total number of industrial workers in each governorate in 1991 the total number of industrial workers in each governorate was taken from the *Bulletin of Annual Industrial Production Statistics for the Public Sector 1990/91* and the *Bulletin of Annual Industrial Production Statistics for the Private Sector 1990/91.* Then by multiplying the estimated industrial employment figures by the proportion of each worker in each governorate, the estimated number of industrial workers of each type in each governorate was obtained. This method was used because the industrial employment figures are not broken down by age and sex.

$$X_i = \Phi_i * \widetilde{P}$$ **Equation (5.4)**

where $\widetilde{P}$: the total number of industrial workers for a given governorate

Using the above example, if .01 of the population in Giza are child workers ($\Phi_C = .01$) and the estimated employed population in Giza in 1991 is 24,300 ($\widetilde{P} = 24{,}300$) then 243 child workers are estimated to be working in Giza ($X_C = 243$).

$$X_C = \Phi_C * \widetilde{P} = .01 * 24{,}300 = 243$$ **Equation (5. 5)**

CONSTRUCTION OF WAGE DATA FOR INDUSTRY

After calculating the estimated total industrial workers of each type for each governorate, it was necessary to calculate the total wages paid to each type of worker in the corresponding governorate in order to be able to calculate the share of each type of labor in total revenue since share data will be used in later regressions. In order to calculate the total wages per governorate, sample wages were averaged for each group in each governorate.

$$\overline{w}_i = \frac{\sum_{j=1}^{n} w_{ij}}{n} \qquad i = \{C, M, F\} \qquad \textbf{Equation (5.6)}$$

where n : *number of type i industrial workers in the sample for each governorate*

$\overline{w}_i$: *average wage for type i industrial workers for each governorate*

The result, $\overline{w}_i$, was multiplied by the estimated number of industrial workers for each group, X_i, in each governorate to obtain the total estimated industrial wages for each type of worker for each governorate.

$$T_i = \overline{w}_i * X_i \qquad i = \{C, M, F\} \qquad \textbf{Equation (5.7)}$$

where T_i: *total wages for type i industrial workers for each governorate*

Continuing the above example of working children in Giza, if the average industrial wages were found to be 50 Egyptian pounds (*£E*) per year for children in Giza ($\overline{w}_C = 50$ *£E*), and 243 children were estimated to be working in Giza ($X_C = 243$) then 243 children earning 50 pounds implies 12,150 *£E* was paid as child wages in industry in Giza ($T_C = 12{,}150$ *£E*).

$$T_C = \overline{w}_C * X_C = 50 * 243 = 12{,}150 \text{ £E} \qquad \textbf{Equation (5. 8)}$$

This type of calculation was performed for all categories in each governorate.

CONSTRUCTION OF SHARE DATA FOR INDUSTRY

In order to calculate the share of each type of worker for each governorate, a measure of revenue for each governorate was needed. Industrial value added per governorate was chosen as this measurement of output. This figure was taken from the *Bulletin of Annual Industrial Production Statistics for the Public Sector 1990/91* and the *Bulletin of Annual Industrial Production Statistics for the Private Sector 1990/91.*

By dividing total estimated wages, T_i, paid to each category of worker for each governorate by the industrial value added for each respective governorate, Q, the share in total revenue of each type of industrial labor for each governorate was obtained.

$$S_i = \frac{T_i}{Q} \quad i = \{C, M, F\}$$ **Equation (5.9)**

where S_i*: share of type i industrial workers in total revenue*

Q *: industrial value added per governorate*

For example, if total estimated child wages were 12,150 *£E* in Giza ($T_C = 12{,}150$ *£E*) and industrial value added for Giza were 2,430,000 *£E* then the share of child labor in total revenue for Giza would be

$$S_C = \frac{T_C}{Q} = \frac{12\ 150}{2\ 430\ 000} = .005$$ **Equation (5. 10)**

Shares for the three types of labor were calculated in this manner for all governorates.

CONSTRUCTION OF CAPITAL DATA FOR INDUSTRY

After obtaining the estimated number of workers of each type in each governorate, X_i, and the share of each type of worker in each governorate, S_i, the only remaining data needed for the statistical analysis were capital stock per governorate, X_K, and capital's share per governorate, S_K. The net value after depreciation of capital stock per governorate at the end of the year 1990/91 was taken from the *Bulletin of Annual Industrial Production Statistics for the Public Sector 1990/91* and the *Bulletin of Annual Industrial Production Statistics for the Private Sector 1990/91.* For construction of capital's share in total revenue, it was assumed that capital's share equals one minus the sum of labor's shares:

$$S_K = 1 - (S_C + S_M + S_F) \qquad \textbf{Equation (5. 11)}$$

Capital stock and capital's share per governorate were calculated for each governorate in this manner.

DATA ERRORS

Because of reporting/coding errors, some observations have been removed from the original HIECS. For instance, five men and two women were listed as more than 200 years old. Since it was not possible to determine the proper ages of the respondents in order to classify them as a children or adults, the observations were omitted from estimations. Although some observations had to be disregarded, the size of the sample (observations on more than 16,000 individuals) allows these observations to be omitted without fear of biasing the sample.

In addition to the exclusion of some individual observations, some governorates were also omitted. There are 26 governorates in Egypt; however, North and South Sinai are combined by CAPMAS into one statistical area, thus reducing the number to 25. In addition, not all governorates in the HIECS had observations on all worker types. In particular, observations on children were missing. For this reason, the governorates missing observations on children were removed from the sample. After omitting governorates containing missing data, the sample size decreased to 15 geographical regions. This is one of the drawbacks of choosing to estimate industrial elasticities rather than overall elasticities. Removing some children from the original sample who were employed but not working in industry, increases the number of governorate which had to be omitted from 5 in the case where all child workers are included to 10 when only industrial workers are considered. While 15 observations are far from ideal, it is similar to another published study (Grossman, 1982) which estimates the same number of parameters using 19 geographical locations.

ALTERNATIVE DATA CONSTRUCTIONS

As stated earlier, although there is no official data for overall GDP and capital stock per governorate, it is possible to estimate GDP and capital stock per governorate using various weights for the overall GDP and capital stock figures. While there are many ways to weight the overall figures, three possible methods will be discussed briefly below and the parameter estimates they produce will also be discussed in a later section. The three methods are labeled respectively for convenience "GDP by Population", "GDP by Workers", and "GDP by Industry and Agriculture" methods.

THE "GDP BY POPULATION" METHOD

The idea behind the "GDP by Population" method of data construction is that GDP may be higher where there are more people available to work. For this reason, data constructed for this method takes the overall GDP as published in the *World Tables* and calculates the overall GDP per capita by dividing the GDP by the total Egyptian population and then multiplying that figure by the respective population in each governorate. This method implicitly assumes that each individual is equally productive.

Capital stock estimation is difficult in this construction. In addition to there being no official governorate level capital stock figures for Egypt, there is also no official overall capital stock figure. For this reason, capital investment figures for the 10 years prior to 1991 were converted to constant 1991 Egyptian pounds and depreciated at a constant rate of 10% annually. The net investments remaining in 1991 after depreciation were then summed to arrive at the estimated overall capital stock in 1991. This figure was then weighted in the same way as GDP. That is, the total capital stock was divided by the total population to arrive at the capital stock per capita. This figure was then multiplied by the population in each governorate to calculate the estimated capital stock per governorate. This method implicitly assumes that all governorates are equally capital intensive.

In addition, for this method, data for employment in 1991 had to be estimated because the most recent figures per governorate are from the 1986 *Census of Population, Housing, and Establishments.* In order to arrive at the 1991 figures, labor force growth rates were calculated from World Bank labor force estimates for 1986-91 (as given in the *World Tables*) and the 1986 employment figures were increased by the corresponding labor force growth rate for that year. This method implicitly assumes that employment growth equals labor force growth.

As is apparent, the "GDP by Population" method of data construction is based on many implicit and explicit assumptions. Although this method may not be the most desirable, it is--for lack of an official set of governorate level data--one possible construction.

THE "GDP BY WORKER" METHOD

Similar to the "GDP by Population" method, the "GDP by Worker" method also weights GDP, constructs and weights capital stock, and constructs employment data. The "GDP by Worker" method is an improvement over the "GDP by Population" method, however, because GDP and capital stock are weighted by the number of workers in each governorate using the estimated 1991 employment figures per governorate rather than weighting them by population. Theoretically, this method appears to be more sound than weighting GDP and capital stock by total population. It seems logical that the more employed people there are in one governorate, the higher the output will be. On the other hand, this may not be true when GDP and capital stock are weighted by population. For instance, if there were 1 million people in Aswan and 1 million people in Alexandria, then weighting GDP by population would imply that the output in Aswan and Alexandria were the same. On the other hand, if only 500,000 of the people in Aswan were employed and producing output while 900,000 of the people in Alexandria were employed and producing output, all else equal, Alexandria should have greater output. Although the "GDP by Worker" method also constructs employment and capital stock, it is an improvement over the "GDP by Population" method. This does not imply that either of the two methods is ideal. Of course, the ideal method would be to have a good, officially reported number for GDP and capital stock which could be used directly in statistical estimation. However, in the absence of direct measures, such constructions as the above and the following constructions may have to suffice at the present.

THE "GDP BY INDUSTRY AND AGRICULTURE" METHOD

This method is somewhat different that the two previous methods. Although this method uses the estimated 1991 employment figures, its GDP and capital stock figures differ. For GDP, this method--like the previous two methods--weights overall GDP to obtain estimated GDP per governorate; however, instead of weighting GDP by population or workers, it uses the official figures for industry and agriculture value added per governorate to weight the overall GDP. By adding the industry and agriculture value added per governorate and dividing that number by the total industry and agriculture value added, the estimated share each governorate contributes to total GDP is found. By multiplying each governorate's share of industry and agriculture output by the total Egyptian GDP, the estimated GDP per governorate is found. This method implicitly assumes that GDP per governorate has the same distribution as the sum of industry and agriculture value added.

For capital stock, the method proposed by Grossman (1982) was used. The value of industrial capital stock was retrieved from the *Bulletin of Annual Industrial Production Statistics for the Public Sector 1990/91* and the *Bulletin of Annual Industrial Production Statistics for the Private Sector 1990/91*; however, the remainder of the capital stock was unknown. Therefore, it was assumed that capital stock in the non-industrial sectors are proportional to the capital stock in industry. By assuming this, the industry capital stock figures may be used directly in equations.

This method is an improvement over the previous two methods. Although the GDP and capital stock per governorate are unknown in all three cases, the "GDP by Industry and Agriculture" method uses figures which have already been broken down by governorate to weight the figures which have not been broken down by governorate. This is a less restrictive assumption than assuming GDP and capital stock are proportional to either the population or number of workers.

In the previous pages, a description of the main data set for this research has been given as well as a brief description of three alternative data sets which attempt to estimate the overall GDP and capital stock per governorate rather than relying on only the industrial data. In the following section of this research, parameter and elasticity estimates will be presented using all three methods, so that a comparison might be made to see how the estimates change when the data set changes. The estimates may be an indicator of how reliable the data sets themselves actually are. By comparing the estimates with the estimates other studies have obtained, the quality (or lack thereof) of the data sets may be more easily judged than by merely judging by their description.

CHAPTER 6
ESTIMATION

METHOD OF ESTIMATION

Once a system of equations has been specified and data has been constructed to attempt to answer the question of substitutability between adults and children, it is necessary to choose a method of estimation which is most appropriate given the available options. The first method of estimation considered was Ordinary Least Squares (OLS); however, this method is unsatisfactory for the system of equations to be estimated in this research. OLS is an equation by equation estimation technique that minimizes the sum of squared residuals for each equation. However, this method does not account for correlations between equations.

Johnson (1984) states that covariances between equations should be expected when a system of share equations are estimated since the shares sum to one at all observations. In addition, he states that there is no reason to assume that disturbance variances for each equation are the same, as OLS does. In addition, Johnson states that if OLS is used when the system contains autocorrelated disturbances, the estimates obtained will be inefficient (*i.e.* will not be minimum variance). This implies that estimates obtained using OLS will have larger standard errors than estimates obtained using a method which takes into spatial account autocorrelation. Spatial autocorrelation could be expected not only because this study estimates a system of share equations, but also because observation points are from political units rather than economic units. It is feasible that production in Giza is correlated with production in Cairo because Cairo and Giza are not two distinct production centers but rather overlap one another. For this reason, a method which takes into account spatial autocorrelation it needed for estimating the system.

In an attempt to account for correlation between equations, both Zellner's seemingly unrelated regression technique (SURE) and the iterated Zellner-efficient estimation technique (IZEF) were considered as possible estimation techniques. The SURE method, according to Berndt (1991), uses OLS to estimate the covariance matrix of the disturbance terms and then performs Generalized Least Squares using the estimated covariance matrix. The IZEF method, on the other hand, repeats the SURE procedure, updating the estimated covariance matrix until the estimates become arbitrarily small (Berndt 1991). IZEF produces estimates which are numerically equal to maximum likelihood estimation.

Maximum likelihood is a estimation technique that obtains parameter estimates by maximizing the probability of randomly choosing the sample that was actually obtained (Kennedy 1992). That is, for a given probability distribution, maximum likelihood calculates the values of the parameters which give the greatest chance that the sample used for estimation would be randomly chosen from the population. This method of estimation has the asymptotic properties of unbiasedness and efficiency and, therefore, is an improvement over OLS for estimating system of equations where autocorrelations exist.

Two of the main sources for this research (Grant and Hamermesh 1981 and Grossman 1982) rely either on IZEF or SURE for their estimates. Grant and Hamermesh (1981) uses IZEF to estimate elasticities with observations from 67 Standard Metropolitan Statistical Areas (SMSAs) in the US for 1969. Grossman (1982), on the other hand, uses SURE to estimate elasticities with observations from 19 SMSAs in 1970. Greene (1993) states that, in general, both SURE and IZEF account for autocorrelation between equations but that the most appropriate choice between SURE and IZEF will depend on the particular data set used.

However, Berndt (1991) points out that when a system of share equations is estimated, the fact that shares sum to one at each observation results in an estimated covariance matrix which is singular and nondiagonal. For this reason, one share equation must be dropped and the resulting system estimated. The parameter estimates from the omitted equation may later be obtained indirectly by rearranging the homogeneity and symmetry constraints and substituting the estimated values of the directly estimated parameters. When determining which equation should be omitted from the system, Berndt (1991) also states that IZEF provides parameter estimates which are invariant to the equation which is omitted. SURE estimates, on the other hand, depend on which equation is omitted. For this reason, IZEF was chosen over SURE as the better of the two methods for this system of equations.

OLS, SURE, and IZEF, however, are not the only available techniques for estimating this system of equations; Two-Stage (2SLS) and Three-Stage Least Squares (3SLS) must also be considered. The 2SLS estimation is an equation-by-equation method that uses a set of instruments to take into account correlations between dependent variables and disturbance terms. However, like OLS, this method does not take into account correlation between equations in a system and is, therefore, inappropriate for estimating the system of equations in this research where autocorrelations may exist.

The 3SLS estimator, also an instrumental variable technique, estimates the entire system of equations rather than estimating the system equation by equation. For this reason, 3SLS, unlike 2SLS, takes into account autocorrelation between equations. However, for the system of equations used in the present study, there is no appropriate set of instruments to use which are correlated with the dependent variables but not with the disturbance term. In addition, the small sample size used in this study is not sufficiently large enough to use 3SLS. For these reasons, 3SLS must also be rejected.

After examining the possible alternative methods for estimating the system of equations for this research, IZEF appears to be the best choice. Therefore, the results in the remaining pages of this research will use the estimates produced by IZEF for parameter and elasticity estimates. Before performing the desired regressions; however, it is necessary to delete one row and the corresponding column from System (4.1) that was derived in Chapter 4 to overcome the singularity problem described by Berndt (1991). Since IZEF produces estimates which are invariant to which row and corresponding column is deleted, capital will be arbitrarily chosen. System (6.1) is the resulting system if homogeneity restrictions are imposed on the child, male, and female labor share equations from System (4.1) and if the capital equation is deleted:[6]

System (6.1)

$$S_C = \alpha_C + \gamma_{CC}\left(\ln\frac{X_C}{X_K}\right) + \gamma_{CM}\left(\ln\frac{X_M}{X_K}\right) + \gamma_{CF}\left(\ln\frac{X_F}{X_K}\right)$$

$$S_M = \alpha_M + \gamma_{CM}\left(\ln\frac{X_C}{X_K}\right) + \gamma_{MM}\left(\ln\frac{X_M}{X_K}\right) + \gamma_{MF}\left(\ln\frac{X_F}{X_K}\right)$$

$$S_F = \alpha_F + \gamma_{CF}\left(\ln\frac{X_C}{X_K}\right) + \gamma_{MF}\left(\ln\frac{X_M}{X_K}\right) + \gamma_{FF}\left(\ln\frac{X_F}{X_K}\right)$$

Subject to the constraints:

1) $\gamma_{CM} = \gamma_{MC}$ $\quad \gamma_{CF} = \gamma_{FC}$ $\quad \gamma_{CK} = \gamma_{KC}$

$\gamma_{MF} = \gamma_{FM}$ $\quad \gamma_{MK} = \gamma_{KM}$ $\quad \gamma_{FK} = \gamma_{KF}$

2) $\sum_i a_i = 1$ $\qquad i = \{C, M, F, K\}$

$\sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0$

[6] See the Mathematical Appendix C for details of the deletion of capital from the system.

HYPOTHESIS TESTING

At this point the separability of capital may be tested. If capital and labor are separable, capital measures will not have a significant impact on labor-labor elasticities and may be omitted from estimation and from the calculation of labor-labor elasticities. Hamermesh and Grant (1979) indicate that testing for capital separability is necessary rather than assuming capital to be separable. The test for weak separability is that all capital coefficients simultaneously equal zero (*i.e.* $\gamma_{KC} = \gamma_{KM} = \gamma_{KF} = \gamma_{KK} = 0$). The test for this hypothesis is an F-test (Denny and Fuss 1977). F-tests measures the validity of restrictions imposed on systems of equations. As Table 6.1 indicates, the F-statistic for the null hypothesis that all capital coefficients are simultaneously equal to zero is 6.78 with a p-value of 0.0236. This implies the null hypothesis that the capital coefficients simultaneously equal zero is rejected at the 0.05 level of significance. Therefore, capital should be included in labor-labor elasticities or the elasticities may be biased. Although the null hypothesis may be accepted at the 0.01 level of significance, this research will continue to include capital in the model since there is not overwhelming evidence in favor of deletion. Indeed, the literature discussed earlier in this study suggests the capital variable should not be deleted.

Table 6.1 Hypothesis Testing

Separability of Capital	F-statistic	P-value
$\gamma_{CK} = \gamma_{MK} = \gamma_{FK} = \gamma_{KK} = 0$	6.78	0.0236

Tests of Weak Separability	χ^2-statistic	P-value [a]
(X_C, X_M), X_F, X_K	0.4819	0.7859
(X_C, X_F), X_M, X_K	9.7206	0.0077
(X_C, X_K), X_M, X_F	10.9235	0.0042
(X_M, X_F), X_C, X_K	2.5319	0.2820
(X_M, X_C), X_C, X_F	5.3958	0.0673
(X_F, X_K), X_C, X_M	1.4143	0.4930
(X_C, X_M, X_F), X_K	1.8032	0.6142
(X_C, X_M, X_K), X_F	6.1860	0.1029
(X_C, X_F, X_K), X_M	10.4293	0.0152
(X_M, X_F, X_F), X_K	1.2822	0.7333

[a] Denny and Fuss (1977) adopt an α=0.01 for tests of weak separability.

In addition to the test for separability of capital, other tests of separability may be performed on the translog production function to determine if a specification such as a CES or Cobb-Douglas production function may be used to replace a translog specification and obtain the same elasticity estimates. Testing for other model specifications, according to Denny and Fuss (1977), begins by testing the null hypothesis of weak separability of factors. If the hypothesis of weak separability may be accepted, partially strong separability may then be tested; if partially strong separability may be accepted, then complete strong separability may be tested. Complete strong separability implies that a CES function may be used in place of a translog specification. Finally, if complete strong separability may be accepted, then a Cobb-Douglas specification may be tested. If a null hypothesis is rejected at any stage in the testing, the testing procedure is terminated and no further model restrictions may be imposed on the system. From Table 6.1, there are only two tests for which the null hypothesis of weak separability may be accepted at the 0.01 level of significance that is adopted by Denny and Fuss (1977); therefore, testing is terminated at this stage. This implies that the complete translog model in System 6.1, rather than a more restricted version, is needed to measure the substitutability of child and adult labor in Egypt.

PARAMETER ESTIMATES

Table 6.2 presents the estimated values of the parameters in System (6.1) using IZEF and industry data as described in Chapter 5. Standard errors are presented in the second column and indicated by parentheses. Capital parameters and their standard errors have been calculated as functions of the directly obtained parameters using a Taylor series expansion and the homogeneity and symmetry restrictions. It is important to note that the parameter values and standard errors have been calculated using constructed data points rather than from observed data points. For this reason, some caution should be observed when interpreting the values presented in Table 6.2.

In addition to the parameter values and standard errors, Table 6.2 also presents the p-values of the estimates. The p-value is the maximum level of significance at which the null hypothesis that the parameter is equal to zero may be rejected. For example, the p-value for γ_{cc} is 0.0000. This implies that at a significance level as stringent as 0.0000, the null hypothesis that γ_{cc} is equal to zero may be rejected. For significance levels of either 0.01 or 0.05 that are normally chosen by researchers as the level of significance for hypothesis testing, the null hypothesis that γ_{cc} is equal to zero must be rejected. For this reason, one may say that γ_{cc} is significantly differently than zero.

Table 6.2 Parameter Estimates Using IZEF and Industry Data

Parameters	Estimated Value	Standard Error [a]	P-value
α_C	0.0431	(0.0079)	0.0002
α_M	0.7672	(0.2603)	0.0133
α_F	0.0737	(0.0155)	0.0006
α_K	0.1160	(0.2720)	0.6782
γ_{CC}	0.0031	(0.0004)	0.0000
$\gamma_{CM} = \gamma_{MC}$	0.0007	(0.0011)	0.5618
$\gamma_{CF} = \gamma_{FC}$	-0.0007	(0.0004)	0.1456
$\gamma_{CK} = \gamma_{KC}$	-0.0031	(0.0261)	0.9089
γ_{MM}	0.0614	(0.0261)	0.0385
$\gamma_{MF} = \gamma_{FM}$	-0.0060	(0.0020)	0.0131
$\gamma_{MK} = \gamma_{KM}$	-0.0560	(0.0263)	0.0567
γ_{FF}	0.0103	(0.0012)	0.0000
$\gamma_{FK} = \gamma_{KF}$	-0.0036	(0.0035)	0.3239
γ_{KK}	0.0627	(0.0528)	0.2603

a Standard errors for indirectly obtained parameter estimates were calculated as functions of directly obtained parameters.

It is important to note that many of the estimated parameters are not significantly different than zero both at the .01 and .05 levels of significance. However, the numerical values in Table 6.2 are similar in magnitude to the parameter estimates obtained by Grossman (1982). Grossman's estimates range in absolute value from 0.004 to 0.40; the estimates presented in Table 6.2 range in absolute value from 0.0007 to 0.7672. Unfortunately, no comparison may be made between the parameter estimates in either the Field (1988) or Grant and Hamermesh (1981) articles because neither article has presented either their parameter estimates or the mean values of their share equations so that the parameter estimates could be calculated indirectly using elasticity formulas.

ELASTICITY ESTIMATES

After an estimation technique was chosen for the system of equations and parameters were estimated, the Hicks elasticities of complementarity presented in Chapter 4 as Equations (4.6) and (4.7) were calculated in order to determine if children and adults are substitutable in industry in Egypt.

The elasticities were evaluated at the mean value of shares across governorates. Table 6.3 presents the mean values of shares across governorates used in elasticity estimates as well as the mean values of the number of workers in each governorate. Although the mean value of the number of workers may appear to be low, it is important to remember that these numbers are the mean number of workers per governorate for industry only, not for the entire economy.

Table 6.3 Mean Values of Variables for Industry

Variable		Mean Value
S_C	Share of child labor in GDP	0.0041
S_M	Share of adult male labor in GDP	0.2261
S_F	Share of adult female labor in GDP	0.0121
S_K	Share of capital in GDP	0.6951
X_C	Number of child workers	1,399
X_M	Number of adult male workers	56,392
X_F	Number of adult female workers	6,056
X_K	Capital Stock (Egyptian pounds)	1,193,195,625

Using the above mean share values presented in Table 6.3 and parameter estimates presented in Table 6.2, the estimated values for c_{ij} were calculated; the estimates are presented in Table 6.4. Note that $c_{ij} < 0$ implies that factors are substitutes and $c_{ij} > 0$ implies that factors are complements. Since $c_{ij} = c_{ji}$, the table is symmetric.

Table 6.4 Elasticities of Complementarity [a]
(Standard errors of the γ_{ij} coefficients are shown in parentheses.)

	With Respect to the Quantity of			
Wage of	Children	Males	Females	Capital
Children	-65.9078 (0.0004)	1.6227 (0.0011)	-11.4419 (0.0004)	-0.0957 (0.0261)
Males		-2.0898 (0.0261)	-0.9355 (0.0020)	0.6334 (0.0263)
Females			-14.4067 (0.0012)	0.5594 (0.0035)
Capital				-0.4220 (0.0528)

[a] The elasticities of complementarity are defined as $c_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j}$ **Equation (4.6)** and

$c_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2}$ **Equation (4.7).**

There are several worthy points to note about this chart. Firstly, these estimates indicate whether or not factors are substitutable; however, they do not measure the change in price due to a change in the fixed quantity of labor. Own and cross-price elasticities measure the change in relative factor prices due to a change in relative factor quantities. Own and cross-price elasticities are presented in Table 6.5.

Secondly, the estimates involving child labor are unusually high. This can easily be explained by the small mean value of the share of child labor in governorate GDP. The formulas for c_{ij} divide by either the product of two shares or by the share squared as the formulas for elasticities of complementarity above show. For the case of child labor, the mean share of child labor is approximately 0.0041. Dividing by this number is equivalent to multiplying by 243. The case is even worse for the elasticity of complementarity of children with respect to children (c_{CC}) where the numerator is divided by the square of the share of child labor. In this case, the numerator is multiplied by approximately 60,000. Even if γ_{ij} were very small, estimate of c_{ij} could still be very large. The same is true of the estimate for the elasticity of complementarity of women with respect to women. In Egypt, the labor force participation rate for women is low (10.2% according to *World Table es*timates), and this study indicates that either because of their low wages or their low participation level in industry, their share of industry output is even smaller than 10.2%. The mean share of female labor is 0.0121. Similar to the case of child labor, c_{FF} is also very large. This can also be explained by the small share of female labor. Dividing by the square of female labor to obtain c_{FF} is equivalent to multiplying by 6,830. This accounts for the large estimates; however, when own and cross-price elasticities are calculated in Table 6.5, the estimates become more reasonable because c_{ij} is multiplied by S_j, thus decreasing the numerical value of the estimates as Table 6.5 shows. Although these numbers are often large, Field (1988) finds some elasticities of complementarity for farms in the South of the US during the 1800's to be as large as -1227.69.

The estimates in Table 6.5 are more typical of the estimates other studies on substitutability have obtained. For example, Grant and Hamermesh (1981) found that young workers were complements with white women in the US. They calculated a cross-price elasticity of the change in the wage of young workers with respect to the quantity of white women to be -0.1532, an estimate very close to the estimate of the change in the wage of children with respect to the quantity of females which from Table 6.5 is -0.1477. In addition, Grant and Hamermesh found youths and white men to be complements--with the change in the wage of youths with respect to a change in the quantity of white men to be 0.0476. While this study estimates a larger change in the wage of children with respect to a change in the quantity of men in industry in Egypt (0.3913), it is consistent with Grant and Hamermesh's finding that young workers and men were complements in 1969. Also, the range in the size of the estimates in Table 6.5 are consistent with Grant and Hamermesh. In their study, the cross and own-price elasticities lie between -0.4282 and 0.4337. Grossman (1982) also finds small own and cross-price elasticities ranging between -0.39 and 0.42. Similar to Grant and Hamermesh and Grossman, this study finds own and cross-price elasticities between -0.5042 and 0.4014.

Table 6.5 Own and Cross-Price Elasticities
(Standard errors of the γ_{ij} coefficients are shown in parentheses [a])

The change in the wage of	With Respect to the Quantity of Children	Males	Females	Capital
Children	-0.2909 (0.0004)	0.3915 (0.0011)	-0.1477 (0.0004)	-0.0607 (0.0261)
Males	0.0072 (0.0011)	-0.5042 (0.0261)	-0.0121 (0.0020)	0.4014 (0.0263)
Females	-0.0505 (0.0004)	-0.2257 (0.0020)	-0.1860 (0.0012)	0.3545 (0.0035)
Capital	-0.0004 (0.0261)	0.1528 (0.0263)	0.0072 (0.0035)	-0.2674 (0.0528)

[a] The standard errors presented here are the same as those presented in Table 6.2 since the formula for Cross-Price Elasticity is $\frac{\partial \ln(w_i)}{\partial \ln(X_j)} = C_{ij} S_j$ and the Own-Price Elasticity is $\frac{\partial \ln(w_i)}{\partial \ln(X_i)} = C_{ii} S_i$ (Grossman 1982).

IS CHILD LABOR SUBSTITUTABLE FOR ADULT LABOR?

From the estimates found and presented in the above Tables 6.4 and 6.5, the answer to the question of substitutability between adult and child workers is mixed. In Table 6.4, c_{CF} = -11.4419 indicates that children and adult females are, in fact, substitutes in industry in Egypt. For adult males, on the other hand, the situation is different. In Table 6.4, the elasticity of complementarity of males with respect to children, c_{CM} = 1.6227, indicates that children and adult males are complements rather than substitutes for one another. Additionally, male and female labor are found to be complementary (c_{CF} = -0.9345).

Table 6.5 shows that *under the assumption of a vertical labor supply curve*, a 1% increase in child labor leads to a 0.0072% increase in male wages and a 0.0505% decrease in female wages. In addition, a 1% increase in male labor leads to a 0.3915% increase in child wages. And a 1% increase in female labor leads to a 0.1477% decrease in child wages. Assuming a vertical labor supply implicitly assumes that exogenous changes in labor supply cause no employment changes and that all changes in the labor market will be in wages. This assumption is problematic when considering the case of Egypt because the economy is not currently operating at full employment. For this reason, the results should be considered as providing an upper bound for wage changes, not an *exact* percentage change in wages. Just as Grant and Hamermesh (1981) and Grossman (1982) have done, a later section of this chapter will consider alternative labor market conditions in attempt to discover what changes might occur in the labor market if the assumption of a vertical labor supply is modified.

INTERPRETATION OF THE RESULTS

One important point to consider when examining the results presented in Tables 6.1-6.5 is the amount of aggregation of the labor force done to obtain the estimates list above. Although these results indicate that, overall in industry, child labor and adult labor is substitutable, they do not indicate in which jobs children and adults are substitutable. Other studies (Borjas 1983, Costrell *et al* 1986, Field 1988, Grant and Hamermesh 1981, Grossman 1982, Nissim 1984) which have disaggregated labor along finer lines indicate that not all forms of adult labor are substitutable for one another even in manufacturing. Therefore, the results should be considered with some caution. It is obvious in some occupations that children and adults would not be substitutable. For example, a child who works in chemical factory and brings the adult workers tea and sandwiches would not be substitutable for a chemist in the same factory. In some cases, however, substitutability is not so obvious. For example, in a textile factory where children and adults are both working to produce textiles, will the adults and children be substitutable? The above analysis implies that adult females and children will, but adult men and children will not.

It is important to note that for the analysis presented here, it has been implicitly assumed that workers are producing a homogeneous product, but in reality that is not the case. In addition, there has been no attempt to control for worker characteristics. Obviously, the child who is illiterate and serving tea is not substitutable for the chemist. In addition to not accounting for a different product, it is implicitly assumed that the chemist and the child have the same educational level, the same skills, and the same physical abilities. In order to control for these factors, workers characteristics would have to be taken into account. It is far more likely that a child and a low-skilled adult will be substitutable than a child and a highskilled adult; however, a more detailed division of the labor force and more detailed data would be necessary to determine if, in fact, this is the case.

ESTIMATES OBTAINED FROM OTHER DATA CONSTRUCTIONS

As stated in Chapter 1, this study was originally conceived to measure the overall substitutability of child and adult workers in Egypt. However, because of data inavailability, the original scope of this study was modified to cover only industry. There has been an attempt to use the limited available data to obtain overall elasticity estimates for Egypt. The parameter estimates obtained using different data sets discussed in Chapter 5 as well as the standard errors and p-values for each estimate are presented in Table 6.6. It is interesting to note that the general trend in Table 6.6 is decreasing standard errors and p-values from the original data set labeled "GDP by Population" to "GDP by Workers" to "GDP by Industry and Agriculture".

Table 6.6 Parameter Estimates Using Different Data Constructions

(Standard errors are shown in parentheses.)
[P-values are shown in brackets.]

Parameter	GDP by Population	GDP by Workers	GDP by Industry & Agriculture
α_C	**-0.1637** (0.2199) [0.4673]	**-0.4532** (0.1193) [0.0016]	**-0.0137** (0.0027) [0.0001]
α_M	**-22.4023** (16.6429) [0.1970]	**-11.0436** (7.7861) [0.1753]	**-0.2104** (0.1554) [0.1947]
α_F	**-2.9960** (2.3450) [0.2205]	**-1.4527** (1.1978) [0.2884]	**-0.0844** (0.0193) [0.0000]
α_K	**26.5620** (17.1522) [0.1410]	**13.9495** (8.9737) [0.1396]	**2.3001** (3.1258) [0.8579]
γ_{CC}	**0.0018** (0.0005) [0.0034]	**0.0013** (0.0013) [0.0018]	**0.0029** (0.0004) [0.0000]
$\gamma_{CM} = \gamma_{MC}$	**-0.0208** (0.0244) [0.4068]	**-0.0517** (0.0130) [0.0011]	**-0.0008** (0.0008) [0.3058]
$\gamma_{CF} = \gamma_{FC}$	**-0.0033** (0.0035) [0.3631]	**-0.0085** (0.0021) [0.0009]	**-0.0018** (0.0007) [0.0259]
$\gamma_{CK} = \gamma_{KC}$	**0.0223** (1.8648) [0.9876]	**0.0589** (0.8675) [0.9467]	**0.0003** (0.0207) [0.9837]
γ_{MM}	**-2.4975** (1.8642) [0.1991]	**-1.1768** (0.8672) [0.1936]	**0.0253** (0.0253) [0.2265]
$\gamma_{MF} = \gamma_{FM}$	**-0.3815** (0.2612) [0.1635]	**-0.1964** (0.1305) [0.1517]	**-0.0356** (0.0052) [0.0000]
$\gamma_{MK} = \gamma_{KM}$	**2.8999** (2.1206) [0.1904]	**1.4250** (1.0140) [0.1791]	**0.0111** (0.0214) [0.6616]
γ_{FF}	**-0.0120** (0.0384) [0.7592]	**0.0104** (0.0217) [0.6381]	**0.0351** (0.0053) [0.0000]
$\gamma_{FK} = \gamma_{KF}$	**0.3968** (1.0091) [0.6994]	**0.1945** (0.4797) [0.7020]	**0.0022** (0.0048) [0.8000]
γ_{KK}	**-3.3189** (4.1537) [0.4350]	**-1.6784** (1.9771) [0.4105]	**-0.0130** (0.7906) [0.7677]

As a means of comparison, Table 6.7 presents the mean values for the shares of each type of labor as well as for the mean number of each type of worker in each governorate for the three data constructions. Notice that the mean number of workers in each governorate does not change for the three data sets. This is because the same total employment figures per governorate and the same number of governorates were used in each data set. The shares of each type of labor in GDP does change, however, for each governorate because the denominator of the share (total estimated governorate output) changes with each method.

Table 6.7 Mean Values of the Variables Under Different Data Constructions

Variable	GDP by Population	GDP by Workers	GDP by Industry & Agriculture
S_C Share of child labor	0.0027	0.0027	0.0032
S_M Share of adult male labor	0.3016	0.3041	0.3520
S_F Share of adult female labor	0.0371	0.0368	0.0453
S_K Share of capital	0.6586	0.6563	0.5996
X_C Number of child workers	10,883	10,883	10,883
X_M Number of male workers	522,420	522,420	522,420
X_F Number of female workers	104,716	104,716	104,716
X_K Capital Stock (Egyptian pounds)	1,031,875,082	1,031,875,082	1,052,240,450
Number of governorates used in regressions	20	20	20

Once the parameter estimates were calculated, these estimates were used to calculate both elasticities of complementarity and own and cross-price elasticities. The elasticities of complementarity are presented in Table 6.8. There are two points to notice about this table.

Firstly, the estimates for elasticities of complementarity decrease in absolute value with each change in the data set from the "GDP by Population" to "GDP by Workers" to "GDP by Industry and Agriculture. Secondly, only one elasticity estimate has changed signs. This indicates that while the estimates may be rough estimates, they may at least provide tentative answers to the question of substitutability. However, one should not be quick to celebrate. The main aim of this study is to determine the substitutability of children and adults and since the labor force participation of females is low, the main elasticity of interest is c_{CM}, the elasticity of complementarity between children and men. Unfortunately, this is the estimate which changes sign using the "GDP by Industry and Agriculture" data set. The remaining results in Table 6.8 are consistent with Grant and Hamermesh who have found that white women and youths were substitutes in the US in 1969 and with other studies[7] which have consistently found subcategories of labor to be complements with capital. While these results provide some indication that children and females may be substitutable in Egypt, a more reliable data set is needed to determine if the sign of c_{CM} will remain positive as was found with the industry data set whose results were presented in Tables 6.1-6.5 or will switch again to be negative as with the "GDP by Population" and "GDP by Workers" results.

[7] See Hamermesh 1993, Chapter 3 for a summary of the results of substitutability studies and their findings.

Table 6.8 Elasticities of Complementarity Using Different Data Constructions

	With Respect to the Quantity of				
Change in the wage of	Children	Males	Females	Capital	Method
Children	-123.1813	-24.4441	-31.4765	13.4751	GDP by Pop.
	-188.5399	-61.7469	-83.4746	34.1149	GDP by Workers
	-27.0404	0.2691	-11.3101	0.8385	GDP by Indus & Agr
Males		-29.7790	-33.0612	15.6011	GDP by Pop.
		-15.0105	-16.3902	8.1385	GDP by Workers
		-1.6363	-1.2331	1.0524	GDP by Indus & Agr
Females			-34.5914	17.2193	GDP by Pop.
			-18.3672	8.9794	GDP by Workers
			-3.9601	1.0826	GDP by Indus & Agr
Capital				-8.1704	GDP by Pop.
				-4.4197	GDP by Workers
				-0.7040	GDP by Indus & Agr

Just as in the case of the estimates from industry, the own and cross-price elasticity estimates were calculated and are presented in Table 6.9. Again, the elasticity estimates have decreased from the first to the third data set and are close to the results found in other studies and the results obtained using the data from industry. The largest value for the "GDP by Industry and Agriculture" data set in absolute value is 0.6491 for the change in the wage of females with respect to a change in the quantity of capital. On the other hand, the largest elasticity estimate for the "GDP by Population" data set is 23.3910 and for the "GDP by Workers" it is 11.3403.

Table 6.9 Own and Cross-Price Elasticities Using Different Data Constructions

	With Respect to the Quantity of				
Change in the wage of	Children	Males	Females	Capital	Method
Children	-0.3338	-7.3715	-1.1691	8.8744	GDP by Pop.
	-0.5109	-18.7793	-3.1005	22.3910	GDP by Workers
	-0.0854	0.0947	-0.5120	0.5027	GDP by Indus & Agr
Males	-0.0662	-8.9803	-1.2280	10.2746	GDP by Pop.
	-0.1673	-4.5652	-0.6088	5.3416	GDP by Workers
	0.0009	-0.5760	-0.0558	0.6310	GDP by Indus & Agr
Females	-0.0853	-9.9701	-1.2848	11.3403	GDP by Pop.
	-0.2262	-4.9848	-0.6822	5.89356	GDP by Workers
	-0.0357	-0.4341	-0.1793	0.6491	GDP by Indus & Agr
Capital	0.0365	4.7048	0.6396	-5.3809	GDP by Pop.
	0.0925	2.4752	0.3335	-2.909	GDP by Workers
	0.0026	0.3705	0.0490	-0.4221	GDP by Indus & Agr

RESULTS OF ESTIMATIONS

While there is some doubt about the substitutability of child and male labor, the data set which best matches output, capital stock and employment, namely the industry data set presented alone earlier in Tables 6.1-6.5, indicates that child and male labor are not substitutable but rather are complements. This conclusion is supported by the estimates obtained for the entire economy using the "GDP by Industry and Agriculture" method.

Although there is some conflict in the findings of the substitutability of child and male labor, the same is not true of child and female labor. There is no evidence to reject the hypothesis that child and female labor are substitutable either in industry or in the entire economy. For this reason, it seems reasonable at this point to assume that child and female labor are substitutable in Egypt. This hypothesis is consistent with the findings of Grant and Hamermesh (1981) who find that youths and white women are substitutable in production. This indicates that if child labor were reduced in Egypt, the employment of women would increase.

While these results are not definitive, they do provide some insight into the substitutability of different classes of workers in Egypt. Of course, the reliability of these results would increase dramatically if a better data set were available to use to calculate more reliable elasticity estimates. However, given the current data availability situation, these results provide a tentative result which may be tested at a later date when a more reliable data set becomes available.

SIMULATION OF EMPLOYMENT EFFECTS

As stated earlier in this research, assuming a vertical labor supply curve and estimating a system of equations based on that assumption, produces estimates for wage changes given exogenous changes in the fixed labor supply. The elasticities of complementarity and own and cross-price elasticities do not answer the question of what the change in adult employment will be from removing child labor from the market. Elasticities of complementarity answer the question of whether or not two factors are substitutable; own and cross-price elasticities answer the question of how much wages would change as a result of changing the supply of child labor. While own and cross-price elasticities provide an upper bound for wage changes, it is also important to know what might happen if the assumption of a perfectly inelastic labor supply curve for all categories of workers were relaxed.

In order to calculate the employment and/or wage effects of a decrease in child labor, it is first necessary to determine the equations to use under alternative assumptions about the labor market.[8] First it will be assumed that all wages except male wages are flexible and that all employment changes will be in male employment while other workers and capital will experience wage changes but no employment changes. That is, that the male labor supply curve will be assumed to be perfectly elastic while other workers will have perfectly inelastic supply curves. Once male employment changes have be found, it will be assumed that female workers have inflexible wages while all other workers (including males) will be assumed to have flexible wages. This implies that the female labor supply curve will be perfectly elastic while the male labor supply curve will be perfectly inelastic. And lastly, it will be assumed that both male and female workers have inflexible wages (perfectly elastic supply curves) while the wages of children and capital are flexible (perfectly inelastic supply curves). In this case, there will be employment changes for males and females but only wage changes for children and capital. These assumptions are made to establish boundaries for wage and employment changes under different market conditions.

Earlier in this research in Chapter 4, a translog production function was specified and a system of share equations were derived under the implicit assumptions of profit maximization and perfect competition. By differentiating the translog production function, Equation (4.2), and using the different assumptions about the labor force described above,

[8] The derivations and analysis in this section are based on the works of Johnson (1980), Grant and Hamermesh (1981), and Grossman (1982).

one may derive equations which will provide a framework to determine employment changes for adults under different market conditions. The following paragraphs list the formulas for employment and wage changes under different assumptions about labor market conditions which will be used to calculate the employment and/or wage changes presented in Table 6.10.[9]

MARKET CHANGES WITH INFLEXIBLE MALE WAGES

Under the assumption that male wages are inflexible while all other wages are flexible, the formula for the percentage change in male employment as a result of reducing child labor may be found to be the following:[10]

$$\frac{d \ln X_M}{d \ln X_C} = \frac{-c_{MC} \; S_C}{c_{MM} \; S_M} \qquad \textbf{Equation (6.1)}$$

where c_{ij}: *elasticity of complementarity of factor i with respect to factor j*

In addition, the formula for the percentage changes in the wages of children, females, and capital may be found to be the following:

$$\frac{d \ln w_i}{d \ln X_c} = \left[c_{iC} + \frac{c_{iM} - c_{MC}}{c_{MM}} \right] S_C \qquad \textbf{Equation (6.2)}$$

These formulas contain only information presented in Tables 6.3 and 6.4; therefore, they may be calculated directly from the results presented in Tables 6.3 and 6.4. Since the main results of this study are the substitutability of adult and child labor in industry (Tables 6.1-6.5), the

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9 For further details regarding the derivation of formulas for employment and wage changes, see the appropriate Mathematical Appendix.

10 See the Mathematical Appendix D for derivations of the formulas for male employment changes and child, female and capital wage changes under the assumption of inflexible male wages.

employment changes which will be calculated and presented in Table 6.10 will only be calculated for industrial workers.

MARKET CHANGES WITH INFLEXIBLE FEMALE WAGES

Similar to the formulas for the case of inflexible male wages, the formulas for the percentage change in female employment and male, child, and capital wages with inflexible female wages are given in Equations (6.3) and (6.4):[11]

$$\frac{d\ln X_F}{d\ln X_C} = \frac{-c_{FC}\;S_C}{c_{FF}\;S_F} \qquad \textbf{Equation (6.3)}$$

$$\frac{d\ln w_i}{d\ln X_c} = \left[c_{iC} + \frac{c_{iF} - c_{FC}}{c_{FF}}\right] S_C \qquad \textbf{Equation (6.4)}$$

$$i = \{C,\ M,\ K\}$$

MARKET CHANGES WITH INFLEXIBLE MALE AND FEMALE WAGES

When male and female wages are both inflexible, the above results must be modified. The formulas for percentage changes in male and female labor under the assumption of inflexible male and female wages are given in Equations (6.5) and (6.6).[12]

$$\frac{d\ln X_M}{d\ln X_C} = \frac{\left(c_{CM}\;c_{FF} - c_{MF}\;c_{CF}\right) S_C}{\left(c_{MF}^2 - c_{MM}\;c_{FF}\right) S_M} \qquad \textbf{Equation (6.5)}$$

$$\frac{d\ln X_F}{d\ln X_C} = \frac{\left(c_{CF}\;c_{MM} - c_{MF}\;c_{CM}\right) S_C}{\left(c_{MF}^2 - c_{MM}\;c_{FF}\right) S_F} \qquad \textbf{Equation (6.6)}$$

Additionally, the formulas for the percentage change in the wages of children and capital are given in Equation (6.7).

[11] See the Mathematical Appendix D for the derivation of the formulas. The formula derivations under the assumption of inflexible female wages are similar to that with inflexible male wages--only the subscripts change.

[12] See the Mathematical Appendix E for the derivation of Equations (6.5) and (6.6).

$$\frac{d\ln w_i}{d\ln X_c} = \left[c_{ic} + \frac{c_{iM}\ c_{CM}\ c_{FF} - c_{iM}\ c_{MF}\ c_{FF} + c_{iF}\ c_{CF}\ c_{MM} - c_{iF}\ c_{MF}\ c_{MM}}{c_{MF}^2 - c_{MM}\ c_{FF}} \right] S_c$$

Equation (6.7)

By substituting the estimated value for the elasticities of complementarity from Table 6.4 and the mean value of the shares from Table 6.3, the average employment changes per governorate may be found. These results under the three alternative assumptions about the labor market as well as the original labor supply curve are presented in Table 6.10.

Table 6.10 Changes in the Labor Market from Reducing Child Labor Under Different Market Conditions [a]

	All Wages Flexible	**Inflexible Male Wages**	**Inflexible Female Wages**	**Inflexible Male and Female Wages**
% Change in the wage of				
Children	0.2909	0.2853	0.2507	0.2466
Males	-0.0072	-------	-0.0104	------
Females	0.0505	0.0537	------	------
Capital	0.0004	0.0032	0.0024	0.0015
% Change in the employment of				
Males	-------	-0.0236	-------	-0.0213
Females	-------	-------	0.2714	0.2973

[a] Reducing child labor is the same as a negative increase in quantity. For this reason, the figures when all wages are flexible are the opposite sign of those presented in Table 6.5.

EMPLOYMENT CHANGES FROM REDUCING CHILD LABOR

Will more adults gain jobs as a result of removing child labor? The answer to this question is unclear. Table 6.10 indicates that when male wages are inflexible, a 1% decrease in child labor will result in a 0.0236% decrease in male employment--all else constant. On the other hand, Table 6.10 also indicates that when female wages are inflexible, female employment will increase by 0.2714%. In addition, if male and female wages are both inflexible, a 1% decrease in child labor will result in a 0.0213% decrease in male employment and a 0.2973% increase in female employment. If the mean values from Table 6.3 for the number of males and females and the percentage changes of male and female employment from Table 6.10 are used to estimate average employment effects per governorate, a 1% decrease in child labor will result in an average decrease in male employment of 1,331 workers per governorate. If female wages are inflexible, on the other hand, an average of 1,644 female workers per governorate will gain the jobs lost by children. Additionally, if both male and female workers have inflexible wages, male employment will decrease by an average of 1,201 male workers per governorate while female employment will increase by an average of 1,800 female workers per governorate. If it is the case that either both male and female wages are inflexible or only female wages are inflexible, then the net result of reducing child labor would be a net increase in adult employment. If, however, only male wages are inflexible, then reducing child labor would result in a net decrease in adult employment.

There are, of course, other possible labor market conditions. Ideally, the results presented above would present other market conditions with upward sloping supply curves. As stated earlier in this research, however, assuming an upward sloping supply curve adds considerable complexity to the given problem and also presents problems of collinearity for estimating systems of equations. The above results are not meant to imply that it reasonable to assume that the labor supply curve is either perfectly inelastic or perfectly elastic. They merely provide boundaries for a myriad of possible results which may exist within those boundaries depending on the actual structure of the labor market.

CHAPTER 7
CONCLUSION

In some countries in the world, there has been an effort to reduce the employment of children in the hopes of increasing the employment of adults.[14] It is unclear, however, if these programs actually increase adult employment. For this reason, studies which measure the substitutability of children and adults are important to determine if such substitutions are likely given the current technology within a country. If it is the case child and adult labor are substitutable, then, *ceteris paribus,* programs which reduce child labor will increase adult employment in the short run.

IS CHILD LABOR SUBSTITUTABLE FOR ADULT LABOR?

From the main data set used in this study--namely data set using industrial employment, output, and capital stock--the tentative results of this research indicate that the substitutability of adult and child labor is mixed. While the data from industry indicates that female and child labor are substitutable in the short run in Egyptian industry, the opposite has tentatively been found to be true for children and males in Egyptian industry. The results from Table 6.10 in Chapter 6 indicate that decreasing the employment of children will decrease, rather than increase, the employment of adult males.

What is the net result of reducing the supply of child labor on adult employment? The figures from Table 6.10 in Chapter 6 show that under the assumptions of either inflexible male and female labor supply curves (perfectly elastic supply curves) or an inflexible female supply curve, the net result of reducing child labor will be a net increase in adult employment. On the other hand, under the assumption of an inflexible male supply curve, the net result of

[14] See ILO (1988) for a description of the programs of some developing countries which attempt to decrease the employment of children.

reducing child labor will be a net decrease in adult employment. These results tentatively indicate that the net effect of reducing child labor depends on the actual structure of the labor market.

RESERVATIONS ABOUT THE RESULTS

While the tentative results of this study indicate that child and female labor are substitutable and that child and male labor are complementary in Egyptian industry, these results should be viewed with caution. There are severe problems in Egypt, as well as in other developing countries, with the availability and reliability of data. As stated earlier in this research, desired data is often unavailable, and when data can be located, it is often unreliable. Different governmental agencies often report different figures for the same variables during the same year. In addition, there are problems with consistency of data collection over time. Survey questions often vary from year to year so that the samples are often not comparable from different years. Furthermore, given that the employment of children in industry in Egypt is illegal except in family businesses, there is likely to be substantial underreporting of child employment in the *Households, Income, Expenditure and Consumption Survey* which has been used to determine the percentage of children, males, and females working in industry.

Given all of these problems with the data used for this study, the figures presented in all the tables in Chapter 6 should be viewed with caution. Although the results indicate that child and female labor is substitutable and child and male labor is complementary in Egyptian industry, these results may only be considered tentative. If a more reliable data set were available, the results could easily be recalculated to obtain more reliable elasticity estimates. Since more reliable data is unavailable, however, it is necessary to use what is available to calculate tentative results and when (or if) a more reliable data set becomes available, the tentative results may be improved and updated.

SHORT TERM VERSUS LONG TERM AND THE LUCAS CRITIQUE

Aside from the obvious data problems present in this study, there is also the question of what the results presented in Chapter 6 imply for the short and long term and for policy evaluation. The results presented in Chapter 6 measure the substitutability of child and adult labor in Egyptian industry in 1990/91. The results do not measure substitutability of child and adult labor over time. For this reason, the results may only be considered valid[15] in the short run. In the long run, as stated earlier in this research, firms have the option of changing their technologies to better suit the labor market conditions. If it is the case that child labor is removed from the market, firms who previously depended heavily on child labor may not find their current technology profitable after the removal of child labor. For this reason, they may either shut down or change their technologies to more profitable technologies.

The criticism of econometric studies which attempt to determine *ex ante* the effect of policies is known as the "Lucas Critique".[16] The "Lucas Critique" is named for an article written by Robert Lucas which maintains that policies cannot be evaluated using econometric studies because these studies attempt to predict, under a given set of policies, what will happen if the policies themselves are changed. Lucas argues that changing policies in an economy changes the constraints placed upon agents in the economy. For this reason, he states that policies cannot be evaluated using econometric studies because the observations used to predict agents' behaviors are under the old policies and no observations are available

15 The term "valid" is used here ignoring the data problems discussed.

16 See Lucas (1981).

under the new policies since they have not yet been implemented. Therefore, he claims that the policy implications that econometric studies might have are invalid.

In the current study of child labor, it has been found that child and female labor were substitutable in 1990/91 while child and male labor were complementary. Although this study may appear to have broad policy implications, Lucas' criticism must be taken into account. Although this study indicates that child and adult male labor are complementary when child labor laws exist but are not enforced, this study cannot conclusively predict what the change in adult labor will be under a policy of strict enforcement of child labor laws. Although child and male labor have been found to be complementary, it may be the case that some males will be used by firms to do the work once performed by children if children are forced out of the market. Under the given policy, firms have the option to hire child labor. If this option were removed, firms may choose to hire more men to do the work of children even though when child and male labor were both available, the two tended to be used together.

The results of this study indicate that child and male labor are *slightly*, not highly, complementary; the relationship between male and child labor is not strong even when child and adult labor are both available. For this reason, it is unlikely that a change in policy would produce substantial increases in male employment. However, Hicks elasticity estimates that are positive also do not rule out the possibility of substitution when one type of labor is no longer available to firms. For this reason, the "Lucas Critique" provides an additional caution for interpreting the results of this study.

DIRECTIONS FOR FUTURE RESEARCH

While the current research provides some tentative results about the substitutability of adult and child labor, there is room for improvement in future research. Ideally, future research would be based on more reliable data on output and capital stock so that the results obtained could be considered more reliable. If it were possible to obtain data that accurately indicated the numbers of working children, this would also be an improvement over the current research.

In addition, it would be desirable to have a more precise matching of workers, output, and capital stock. Although this study has mainly been limited to industry--as opposed to the entire Egyptian economy--there are many products and many production technologies classified as industry. For example, mining and quarrying, petroleum, and textiles are all considered industries but each has its own technology and output. Aggregating all output and capital into industrial output and capital does not precisely match workers with the capital they used and the output they produced. For this reason, a more detailed division of data would be desirable.

CONCLUSION

Although the results presented in these pages may only be considered tentative and must be viewed with caution, they do provide some insight into the relationship between child and adult workers in Egyptian industry. While more research needs to be performed in the area of the substitutability of child and adult workers, this research indicates that the previous statements about increasing the employment of adults by reducing child labor may not be as accurate as they appear on the surface.

MATHEMATICAL APPENDIX A

DERIVATION OF PROFIT MAXIMIZING CONDITIONS

The following describes the derivation for the conditions for profit maximization which will be used in the Mathematical Appendix B to transform the production function into share equations:

$$\begin{aligned} &Let\ P_Q = 1 \\ &\quad where\ P_Q : price\ of\ output \end{aligned} \qquad \textbf{Equation (A.1)}$$

In order to maximize profits firms must maximize the difference between their revenues and costs as Equation (A.2) shows.

$$\begin{aligned} &Max\ \Pi = Revenue - Cost \\ &\quad where\ \Pi : profit \end{aligned} \qquad \textbf{Equation (A.2)}$$

Since $P_Q = 1$, Equation (A.2) may be rewritten by substituting the mathematical expressions for revenue and costs as Equation (A.3) shows.

$$\begin{aligned} &Max\ \Pi = Q - \left(P_C X_C + P_M X_M + P_F X_F + P_K X_K\right) \\ &\quad where\ P_i : price\ of\ factor\ i \quad i = \{C, M, F, K\} \end{aligned} \qquad \textbf{Equation (A.3)}$$

By taking the first partial derivatives of the profit function (Equation (A.3)) with respect to factor prices and setting them equal to zero as in Equation (A.4), it may be found that in order to maximize profits, firms will hire factors of production up to the point where the their marginal products equal their respective market wages. The result, presented in Chapter 4 Equation (4.3), mathematically represents the profit maximization rule for firms.

$$First\ Order\ Conditions: \frac{\delta \Pi}{\delta X_i} = \frac{\delta Q}{\delta X_i} - P_i = 0 \qquad \textbf{Equation (A.4)}$$

$$\frac{\delta Q}{\delta X_i} = P_i \qquad i = \{C, M, F, K\} \qquad \textbf{Equation (4.3)}$$

This completes the derivation of profit maximizing conditions presented in Chapter 4.

MATHEMATICAL APPENDIX B

DERIVATION OF SHARE EQUATIONS

The following pages describe the mathematical transformation of the production function, Chapter 4's Equation (4.2) into a system of share equations using the result from the Mathematical Appendix A's Equation (4.3) that profit maximizing firms set the marginal products of factor inputs equal to their respective prices in the market.

$$\ln Q = \ln a_0 + \sum_i a_i \ln X_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln X_i \ln X_j \qquad \textbf{Equation (4.2)}$$

where a_0, a_i, γ_{ij} *are technological parameters*

$i, j = \{C, M, F, K\}$

By reformulating the left hand side of the production function (Equation (4.2)) using the chain rule and then rearranging, Equation (B.2) may be obtained.

$$\frac{\delta \ln Q}{\delta \ln X_i} = \frac{\delta \ln Q}{\delta Q} * \frac{\delta Q}{\delta X_i} * \frac{\delta X_i}{\delta \ln X_i} \quad \textit{by chain rule} \qquad \textbf{Equation (B.1)}$$

$$= \frac{\delta \ln Q}{\delta Q} * \frac{\delta Q}{\delta X_i} * \frac{1}{\frac{\delta \ln X_i}{\delta X_i}} \qquad \textbf{Equation (B.2)}$$

By substituting Equation (4.3) $\frac{\delta Q}{\delta X_i} = P_i$ into Equation (B.2), Equation (B.3) may be found.

$$\frac{\delta \ln Q}{\delta \ln X_i} = \frac{1}{Q} * P_i * \frac{1}{\frac{1}{X_i}}$$

$$= \frac{X_i P_i}{Q} \qquad \textbf{Equation (B.3)}$$

Equation (B.3) is X_i's share in producing Q.

$$\textit{Let } S_i = \frac{X_i P_i}{Q} \qquad i = \{C, M, F, K\} \qquad \textbf{Equation (B.4)}$$

where S_i*: share of factor i in total revenue*

Differentiating Equation (4.2) with respect to the log of factors of production Equation (B.5) is found.

$$\frac{\delta \ln Q}{\delta \ln X_i} = a_i + \sum_j \gamma_{ij} \ln X_j \qquad \textbf{Equation (B.5)}$$

Since $\frac{X_i \; P_i}{Q} = \frac{\delta \ln Q}{\delta \ln X_i}$ from Equation (B.3), Equation (B.4) may be set equal to Equation (B.5) as in Equation (B.6).

$$S_i = \frac{X_i \; P_i}{Q} = \frac{\delta \ln Q}{\delta \ln X_i} = a_i + \sum_j \gamma_{ij} \ln X_j \qquad \textbf{Equation (B.6)}$$

$$S_i = a_i + \sum_j \gamma_{ij} \ln X_j \qquad \textbf{Equation (B.7)}$$

Equation (B.7) is the desired system of share equations. Explicitly the system may be written as shown in Chapter 4, System 4.1:

System 4.1

$$S_C = a_C + \gamma_{CC} \ln X_C + \gamma_{CM} \ln X_M + \gamma_{CF} \ln X_F + \gamma_{CK} \ln X_K$$
$$S_M = a_M + \gamma_{MC} \ln X_C + \gamma_{MM} \ln X_M + \gamma_{MF} \ln X_F + \gamma_{MK} \ln X_K$$
$$S_F = a_F + \gamma_{FC} \ln X_C + \gamma_{FM} \ln X_M + \gamma_{FF} \ln X_F + \gamma_{FK} \ln X_K$$
$$S_K = a_K + \gamma_{KC} \ln X_C + \gamma_{KM} \ln X_M + \gamma_{KF} \ln X_F + \gamma_{KK} \ln X_K$$

where S_C: *share of child labor in total revenue*
S_M: *share of male labor in total revenue*
S_F: *share of female labor in total revenue*
S_K: *share of captial in total revenue*

This completes the derivation of the system of share equations presented in Chapter 4.

MATHEMATICAL APPENDIX C

TRANSFORMATION OF SHARE EQUATIONS BY DELETING CAPITAL

In order to estimate a system of share equations, it is first necessary to delete one row and the corresponding column from the original system of equations. The following pages describe the method for deleting capital from Chapter 4's System 4.1:

System 4.1

$$S_C = a_C + \gamma_{CC} \ln X_C + \gamma_{CM} \ln X_M + \gamma_{CF} \ln X_F + \gamma_{CK} \ln X_K$$
$$S_M = a_M + \gamma_{MC} \ln X_C + \gamma_{MM} \ln X_M + \gamma_{MF} \ln X_F + \gamma_{MK} \ln X_K$$
$$S_F = a_F + \gamma_{FC} \ln X_C + \gamma_{FM} \ln X_M + \gamma_{FF} \ln X_F + \gamma_{FK} \ln X_K$$
$$S_K = a_K + \gamma_{KC} \ln X_C + \gamma_{KM} \ln X_M + \gamma_{KF} \ln X_F + \gamma_{KK} \ln X_K$$

where S_c: *share of child labor in total revenue*

S_M: *share of male labor in total revenue*

S_F: *share of female labor in total revenue*

S_K: *share of captial in total revenue*

As an example of the transformation that will be performed on all equations in System 4.1, the following describes the transformation obtained by imposing the symmetry and homogeneity restrictions, Constraints (4.1) and (4.2), on the first equation, (S_C), in System 4.1.

From homogeneity restrictions:

$$\gamma_{CC} + \gamma_{CM} + \gamma_{CF} + \gamma_{CK} = 0$$ **Constraint (4.2)**

Multiplying both sides of Constraint (4.2) by (-ln X_K) gives Equation (C.1).

$$-\ln X_K \ (\gamma_{CC} + \gamma_{CM} + \gamma_{CF} + \gamma_{CK}) = (-\ln X_K) * 0$$
$$-\gamma_{CC} \ln X_K - \gamma_{CM} \ln X_K - \gamma_{CF} \ln X_K - \gamma_{CK} \ln X_K = 0$$ **Equation (C.1)**

Since the left hand side above equals zero, it may be added to the original first equation in System 4.1:

$$S_C = \alpha_C + \gamma_{CC} \ln X_C - \gamma_{CC} \ln X_K + \gamma_{CM} \ln X_M - \gamma_{CM} \ln X_K + \gamma_{CF} \ln X_F - \gamma_{CF} \ln X_K + \gamma_{CK} \ln X_F - \gamma_{CK} \ln X_K$$ **Equation (C.2)**

By combining terms in Equation (C.2) with similar coefficients, Equation (C.3) is found.

$$S_C = \alpha_C + \gamma_{CC}(\ln X_C - \ln X_K) + \gamma_{CM}(\ln X_M - \ln X_K) + \gamma_{CF}(\ln X_F - \ln X_K) + \gamma_{CK}(\ln X_K - \ln X_K) \qquad \textbf{Equation (C.3)}$$

By using the mathematical result that $\log a - \log b = \log \frac{a}{b}$, Equation (C.3) is transformed into Equation (C.4).

$$S_C = \alpha_C + \gamma_{CC}\left(\ln \frac{X_C}{X_K}\right) + \gamma_{CM}\left(\ln \frac{X_M}{X_K}\right) + \gamma_{CF}\left(\ln \frac{X_F}{X_K}\right) \qquad \textbf{Equation (C.4)}$$

This deletes the capital column. Similarly, if homogeneity and symmetry restrictions, Constraints (4.1) and (4.2), are imposed on the remaining equations, the following is the resulting system presented in Chapter 6:

System 6.1

$$S_C = \alpha_C + \gamma_{CC}\left(\ln \frac{X_C}{X_K}\right) + \gamma_{CM}\left(\ln \frac{X_M}{X_K}\right) + \gamma_{CF}\left(\ln \frac{X_F}{X_K}\right)$$

$$S_M = \alpha_M + \gamma_{CM}\left(\ln \frac{X_C}{X_K}\right) + \gamma_{MM}\left(\ln \frac{X_M}{X_K}\right) + \gamma_{MF}\left(\ln \frac{X_F}{X_K}\right)$$

$$S_F = \alpha_F + \gamma_{CF}\left(\ln \frac{X_C}{X_K}\right) + \gamma_{MF}\left(\ln \frac{X_M}{X_K}\right) + \gamma_{FF}\left(\ln \frac{X_F}{X_K}\right)$$

This completes the removal of capital from the original system of equations.

MATHEMATICAL APPENDIX D

DERIVATIONS OF CHANGES IN LABOR MARKET WITH INFLEXIBLE MALE OR FEMALE WAGES

The following describes the derivation of the formulas to measure employment and wage changes under the assumption that male (or female) wages are inflexible while all other wages are flexible. First, from the Mathematical Appendix A's Equation (4.3), under the assumption of perfect competition and profit maximization, firms set the marginal products of factor inputs equal to their respective prices as Equation (D.1), a slight modification of Equation (4.3) shows.

$$P_i = F_i\,(X_C, X_M, X_F, X_K) \qquad \textbf{Equation (D.1)}$$

where P_i: *wage factor i* $\quad i = \{C, M, F\,K\}$

F_i: *partial derivative of the production function with respect to factor i*

Totally differentiating Equation (D.1) with respect to each factor gives Equation (D.2).

$$d\,P_i = F_{iC}\;d\,X_C + F_{iM}\,d\,X_M + F_{iF}\;d\,X_F + F_{iK}\,d\,X_K \qquad \textbf{Equation (D.2)}$$

where d: *total derivative*

F_{ij}: *second partial derivative of the production function with respect to factors i and j* $\quad i, j = \{C, M, F\,K\}$

Equation (D.2) may be explicitly written as the following system of differential equations:

System (D.1)

$$d\,P_C = F_{CC}\;d\,X_C + F_{CM}\;d\,X_M + F_{CF}\;d\,X_F + F_{CK}\;d\,X_K$$
$$d\,P_M = F_{MC}\;d\,X_C + F_{MM}\;d\,X_M + F_{MF}\;d\,X_F + F_{MK}\;d\,X_K$$
$$d\,P_F = F_{FC}\;d\,X_C + F_{FM}\;d\,X_M + F_{FF}\;d\,X_F + F_{FK}\;d\,X_K$$
$$d\,P_K = F_{KC}\;d\,X_C + F_{KM}\;d\,X_M + F_{KF}\;d\,X_F + F_{KK}\;d\,X_K$$

Under the assumption that male wages are inflexible while all other wages are flexible, there will be no change in the wages of men but changes in male employment and changes in the wages of other workers but no employment changes for other workers. Using this information, the following modifications may be made to System (D.1):

<u>System (D.2)</u>

$$
\begin{aligned}
dP_C &= F_{CC}\, dX_C + F_{CM}\, dX_M + F_{CF} * 0 + F_{CK} * 0 \\
0 &= F_{MC}\, dX_C + F_{MM}\, dX_M + F_{MF} * 0 + F_{MK} * 0 \\
dP_C &= F_{FC}\, dX_C + F_{FM}\, dX_M + F_{FF} * 0 + F_{FK} * 0 \\
dP_C &= F_{KC}\, dX_C + F_{KM}\, dX_M + F_{KF} * 0 + F_{KK} * 0
\end{aligned}
$$

The second equation in System (D.2) may be solved to find the change in adult male employment due to a change in child employment as shown in Equation (D.3).

$$0 = F_{MC}\, dX_C + F_{MM}\, dX_M$$

$$\frac{dX_M}{dX_C} = -\frac{F_{MC}}{F_{MM}}$$ **Equation (D.3)**

This condition, however, does not contain any formulas for which there are available values that may be substituted. Therefore, Equation (D.3) must be transformed to arrive at a formula which may be calculated. In order to transform the system, first recall from Chapter 4 the definitions for Hicks elasticities of complementarity:

$$c_{ij} = \frac{F\, F_{ij}}{F_i\, F_i} \qquad i \neq j$$ **Equation (4.6)**

$$c_{ii} = \frac{F\, F_{ii}}{F_i^2}$$ **Equation (4.7)**

Under the assumption of profit maximization from Equation (D.1), $P_i = F_i$ and $P_j = F_j$; therefore, by substituting and rearranging the Equations (4.6) and (4.7), Equation (D.4) may be derived.

$$\frac{c_{ij}\, P_i\, P_j}{Q} = F_{ij}$$ **Equation (D.4)**

$$\text{where } Q = F(X_C,\, X_M,\, X_F,\, X_K)$$

By substituting for F_{ij} into Equation (D.3) the following is the resulting equation:

$$\frac{d\,X_M}{d\,X_C} = \frac{-\dfrac{c_{MC}\;P_M\;P_C}{Q}}{\dfrac{c_{MM}\;P_M^2}{Q}} = \frac{-c_{MC}\;P_c}{c_{MM}\;P_M}$$ **Equation (D.5)**

Equation (D.5) gives the change in male labor as a result of changing child labor; however, it is often more convenient to calculate percentage changes. But multiplying each side of Equation (D.5) by $\frac{X_C}{X_M}$, percent changes may be obtained:

$$\frac{X_C\;d\,X_M}{X_M\;d\,X_C} = \frac{-c_{MC}\;P_c}{c_{MM}\;P_M} * \frac{X_C}{X_M}$$

$$\frac{d\ln X_M}{d\ln X_C} = \frac{-c_{MC}\;P_c\;X_C}{c_{MM}\;P_M\;X_M}$$ **Equation (D.6)**

In the Mathematical Appendix B when the model for this research was derived, it was also found in Equation (B.4) that $S_i = \frac{X_i\;P_i}{Q}$;therefore, formulas for X_i may be substituted into Equation (D.6):

$$\frac{d\ln X_M}{d\ln X_C} = \frac{-c_{MC}\;P_c}{c_{MM}\;P_M} * \frac{\dfrac{S_C\;Q}{P_C}}{\dfrac{S_M\;Q}{P_M}}$$

$$\frac{d\ln X_M}{d\ln X_C} = \frac{-c_{MC}\;S_C}{c_{MM}\;S_M}$$ **Equation (6.1)**

Equation (6.1) is the percentage change in male labor under the assumption of inflexible male wages and is presented in Chapter 6.

In order to obtain the wage changes for child, female and male labor System (D.2) should be utilized. From System D.2, Equation (D.7),a general equation may be written.

$$d\,P_i = F_{iC}\;d\,X_C + F_{iM}\;d\,X_M \qquad i = \{C, F, K\}$$ **Equation (D.7)**

From Equation (D.7), the percentage changes in the prices of other workers may be found. By rearranging Equation (D.7), multiplying each side by $\frac{X_C}{P_i}$ to obtain percentage changes, and substituting Equation (4.6) into Equation (D.7), Equation (6.2) is obtained.

$$\frac{d\,P_i}{d\,X_C} * \frac{X_C}{P_i} = \left[F_{iC} + F_{iM} * \frac{-c_{MC}\;P_C}{c_{MM}\;P_m} \right] * \frac{X_C}{P_i}$$

$$\frac{d \ln P_i}{d \ln X_c} = \left[\frac{c_{iC}\;P_i\;P_c}{Q} + \frac{c_{iM}\;P_i\;P_M}{Q} * \frac{-c_{MC}\;P_C}{c_{MM}\;P_M} \right] \frac{\frac{Q\,S_C}{P_C}}{P_i}$$

$$\frac{d \ln P_i}{d \ln X_c} = \left[c_{iC} + \frac{c_{iM} - c_{MC}}{c_{MM}} \right] S_C \qquad \textbf{Equation (6.2)}$$

INFLEXIBLE FEMALE WAGES

Similarly, for female inflexible wages with flexible wages in the remainder of the economy the above Equations (6.1) and (6.2) must be modified. Since the case when female wages are inflexible is identical to the case when male wages are inflexible except for the change in male and female subscripts, the equations may be found by simply exchanging male and female subscripts as in Equations (6.3) and (6.4) which are presented in Chapter 6.

$$\frac{d \ln X_F}{d \ln X_C} = \frac{-c_{FC}\;S_C}{c_{FF}\;S_F} \qquad \textbf{Equation (6.3)}$$

$$\frac{d \ln P_i}{d \ln X_c} = \left[c_{iC} + \frac{c_{iF} - c_{FC}}{c_{FF}} \right] S_C \qquad \textbf{Equation (6.4)}$$

$$i = \{C,\ M,\ K\}$$

This completes the derivation of the formulas for wage and employment changes under the assumption of either inflexible male or inflexible female wages.

MATHEMATICAL APPENDIX E

DERIVATIONS OF CHANGES IN LABOR MARKET WHEN BOTH MALE AND FEMALE WAGES ARE INFLEXIBLE

As with the case for changes in the labor market when either male or female wages were assumed to be inflexible, derivations for changes in the labor market when both male and female wages are inflexible begin with the system of differential equations from the Mathematical Appendix D's System (D.1):

System (D.1)

$$\begin{aligned}
dP_C &= F_{CC}\, dX_C + F_{CM}\, dX_M + F_{CF}\, dX_F + F_{CK}\, dX_K \\
dP_M &= F_{MC}\, dX_C + F_{MM}\, dX_M + F_{MF}\, dX_F + F_{MK}\, dX_K \\
dP_F &= F_{FC}\, dX_C + F_{FM}\, dX_M + F_{FF}\, dX_F + F_{FK}\, dX_K \\
dP_K &= F_{KC}\, dX_C + F_{KM}\, dX_M + F_{KF}\, dX_F + F_{KK}\, dX_K
\end{aligned}$$

For the situation where male and female wages are both inflexible, System (D.2) from the Mathematical Appendix D must be modified. By filling in the new appropriate zeroes in System (D.1), the new system may be developed:

System (E.1)

$$\begin{aligned}
dP_C &= F_{CC}\, dX_C + F_{CM}\, dX_M + F_{CF}\, dX_F + F_{CK} * 0 \\
0 &= F_{MC}\, dX_C + F_{MM}\, dX_M + F_{MF}\, dX_F + F_{MK} * 0 \\
0 &= F_{FC}\, dX_C + F_{FM}\, dX_M + F_{FF}\, dX_F + F_{FK} * 0 \\
dP_K &= F_{KC}\, dX_C + F_{KM}\, dX_M + F_{KF}\, dX_F + F_{KK} * 0
\end{aligned}$$

From the third equation in System (E.1) the following expression for dX_F may be found:

$$dX_F = \frac{-F_{FC}\, dX_C - F_{FM}\, dX_M}{F_{FF}} \qquad \textbf{Equation (E.1)}$$

By substituting Equation (E.1) into the second equation in System (E.1), Equation (E.2) may obtained. This equation my be solved to find the change in the employment of males as a function of only the change in the supply of children.

$$0 = F_{MC}\, d X_C + F_{MM}\, d X_M + F_{MF} \left[\frac{- F_{FC}\, d X_C - F_{FM}\, d X_M}{F_{FF}} \right]$$ **Equation (E.2)**

Rearranging, substituting for F_{ij} from Equation (D.4) into Equation (E.2), as was done in the Mathematical Appendix D, and reducing gives Equation (E.3).

$$\frac{c_{ij}\, P_i\, P_j}{Q} = F_{ij}$$ **Equation (D.4)**

$$\text{where } Q = F(X_C,\, X_M,\, X_F,\, X_K)$$

$$\frac{d X_M}{d X_C} = \frac{c_{CM}\, c_{FF}\, P_C\, P_F - c_{MF}\, c_{CF}\, P_F\, P_C}{c_{MF}^2\, P_M\, P_F - c_{MM}\, c_{FF}\, P_M\, P_F}$$ **Equation (E.3)**

By multiplying Equation (E.3) by $\frac{X_C}{X_M}$ to obtain percentage changes, substituting for X_C and X_M, and reducing, the percentage change in male employment as a result of changing the supply of child labor my be found to be:

$$\frac{d \ln X_M}{d \ln X_C} = \frac{\left(c_{CM}\, c_{FF} - c_{MF}\, c_{CF}\right) S_C}{\left(c_{MF}^2 - c_{MM}\, c_{FF}\right) S_M}$$ **Equation (6.5)**

In order to find the change in female labor as a result of changing the supply child labor, equation 2 of System (E.1) is substituted into equation 3 of the same system. Equation 3 is then rearranged in an identical manner described above for male labor to arrive at Equation (6.6) presented in Chapter 6, the percentage change in the employment of female labor as a result of changing the supply of child labor.

$$\frac{d X_F}{d X_C} = \frac{c_{CF}\, c_{MM}\, P_C\, P_M - c_{MF}\, c_{CF}\, P_M\, P_C}{c_{MF}^2\, P_M\, P_F - c_{FF}\, c_{MM}\, P_M\, P_F}$$ **Equation (E.4)**

$$\frac{d \ln X_F}{d \ln X_C} = \frac{\left(c_{CF}\, c_{MM} - c_{MF}\, c_{CM}\right) S_C}{\left(c_{MF}^2 - c_{MM}\, c_{FF}\right) S_F}$$ **Equation (6.6)**

To obtain the change in the wages of children and capital using System (E.1):

$$d P_i = F_{iC}\, d X_C + F_{iM}\, d X_M + F_{iF}\, d X_F \qquad i = \{C, K\}$$

$$d P_i = c_{iC}\, P_i\, P_c\, d X_C + c_{iM}\, P_i\, P_M\, d X_M + c_{iF}\, P_i\, P_F\, d X_F$$

$$\frac{d w_i}{d X_C} = c_{iC}\, P_i\, P_c + c_{iM}\, P_i\, P_M \frac{d X_M}{d X_C} + c_{iF}\, P_i\, P_F \frac{d X_F}{d X_C} \qquad \textbf{Equation (E.5)}$$

Substituting Equations (E.3) and (E.4) into Equation (E.5), multiplying by $\frac{X_C}{P_i}$ to obtain percentage changes, and rearranging gives Equation (6.7) from Chapter 6, the percentage change in the wage of children and capital with respect to a percentage change in the quantity of children.

$$\frac{d \ln w_i}{d \ln X_c} = \left[c_{ic} + \frac{c_{iM}\, c_{CM}\, c_{FF} - c_{iM}\, c_{MF}\, c_{FF} + c_{iF}\, c_{CF}\, c_{MM} - c_{iF}\, c_{MF}\, c_{MM}}{c_{MF}^2 - c_{MM}\, c_{FF}} \right] S_c$$

Equation (6.7)

This completes the derivation of the formulas presented in Chapter 6 for employment and wage changes as a result of reducing child labor under the assumption of inflexible male and female wages.

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