A Simulation of Industrial Output Utilizing Plant Level Data: Chile 1979-1986[1]

Charlie Braymen[2]

[1] Prepared for presentation at the University of North Carolina at Chapel Hill International Trade and Development Workshop Series, Spring 2004.

[2] The author thanks Prof. Nina Pavcnik of Dartmouth University for help with obtaining data. The author also thanks UNC Chapel Hill faulty and graduate students: namely Professors Patrick J. Conway, Alfred J. Field, Jr., and Xiaodong Wu; and graduate students Codrin C. Nedita, Bidisha Lahiri, Kellin C. Stanfield, Eketerina Tsibarova, and Katherine C. Theyson for helpful comments. All errors, of course are my own.

1. Overview

Any major macroeconomic policy change is likely to have major impact upon the distribution of both households and firms in the economy. Macroeconomic models can be used to predict the aggregate effect of policy changes. However, such models are lacking in their ability to address the effect of policy shifts on households and firms. Recent work has addressed the issue by linking macroeconomic models with microeconomic simulations. These works address the distributional impact of macroeconomic policies and shocks on household income distribution. However, the effect of such policies on firm level output and profits is not specifically explored. In order to examine the distributional impact of policy changes on firms, firm level data must be used. By linking a macroeconomic model with a microsimulation, distributional policy effects can be observed. This paper presents initial attempts to find a suitable microeconometric framework that will later be linked with a macroeconomic model. Production function parameters are estimating utilizing the framework of Pavcnik (2003). These parameters are then utilized to simulate future producer behavior. The econometric model presented herein does an adequate job of estimating firm level production function parameters, but fails to accurately simulate firm level responses to changes in price levels.

The next section of this paper provides a historical background for the economy that is examined, Chile (1979-1986). Section 3 is a literature review, which includes past work addressing production function estimation as well as micro-macro models that have examined distributional changes in household income. In Section 4 the underlying econometric theory utilized in the estimation and simulation is described. The following section describes the data examined and provides descriptive statistics. Section 6 discusses the empirical results, including the resulting simulation results The final section presents possible econometric models that will lead to better simulation results.

Section 2. Chile 1979-1986

When the Socialist regime of Chile was overthrown by Augusto Pinochet in 1973, a process of deregulation and privatization began. The economy had been hurt by hyperinflation, which had reached 487.5 percent in 1972 and 605.9 percent in 1973. Further, extremely protectionist trade barriers existed. The average nominal tariff rate was over 105 percent. In 1975, nontariff trade barriers were abolished. By 1979, the average tariff rate was lowered to a flat rate of ten percent. Export subsidies and credits were also abolished.

Despite the decline in inflation and a return to positive rates of economic growth by 1978, the nominal interest rate remained quite high. Figure 1 shows the extremely high, but declining average lending rates. This decline in interest rates occurred at the same time as the privatization of the banking sector. Under the socialist regime, the banking system had been nationalized. The allocation of credit was not based upon economic criteria, but instead was directed by the state. In 1974, after Pinochet's seizure of power, reserve requirements were lowered. Also, non-bank financial institutions were freed of government regulations regarding interest rates. Between 1975 and 1978 all financially solvent banks besides the state bank were privatized. The number of domestic banks in Chile grew from 18 in 1973 to 26 in 1981. In the same time period, the number of foreign banks operating in Chile grew from one to 19. The total volume of real credit to the private sector grew by over 1000% in the same period.

Although the banking sector grew dramatically in the late 1970's, savings remained low in the years 1978 to 1981, which slowed the fall of the nominal interest rate. The shortage of loanable funds led to an unwillingness of the banking sector to make low risk, low return loans. By November, 1981, the rapid liberalization and privatization of the banking system led the financial system to the brink of collapse. The Central Bank was forced to rescue four banks and four non-bank financial institutions that represented one half of the entire financial system.

The liberalization of the financial system had proceeded with little regard for the development of legal and regulatory institutions to govern the system. The Central Bank was limited in its legal ability to take action during the crisis. For instance, Gallego and Loayza (199) note that the required capital-asset ratios that did exist did not take into account the differences in risk of banks' assets. This coupled with the desire to make high risk, high return loans was a major influence in the crisis. The banking crisis resulted in the reestablishment financial controls in the banking system. Such controls included restrictions on foreign capital and regulated interest rates. However, by 1985 the controls on interests rates were eliminated, but the removal of this restriction on the banking system was coupled with new banking laws that established a more thorough regulatory system for the financial sector.

Most economic research that concerns Chile in the 1970's and 1980's examines the role of trade liberalization. However, the liberalization and reliberalization of the banking system also provides an interesting issue to examine. Such an issue fits nicely in the context of a micro-macro model. First, a policy shift, specifically the liberalization of the banking system, occurs. The effect of this policy on macroeconomic variables is predicted through the macroeconomic model. These variables are then passed to the microeconomic simulation, which predicts the policy's effect on the distribution of firms. While neither the interest rate nor expectations of the interest rate are currently included in the model presented in Section 4, the extensions discussed in the final section of this paper should provide an opportunity to include the interest into the model.

Section 3. Literature Review

This section reviews past work in two areas: micro-macro models addressing household incomes and the microeconometric estimation of production function parameters. A review of past micro-macro models is helpful in understanding the linking of macroeconomic and microeconomic models for the use in predicting distributional impacts. The review of micro-macro models in this section is limited, but is intended to presented in an attempt to allow the reader an understanding of where future work will be directed. The review of microeconometric estimation techniques provides a background of several issues that arise in attempting to estimate production function parameters.

Past micro-macro models seek to specifically address the impact a certain policy may have on the distribution of incomes. One such work is that of Ferreira et. al. (2003), which combines a macroeconomic model with a simulation based on household data. The macroeconomic portion of this work is a general equilibrium model that is estimated on a macroeconomic time-series. The microeconomic portion of this model is econometrically estimated on household survey cross-sectional data.

The macroeconomic parameters that Ferreira et. al. (2003) estimate are used to create a period ahead forecast of macroeconomic conditions. These conditions include 48 linkage aggregated variables that include price, wage, and employment estimates. These variables are then used to calibrate the constant terms of the estimated equations of the microeconomic model, which are then used to forecast future earnings. Poverty and inequality measures are then calculated from these simulate distributions.

Robilliard, Bourguignon, and Robinson (2001) also produce a micro-macro model. The effects of poverty and inequality caused by the 1997 Indonesian financial crisis are examined.

Similar to Ferreira et. al. (2003), the model is "top down;" the macroeconomic model creates variables that are utilized in the microsimulation. However, the macroeconomic model is not dependent upon the estimated or simulated microeconomic variables. The macroeconomic model developed by Robilliard, Bourguignon, and Robinson (2001) is a computable general equilibrium model based on a Social Accounting Matrix with 38 sectors and 15 factors of production.

Robilliard, Bourguignon, and Robinson (2001) estimate the household income determinants and occupational choices of individuals, which is based upon a sub-sample of an income survey. These estimates are combined with the vector of prices, wages, and aggregate employment variables produced by the macroeconomic model to simulate the changes in income generation of households. Robilliard, Bourguignon, and Robinson (2001) then calibrate the model by adjusting the constants of the household income and occupational utility functions to reflect the estimates of the macroeconomic model.

Several issues arise in estimating the production function parameters of firms. To create a microeconomic simulation that predicts firm response to changing market conditions, unbiased estimates of these production function parameters must be obtained. A Cobb-Douglas production function for firms in a given industry could be estimated in the following manner

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \varepsilon_{it}, \quad (3.1)$$

where y_{it} represents firm i's output at time t, and l_{it} and k_{it} represented labor and capital, respectively. However, OLS estimates on such an equation would be flawed for several reasons. First, (3.1) assumes a constant level of productivity, β_0, for all firms in the industry. This assumption is likely inappropriate. Therefore, a parameter could be added to the model that designates a firm specific level of productivity, such ω_i as in

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \omega_i + \varepsilon_{it}. \quad (3.2)$$

The above model could be estimated by a fixed effects regression. However, such an estimation fails to account for changes in productivity. This may be a valid assumption for short time periods in a stable environment; however, the objective of the estimation in this paper is to provide production function parameters to simulate producer behavior under policy changes in the macroeconomic environment. The assumption of a time-invariant productivity parameter is not valid in this context.

Therefore, (3.2) must include a firm level, time-varying productivity measure such as in

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \varepsilon_{it}. \quad (3.2)$$

Estimates via OLS of the above equation do not distinguish between firm level productivity and the error term. In order for the microeconomic simulation to produce accurate results the time-varying, firm level productivity must be measures. Further, it must be possible to predicted future values.

The issue of time-varying productivity has been addressed using several methods. Productivity can be assumed to evolve as function of time. For example, Lui (1993) uses an unobserved productivity measure based on a quadratic function of time such as

$$\omega_{it} = \alpha_{1i} + \alpha_{2i} t + \alpha_{3i} t^2 . \tag{3.3}$$

Such a productivity measure takes into account the past productivity measures of a firm in determining future output. Thus, a time-varying measure of productivity is obtained.

There are two issues that are not addressed by (3.3). First, is the endogeneity of input demand. While the firm level measure of productivity is not observed, it is known by the firm. A firm's level of investment, and use of all variable inputs, may be affected by its level of productivity. More productive firms are likely more likely to use more inputs to maximize their relative advantage in productivity. Therefore, endogeneity exists between the choice of inputs and the estimate unobserved productivity, which should bias the coefficients on the inputs in an upward direction.

The second issue not addressed by any of the previously described methods is a selection bias brought about by the exit and entry of firms into the market. Firms that leave the sample make the decision based upon their productivity and current and future market conditions. Thus, the existence of an observation is in itself dependent upon the firm's productivity. Such an issue is often addressed by using a balanced panel, in which observations are included in the data set only if firms exist throughout the sample period. The creation of a balanced panel eliminates this survival bias. However, in order to produce accurate simulation results production function parameters must be obtained for all firms, including those that leave the sample.

The issues of simultaneity and survival bias are addressed specifically in the model developed by Olley and Pakes (1996). Pavcnik (2003) applies this method to the data set used in this paper. The next section describes this method. However, as previously applied, this estimation method is limited in its forecasting power due to the fact that production function parameters are estimated using dummy variables for given time periods. As the final section of this paper explains, these dummy time variables need to be replaced with variables reflecting current and expected input and output prices in order for the simulation to accurate predict future producer behavior.

Section 4. Production Function Estimation

The model below is developed by Olley and Pakes (1996) , but it is reconstructed with variables similar to Pavcnik (2002), who applies the methodology to the same data discussed in the next sections. However, while the estimation of the production function parameters is identical to Pavcnik, the underlying purpose of such estimation differs. Pavcnik uses these estimates to analyze the effect of trade liberalization on productivity, whereas, in remainder of this paper, the estimates will be used to simulate future output. To accomplish this task, a modification must be made that allows predicted future market conditions to affect the estimated parameters of the model. This modification of the model has not yet been implemented, but is described in the final section of the paper.

This method utilized by Olley and Pakes (1996) is especially attractive for several reasons. First, it allows for a time-varying, firm level estimation of productivity. These productivity estimates are derived from past productivity, which enables a prediction of future productivity to be obtained. Second, the constant change in the economic environment of Chile during the years examined provides a continuous period of exit and entry throughout many industries. It is likely that the exit and entry behavior of these firms is based upon the relative productivity of these firms as compared to their peers.

The traditional method of analyzing industries with high levels of exit and entry is through the analysis of a balanced panel, which is a data set that contains only those firms that were present during the entire sample period. However, such a method may bias an accurate estimation of the production parameters of the firms in the entire sample because it is likely that exit or entry decisions of a firm is based to some degree on the firm's productivity level relative to its peers.   Since the Olley and Pakes (OP) method specifically provides estimates of time-varying productivity and addresses the survival bias, it seems particularly well suited to provide the econometric estimates of production parameters for the simulation. The OP method also eliminates bias due to the endogeneity of input demands that is based, at least partially, upon the firm's belief of future productivity. However, this positive quality of the estimation method also has a downfall. The parameters estimated are extremely sensitive to relative changes in input prices during the simulation, which is an issue that needs to be addressed in future work. This issue will be described in the Section 6. The remainder of this section describes the estimation of firm level production parameters.

Each firm in the econometric model is assumed to belong to a given industry, where it faces the same input prices as its competitor.   However, each firm differs from its peers in several aspects. First, each firm possesses different levels of capital. Further, each firm differs in its level of productivity. Therefore, the production decisions of each firm will differ according to its own state variables, capital and productivity.

Each period a firm must make several decisions. First, the firm must decide to stay in the market or exit. If the firm exits the market, it receives a liquidation value of Φ. If the firms stays in the market, it chooses the optimal level of inputs, taking its current capital as given, to produce output in the current period. The firm must also choose a level of investment, which, when combined with the current period's capital, becomes next period's capital. Capital evolves according to the following equation

$$k_{t+1} = (1-\delta)k_t + i_t, \tag{4.1}$$

where k_t and i_t denote the capital and investment at time period t and δ denotes a time invariant depreciation rate.

A firm's current period profit, defined as net cash flow with disregard for the cost of investment is dependent upon factor prices and market conditions during time t, which is defined explicitly as

$$\pi_t(\omega_t, k_t) = p_{yt}y_t - w_{bt}l_{bt} - w_{wt}l_{wt} - p_{mt}m_t, \tag{4.2}$$

where output, y_t, blue and while collar labor, l_{bt} and l_{wt}, and raw and intermediate goods, m_t, are time specific and p_{yt}, w_{lt}, w_{wt}, and p_{mt}, indicate the respective factor prices. However, since all inputs besides capital are variable and market conditions are equal across firms in a given market, each firm's maximization problem becomes

$$V_t(\omega_t, k_t) = \max\left\{\Phi_t, \sup \pi_t(\omega_t, k_t) - c_t(i_t) + \beta E\left[V_{t+1}(\omega_{t+1}, k_{t+1} \mid \Omega_{it})\right]\right\}, \tag{4.3}$$

where ω_t denotes a level of firm specific unobserved productivity over time, which evolves according to an exogenous Markov process, and $c_t(i_t)$ indicates the cost of investment. However, since market conditions and factor prices do not vary between firms in a given time period, they are embedded in the value functions and profit function by the subscripts on V_t and π_t. The max operator in the above equation denotes the comparison a firm makes in deciding to liquidate or to continue production. A firm liquidates if Φ is greater than its expected profits if it continued to produce.

As implemented in Olley and Pakes (1996) and derived in Ericson and Pakes (1995), the above control problem generates both an exit rule and an investment demand function. It is optimal for a firm to continue to produce if its level of unobserved productivity, ω_t, is greater than a threshold level, ϖ_t. The exit rule can be described by the following indicator function

$$\chi_t = \begin{cases} 1 & if \ \omega_t \geq \varpi_t(i_t, k_t) \\ 0 & otherwise \end{cases}. \tag{4.4}$$

The firm's investment demand relative to other firms is derived by its current level of unobserved productivity and output as

$$i_t = i_t(\omega_t, k_t). \tag{4.5}$$

In estimating the production function parameters, Cobb-Douglas technology is assumed. The production function is

$$y_{it} = \beta_0 + \beta_w l_{w,it} + \beta_b l_{b,it} + \beta_m m_{it} + \beta_k k_{it} + \omega_{it} + \eta_{it}, \tag{4.6}$$

where y_{it} is the log gross output of firm I at time t, the factor variables are as described previously, but in log form. The parameters, β_0 and ω_{it}, represent time-invariant industry-wide productivity and firm-specific, time-specific productivity, respectively. The error term, η_{it}, represents either a measurement error or a non-forecastable productivity shock. Both ω_{it} and η_{it} are unobservable to the econometrician, but ω_{it} is a state variable known by the firm and utilized in its decision making process.

Although firm level productivity cannot be directly measured, it can be expressed by observable variables. Since ω_{it} is dependent upon its past values, a firm with a high level of productivity in the current period expects to possess a high level of productivity in the next period. However, since a firm's next period productivity is also dependent upon its level of next period capital, this must also be taken into account. The level of capital in the next period is directly observable in the current period given current period investment and the depreciation rate in (4.1). Thus, the expectation of next period's productivity can be expressed as

$$E\left[\omega_{it+1} \mid \omega_{it}, k_{it+1}\right] = \omega_{it+1} + \xi_{it+1}, \qquad (4.7)$$

where ξ_{it+1} is an unanticipated productivity shock.

Therefore, the expected future marginal output of capital is indirectly based upon current productivity. As demonstrated in Pakes (1994), even though the current period's investment does not become capital until the next period, a firm's investment, $i_{it} = i_{it}(\omega_{it}, k_{it})$, is increasing in the current period's productivity, ω_{it}, for all levels where $i_{it} > 0$. Therefore, by inverting investment (4.5), unobserved productivity can be expressed as a function of observable variables, which is defined as

$$\omega_{it} = i_{it}^{-1}(\omega_{it}, k_{it}) = h_{it}(i_{it}, k_{it}) \,. \qquad (4.8)$$

By substituting (4.8) into (4.6), the regression model becomes

$$y_{it} = \beta_0 + \beta_w l_{w,it} + \beta_b l_{b,it} + \beta_m m_{it} + \beta_k k_{it} + h_t(i_{it}, k_{it}) + \eta_{it}$$

or

$$y_{it} = \beta_w l_{w,it} + \beta_b l_{b,it} + \beta_m m_{it} + \phi_t(i_{it}, k_{it}) + \eta_{it} \, , \tag{4.9}$$

where

$$\phi_t(i_{it}, k_{it}) = \beta_0 + \beta_k k_{it} + h_t(i_{it}, k_{it}) \, . \tag{4.10}$$

The above equation is now in a partially linear form (Engel, Granger, Rice, and Weiss (1986)) which allows for the consistent identification of β_w, β_b, and β_m, but it does not allow the coefficient on capital to be separated from unobserved productivity. By estimating the above model consistent coefficients for the variable inputs as well as an estimate for $\phi_t(i_{it}, k_{it})$ is obtained. By substituting the estimated coefficients of the variable inputs into (4.9), it becomes

$$y_{it} - (b_w l_{w,it} + b_b l_{b,it} + b_m m_{it}) = \beta_0 + \beta_k k_{it} + h_t(i_{it}, k_{it}) + \eta_{it}$$

or

$$ylm_{it} = \beta_0 + \beta_k k_{it} + h_t(i_{it}, k_{it}) + \eta_{it} \, .^{3} \tag{4.11}$$

In order to identify the coefficient on capital and unobserved productivity, the effect of capital on the decision to invest needs to be separated.

If a firm leaves the market in the next period, such a decision is made based upon the firm's expectation of its next period productivity as well as the firm's beliefs of next period's market conditions. Likewise, its investment is directly affected by its survival expectation, which is dependent upon next period's productivity. The probability that a firm will survive into the next period is

$$\Pr\{\chi_{t+1} = 1 \mid \varpi_{t+1}(k_{t+1}), \omega_t\} \, , \tag{4.12}$$

---

[3] [3] The subscript i is utilized here to distinguish between firm and industry based parameters. It is disregarded for the remainder of the section as future equations refer to firm level parameters.

which can be rewritten using (4.4) as

$$\Pr\left\{\omega_{t+1} \geq \varpi_{t+1}(k_{t+1}) \,|\, \varpi_{t+1}(k_{t+1}), \omega_t\right\}. \tag{4.13}$$

Given the evolution of capital (4.1), the investment rule (4.5), and the evolution of productivity (4.7), future capital and productivity can be calculated from past productivity and capital. Therefore, (4.13) becomes

$$p_t(i_t, k_t) = P_t. \tag{4.14}$$

The one-period ahead expectation of ylm_t in (4.11) can now be considered:

$$E\left[ylm_{t+1} \,|\, k_{t+1}, \chi_{t+1} = 1\right]$$

$$= E\left[\beta_0 + \beta_k k_{t+1} + \omega_{t+1}(i_{t+1}, k_{t+1}) + \eta_{t+1} \,|\, k_{t+1}, \chi_{t+1} = 1\right]$$

$$= \beta_0 + \beta_k k_{t+1} + E\left[\omega_{t+1}(i_{t+1}, k_{t+1}) \,|\, k_{t+1}, \chi_{t+1} = 1\right] \tag{4.15}$$

where the final term represents the expected future productivity conditional upon the firm staying in the market and its future level of capital, which is observable. The survival condition placed on this term eliminates the bias caused by plants that would exit the market as dictated by the exit rule (4.4). Therefore, the expectation of future unobserved productivity can be seem as a function of the probability the firm stays in the market, P_t, and current unobserved productivity as measured by h_t in (4.8). Thus, (4.15) becomes

$$\beta_k k_{t+1} + g(P_t, h_t). \tag{4.15}$$

Now by substituting (4.15) and also the unanticipated productivity shock into the time t+1 realization of (4.11), it is

$$ylm_{t+1} = \beta_k k_{t+1} + g(P_t, h_t) + \varepsilon_t, \tag{4.16}$$

where $\varepsilon_t = \xi_t + \eta_t$. This is the final theoretical equation that will be estimated.

The estimation is implemented in several stages. First, in the estimation of (4.9), a fourth order polynomial in (i_t, k_t) with a full set of interactions is utilized to approximate ϕ. From this regression consistent estimates of coefficients on the variable inputs are obtained as well as $\hat{\phi}_t$. The estimation of the survival probability (4.14) is estimated using a probit with the regressors a fourth order polynomial expansion of capital and investment with full interaction.[4]

Once $\hat{\phi}$ and $\hat{P}_t$ are obtained, these estimates can be used in the final estimation. However, a realization of h_t is needed to estimate (4.16). From (4.10) and $\hat{\phi}$, this realization is created as

$$\hat{h} = \hat{\phi} - \beta_k k_t \, . \tag{4.17}$$

These previously estimated variables can now be utilized in the final estimation, which utilizes a fourth order polynomial expansion to approximate $g(P_t, h_t)$ in the following equation:

$$ylm_{t+1} = \beta_k k_{t+1} + \sum_{j_1=0}^{4-j_2} \sum_{j_2=0}^{4} \beta_{j_1 j_2} \hat{h}_t^{j_2} \hat{P}_t^{j_1} + \varepsilon_t \, . \tag{4.18}$$

The above equation is used in the estimation results presented in Section 6. Several issues regarding this estimation must be discussed. First, as Pavcnik (2002) notes, the asymptotic results for the series estimator in (4.18) have not been proven. However, Olley and Pakes (1996) prove asymptotic results when a kernel estimator is used for (4.16). A kernel estimation of (4.16) would provide for asymptotically proven

[4] As noted by Olley and Pakes (1996) and utilized by Pavcnik (2002). The market structure may vary due to changing market conditions, therefore, ϕ_t and P_t should be indexed by time. The coefficient estimates presented later do not reflect this, which is an error that needs to be corrected in future work.

estimates of the coefficient on capital and, therefore, provide an opportunity for future work. However, Pakes and Olley (1996) do show that the difference in the results between the kernel estimator and the series estimator is minimal, which, given the relative ease of the series estimator, leads to its use in this paper.

Section 5. Data and Descriptive Statistics

The data that this paper utilizes for the previously described estimation is a manufacturing census collected by the Chilean National Institute of Statistics. The census provides detailed information regarding Chilean manufacturing plants with ten or more employees for the years 1979-1986. If market and entry and exit were not prominent throughout the sample, then survival bias would not need to be taken in consideration during the estimation. However, the constantly changing economic environment of Chile during the sample years led to numerous exits and entries. Table 1 shows the total number of plants in the sample, which shows a decline throughout most of the sample period. Likewise, the rates exit and entry do not remain constant, which is shown in Figure 2. From Table 1 and Figure 2, it can be noted that in some years firms exiting the sample account for over 10% of the sample.

In the next section, the data in the sample is divided into nine industries. These industry groups are based on the two-digit ISIC number reported throughout the sample. While a further disaggregation of the industries is possible in some cases, the smaller subset of observations for some three-digit industries is prohibitive of dividing all industries according to three-digit ISIC. A comparison of these industry groups can be seen in Table 2, which includes descriptive statistics of the factor utilization in each industry. It should be noted that the data in Table 2 is calculated from all observations, and, therefore, firms that are in the sample for longer periods have more influence on the descriptive statistics. The construction of the variables displayed in these tables and utilized in the next section is detailed in the Appendix.

It should also be noted that the parameter estimates are obtained utilizing observations from the years 1979-1985. This is intentional. The objective of this paper is to provide an accurate prediction of firm behavior in future years by using a simulation that utilizes parameters estimated from past data. By excluded observations from 1986, a comparison of the simulation's predictions can be made with actual observations for the year 1986.

Section 6. Estimates of Production Function Parameters and Simulation Results

6.1 Production Function Estimates

The estimation results of the production function parameters are presented in Table 3. This table displays the coefficient estimates and standard errors for each of the nine industry groups based upon two-digit ISIC classifications.

Table 3 reports the five different sets of estimates for each industry group. The first columns display the estimates of production parameters from the OLS and fixed effects regressions of the full sample. The next columns describe the production function estimates using a balanced panel. These estimates are obtained by eliminating firms that exited the sample. However, firms that entered the panel are included. The final columns are estimates of production function parameters based upon the Olley-Pakes estimation method described in Section 4. It should also be noted that OP estimation requires lagged variables in its estimation. To provide for an accurate comparison of estimated OLS and OP coefficients, the OLS regressions are based only on the same years as the OP estimates. Further, since Pakes (1994) only proves proves the case where investment is non-negative, only these observations are used.

A comparison of the coefficient estimates in Table 3 reveals that the OP estimates of coefficients on the inputs are typically smaller than the corresponding OLS estimates. As is described in Section 3, the endogeneity of input demands leads more productive firms to use more inputs, and, therefore, to upward bias the estimates of the coefficients on the inputs. Table 3 shows that the OP coefficient white-collar labor is smaller than the OLS coefficient in all industry groups except in the Textiles and Apparel group. However, this upward bias in OLS estimates is not seen for all coefficients in all industries. For example, in five of the nine industry groups, the OP coefficient on blue collar labor is greater than the OLS estimate. Further attention is warranted in both cases. However, an OP estimation that includes a time-varying ϕ_t and P_t will result in different coefficients, and, thus, this discussion is saved for future work.

6.2 Simulation Results

The objective of this paper is to create a microeconometric framework that is able to simulate the production responses of individual firms to changes in macroeconomic variables. As noted previously, the model described in Section 4 allows for firm level productivity to be estimated for each time period. In order to predict future output, several variables must be constructed or predicted.

$$ylm_{t+1} = \beta_k k_{t+1} + \sum_{j_1=0}^{4-j_2} \sum_{j_2=0}^{4} \beta_{j_1 j_2} \hat{h}_t^{j_2} \hat{P}_t^{j_1} + \varepsilon_t \,. \tag{4.18}$$

As shown in (4.18), a future value of capital must be known in order to begin the prediction process. Since the current period's investment becomes part of the next period's capital, the one-period forward capital variable can be constructed according to (4.1),

$$k_{t+1} = (1-\delta)k_t + i_t \,, \tag{4.1}$$

where current period capital and investment as well as the depreciation rate are all known. A predicted value for the left-hand-side of (4.18) can be obtained, which, when deconstructed as in (4.11) becomes

$$\hat{y}_{t+1} = \hat{y}lm_{t+1} + b_w \hat{l}_{w,t+1} + b_b \hat{l}_{b,t+1} + b_m \hat{m}_{t+1} \,. \tag{6.1}$$

The predicted level of output can be obtained if the levels of variable inputs for next period are known. However, the issue of obtaining the predicted levels of variable inputs still remains. In order to obtain these predicted levels, the first order conditions of the firms profit function must be examined. Only capital and unobserved productivity are considered state variables in the firm's optimization problem (4.3). The firm chooses the optimal level of investment given the firm's current level of capital and the firm's expectations of future productivity and market conditions. Once the firm enters a period, it optimally chooses its level of variable inputs, which is dependent upon the firm's current level of capital, technology, and factor prices. Therefore, the firm needs only to maximize its one period profit function as defined by

$$\pi_t(\omega_t, k_t) = p_{yt} y_t - w_{bt} l_{bt} - w_{wt} l_{wt} - p_{mt} m_t \,, \tag{4.2}$$

which can be combined with the firms estimated production function parameters to derive the firm’s optimal level of inputs. The estimated production function parameters include the estimates of the variable inputs taken from (4.9), as well as the firm level and industry productivity parameters in (4.18). The first-order conditions of this constrained maximization problem yield the optimal level of variable inputs as a function of prices, technology, and capital:

$$l*_{bt+1} = l*_{bt+1}(\hat{k}_{t+1}, E(p_{t+1}), \hat{\beta})$$

$$l*_{wt+1} = l*_{wt+1}(\hat{k}_{t+1}, E(p_{t+1}), \hat{\beta})$$

$$m*_{t+1} = m*_{t+1}(\hat{k}_{t+1}, E(p_{t+1}), \hat{\beta}), \tag{6.2}$$

where

$$E(p_{t+1}) = E_t \begin{bmatrix} p_{yt+1} \\ p_{mt+1} \\ w_{lt+1} \\ w_{bt+1} \end{bmatrix} \quad \text{and} \quad \hat{\beta} = \begin{bmatrix} \hat{h} \\ b_0 \\ b_w \\ b_b \\ b_m \end{bmatrix}.$$

The optimal level of inputs (6.2) can then be inserted into (6.1) to create expected future level of output for the firm.

The optimal variables inputs found utilizing the method is based upon the assumption that each firm faces the same cost of labor. This is not a valid assumption. Therefore, the average wage for each labor type is found. These wages are utilized to find the optimal level of variable inputs. However, such an optimal level did not accurately reflect the firm level labor usage. To account for this in the simulation, an optimal level of variable inputs is found for both 1985 and 1986, which allowed an optimal percentage change in variable to be calculated. This percentage change is then used to adjust the variable input usage from 1985 to 1986. If firms did choose variable inputs optimally, the 1985 levels of variable inputs should be the same.

Several issues should be addressed before turning to the simulation results in Table 4. The simulation results are based upon the parameter estimates presented in Table 3. As discussed previously, these estimates were created without varying ϕ_t and P_t with time. Table 4 presents the mean of log output for firms in each industry group. This is not a substitute for simulating the true total expected output of each industry, but serves as a benchmark for future changes in the model. Likewise, when the true expected output of each industry is created, this expectation will need to take into account the probability that a firm will exit. Table 4 shows that the number of firms in the simulation group varies from the number of firms producing in 1986. Such an expectation will need to be based upon a time-varying survival probability. Section 7 proposes the method of creation for time-varying ϕ_t and P_t. It should also be noted that firms will need to enter the sample. Thus, a entry probability needs to be created in a many similar to the creation of the time-varying exit probability.

Table 4 includes the simulation results for each industry group. For each industry group the results of several industry groups are reported. In these first simulations, the firm does not vary its level of variable inputs. Only the level of capital is changed from the previous years values in predicting the level of 1986 output. These results are closest to the actual mean log output in all industry groups except one, Paper and Printing. The second simulation for each industry group is a simulation based on the true price changes for inputs and output. This is not a possible method to predict future output. However, since a firm does choose variable inputs the prices of variables inputs and output are known, this simulation serves as an indicator of the performance of the simulation. Unfortunately, the results of these simulations leave much room for improvement. The final simulation results are based upon predicted price changes. Price changes are predicted from past price indices assuming such indices follow a log-differenced ARMA(1,1) process. Table 5 compares the actual price changes with the predicted values. These predicted values underestimate inflation in all forms. However, a simulation based on expected price changes is similar to that which will be integrated with the macroeconomic model in the future. Such an integration is only possible, however, if the simulation produces more accurate results than those presented in Table 4. The next section suggests several changes that need to be made to accomplish this task.

Section 7. Further Work and Concluding Remarks

The simulation results presented in the previous section need to be improved if the results are to be used to predict distributional changes in output. This section suggests several possible improvements that can be made in future work.

First, the estimation of production parameters needs to include a time-varying ϕ_t and P_t. These variables need to reflect current market conditions and expectations of future market conditions. Olley and Pakes (1996) and Pavcnik (2002) estimate different polynomials for different time periods throughout the sample. Pavcnik (2002) addresses this issue by creating time period dummy variables, which are used to interact with the polynomials. This is designed to reflect changes in market structure and factor prices over the different time periods in the sample. Such an approach is appropriate if the objective is to measure past productivity changes. However, for the purpose of a simulation used to predict future output, a dummy variable for future time periods cannot be estimated. Therefore, ϕ_t and P_t need to be estimated in a model that includes current and expected future market conditions. Such an estimation will then be market structure and factor price dependent, but will not rely upon a dummy variable for time. Applying this change to the estimation of the production parameters will likely lead to an improvement in the results of the simulation.

The estimation of production parameters was conducted at the two-digit industry level. However, the simulation results for smaller and more homogenous industries, such as Paper and Printing, were more accurate. Therefore, where possible, the estimation production parameters and the corresponding simulation should use data from three-digit ISIC industry groups. Further divisions to the subsets may also be made where deemed appropriate. This will lead to a more specific estimation of individual firm production parameters and improve the simulation results.

Appendix.

The plant level data utilized in this paper is taken from the data set utilized by Liu (1993), Tybout (1996), and Pavcnik (2002). The construction of the variables is described in detail by Lui (1993). Each firm reported nominal values for the corresponding census year. These values are expressed in constant 1980 Chilean pesos by deflating each with three-digit industry level price indices.

The construction of the capital value deserves special attention. Capital stock was only reported in 1980 and 1981. The capital variable utilized in this paper was created by a using a perpetual inventory method described by Lui (1993), which involves accumulating capital forward and backward for the appropriate years while also accounting for depreciation. Some plants reported capital stock in only 1980 or 1981, and others reported capital stock in both years. In the case of a plant reporting capital stock in both years, the capital variable utilized in this paper is based upon the 1981 level of capital. If only the year 1980 value exists, then capital measures constructed from this measure are used. The capital variable in the data set includes current year investment. The econometric model used for the estimation of production function parameters assumes a one-period lag before investment becomes capital (4.1), therefore, capital is reconstructed so that it does not contain current year investment.

The data used to created expected price changes for the simulation comes from the International Monetary Fund's International Financial Statistics CD-ROM. The change in output prices is based upon the Consumer Price Index series. The change in intermediate good prices is based upon the Wholesale Price Index. Data was unavailable to calculate the change in wages. Therefore, the change in wages is based upon the Household Goods Price Index.

References.

Engle, R., W. Granger, J. Rice, and A. Weiss (1986) "Semiparametric Estimates of the Relationship between Weather and Electricity Sales," *Journal of the American Statistical Association* **81**, pp. 310-320.

Ericson, R. and A. Pakes (1995) "Markov-Perfect Industry Dynamics: A framework for Empirical Work," *Review of Economic Studies* **62**, pp. 53-82.

Ferreira, F., P. Leite, L. Pereira da Silva, and P. Pichetti (2003) "Aggregate Shocks and Income Distribution: Can Macro-Micro Models Help Identify Winners and Losers from a Devaluation?" Working Paper, version April 8, 2003.

Gallego, F. and N Loayza (1999) "Financial Strusture in Chile: Macroeconomic Developments and Microeconomic Effects" presented at the Financial Structures and Economic Development Conference at the World Bank, Feb. 10-11, 2000.

Lui, L. (1993) "Entry-exit, learning and productivity change: Evidence from Chile", Journal of Development Economics **42**, pp. 218-242.

Pavcnik, N. (2002) "Trade liberalization, Exit, and Productivity improvements: Evidence from Chilean Plants," *Review of Economic Studies* **69**, pp. 245-76.

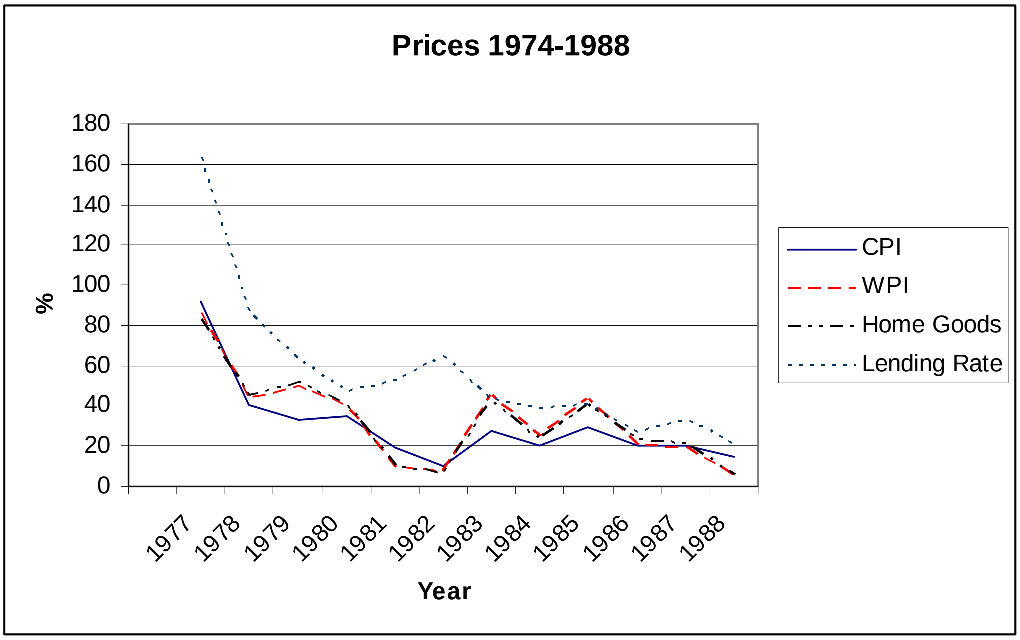
Olley S. and A. Pakes (1996) "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica* **64**, pp. 1263-1297.

Pakes, A. (1994) "Dynamic Structural Models, Problems and Prospects Part II" Mixed Continuos Discrete Control Problems, and Market Interactions," in *Advances in Econometrics*, ed. C. Sims. Cambridge, Cambridge University Press.

Robilliard, A., F. Bourguignon, and S. Robinson (2001) "Crisis and Income Distribution: A Micro-Macro Model for Indonesia" Working Paper, June 2001.

Tybout, J. (1996) "Chile, 1979-1986: Trade Liberalization and Its Aftermath," in *Industrial Evolution in Developing Countries*, eds. M. Roberts and J. Tybout, Oxford, UK, Oxford University Press.

Figure 1.



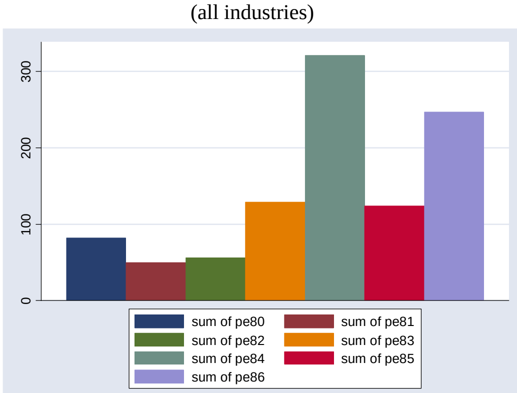
source: IMF IFS

Table 1. **Total Plants**

Year	1979	1980	1981	1982	1983	1984	1985	1986
Total Plants	5814	5308	4872	4484	4205	4378	4333	4205

Figure 2.

Plants Entering Sample (1980-1986)
(all industries)



Plants Exiting Sample (1979-1985)
(all industries)

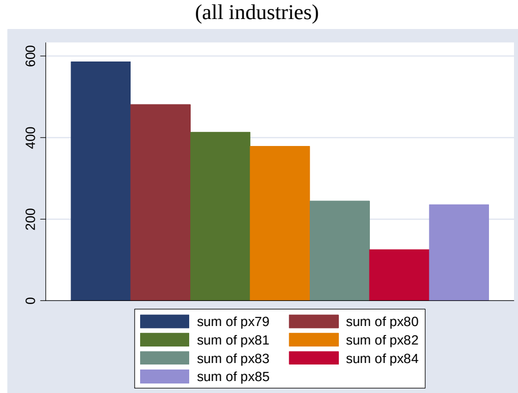


Table 2.

		Mean	Std. Dev
Food Processing (312/313/314)	Labor (blue)	34.93896	59.89781
	Labor (white)	10.57449	26.22595
	Materials	66077.01	205108
	Capital	40999.97	176706.5
	Investment	2745.795	16656.69
	Output	115745.7	421301.5
	N	9666	
Textiles/Apparel (321/322/323/324)	Labor (blue)	44.59738	85.63387
	Labor (white)	10.77526	29.84306
	Materials	32802.78	74990.91
	Capital	20897.5	83954.87
	Investment	1233.833	6558.015
	Output	59723.77	139520.5
	N	5571	
Wood Products (331/332)	Labor (blue)	36.12436	73.13832
	Labor (white)	5.932198	12.42117
	Materials	23972.65	69885.08
	Capital	28595.74	196717.5
	Investment	1461.169	10044.61
	Output	42837.49	139153.1
	N	2935	
Paper/Printing (341/342)	Labor (blue)	44.58498	95.32152
	Labor (white)	24.1357	74.28469
	Materials	100686.5	414566.2
	Capital	163390.3	877523.5
	Output	178090.7	664369.3
	Investment	11352.76	104701.4
	N	1518	
Chemicals (351/352/353/ 354/355/356)	Labor (blue)	41.5464	71.98113
	Labor (white)	23.96835	48.84656
	Materials	242768.1	2362898
	Capital	120579.1	958545.3
	Output	312819.7	2288972
	Investment	3698.292	14074.78
	N	2780	
Ceramics/Glass (361/362/369)	Labor (blue)	43.25054	65.96997
	Labor (white)	14.24401	32.68012
	Materials	72852.18	236892.3
	Capital	141841.9	514994.4
	Investment	12314.56	135721.9
	Output	114281.7	333654.8
	N	918	
Metals (371/372)	Labor (blue)	157.0399	422.596
	Labor (white)	70.50704	160.5222
	Materials	521924.7	1520061
	Capital	244150.8	575991.7
	Investment	31243.35	117610
	Output	1919028	5390300
	N	426	
Machinery (381/382/383 384/385)	Labor (blue)	39.69614	60.49815
	Labor (white)	15.7199	41.30237
	Materials	47589.08	207503.1
	Capital	30298.07	98189.07
	Investment	2328.421	14416.8
	Output	73508.28	221640.7
	N	4252	
Other (390)	Labor (blue)	20.85	20.52676
	Labor (white)	6.594444	9.586839
	Materials	12678.84	21513.13
	Capital	10670.51	61336.13
	Output	23250.87	37749.84
	Investment	520.1731	2823.992
	N	360	

Note: Labor is employees. All other quantities are 1980 Chilean pesos.

Table 3.

		Full Sample				Balanced Panel				Semi-Parametric	
		OLS		Fixed Effects		OLS		Fixed Effects		(Olley-Pakes)	
		Coef.	s.e.	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
Food Processing	Labor (blue)	0.126	0.007	0.193	0.012	0.126	0.007	0.193	0.012	0.133	0.007
(312/313/314)	Labor (white)	0.135	0.006	0.023	0.008	0.135	0.006	0.023	0.008	0.123	0.006
	Materials	0.794	0.005	0.684	0.007	0.794	0.005	0.684	0.007	0.761	0.004
	Capital	0.051	0.003	0.017	0.006	0.051	0.003	0.017	0.006	0.013	0.007
	N	7456				6367				7456	
Textiles/Apparel	Labor (blue)	0.231	0.010	0.237	0.016	0.222	0.011	0.240	0.017	0.225	0.011
(321/322/323/324)	Labor (white)	0.117	0.008	0.062	0.011	0.120	0.008	0.061	0.012	0.118	0.008
	Materials	0.676	0.006	0.585	0.010	0.679	0.007	0.584	0.011	0.665	0.007
	Capital	0.046	0.004	0.011	0.010	0.043	0.005	0.007	0.011	0.010	0.014
	N	4076				3995				4076	
Wood Products	Labor (blue)	0.220	0.013	0.266	0.022	0.208	0.014	0.029	0.018	0.207	0.015
(331/332)	Labor (white)	0.103	0.012	0.028	0.017	0.103	0.013	0.269	0.023	0.095	0.014
	Materials	0.726	0.009	0.575	0.013	0.730	0.010	0.566	0.014	0.717	0.009
	Capital	0.047	0.006	-0.014	0.013	0.051	0.007	-0.013	0.014	0.041	0.008
	N	2237				1776				2237	
Paper/Printing	Labor (blue)	0.205	0.022	0.222	0.030	0.186	0.023	0.229	0.032	0.189	0.024
(341/342)	Labor (white)	0.140	0.014	-0.016	0.021	0.142	0.015	-0.024	0.023	0.109	0.015
	Materials	0.612	0.012	0.526	0.021	0.636	0.013	0.553	0.023	0.587	0.013
	Capital	0.093	0.010	0.062	0.027	0.088	0.010	0.074	0.032	0.080	0.006
	N	1287				1073				1287	
Chemicals	Labor (blue)	0.055	0.013	0.238	0.020	0.038	0.013	0.229	0.020	0.042	0.014
(351/352/353/	Labor (white)	0.179	0.011	0.073	0.015	0.174	0.011	0.070	0.015	0.163	0.012
354/355/356)	Materials	0.707	0.009	0.505	0.013	0.712	0.009	0.509	0.013	0.684	0.010
	Capital	0.091	0.007	0.009	0.013	0.096	0.007	0.004	0.013	0.037	0.019
	N	2549				2317				2549	

Table 3 (cont.)

		Full Sample				Balanced Panel				Semi-Parametric	
		OLS		Fixed Effects		OLS		Fixed Effects		(Olley-Pakes)	
		Coef.	s.e.	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
Ceramics/Glass (361/362/369)	Labor (blue)	0.320	0.028	0.390	0.045	0.314	0.030	0.366	0.047	0.326	0.031
	Labor (white)	0.128	0.027	-0.002	0.035	0.139	0.028	-0.018	0.036	0.116	0.029
	Materials	0.616	0.020	0.507	0.028	0.610	0.021	0.504	0.029	0.607	0.021
	Capital	0.100	0.013	-0.022	0.033	0.098	0.014	-0.027	0.035	0.001	0.030
	N	770				670				770	
Metals (371/372)	Labor (blue)	0.112	0.041	0.271	0.068	0.105	0.041	0.238	0.069	0.131	0.044
	Labor (white)	0.171	0.036	0.115	0.050	0.164	0.036	0.127	0.051	0.069	0.039
	Materials	0.744	0.017	0.412	0.035	0.748	0.016	0.410	0.035	0.724	0.019
	Capital	0.002	0.018	-0.046	0.038	0.015	0.018	-0.044	0.038	0.064	0.015
	N	346				326				346	
Machinery (381/382/383 384/385)	Labor (blue)	0.199	0.012	0.204	0.017	0.182	0.012	0.196	0.018	0.213	0.013
	Labor (white)	0.175	0.009	0.087	0.013	0.185	0.010	0.093	0.014	0.158	0.010
	Materials	0.632	0.007	0.568	0.011	0.631	0.008	0.564	0.012	0.614	0.008
	Capital	0.069	0.005	0.070	0.016	0.069	0.006	0.076	0.016	0.048	0.005
	N	3694				3120				3694	
Other (390)	Labor (blue)	0.364	0.061	0.407	0.082	0.379	0.066	0.435	0.087	0.372	0.071
	Labor (white)	0.059	0.041	0.064	0.060	0.101	0.049	0.091	0.066	0.047	0.047
	Materials	0.531	0.032	0.600	0.049	0.524	0.037	0.561	0.055	0.506	0.036
	Capital	0.092	0.023	0.056	0.054	0.066	0.028	0.069	0.057	0.033	0.051
	N	299				245				299	

Table 4. Simulation Results

	# of Firms	Mean Log Output	Industry Std Dev.	Min.	Max.
31					
Forecast (no change)	938	10.45217	1.502099	6.89564	15.22793
Forecast (Perfect)	938	10.04604	2.812724	4.34144	18.30368
Forecast (ARMA)	938	10.91951	3.049676	4.73435	19.87281
Actual Output	997	10.44629	1.562522	6.65167	15.22351
32					
Forecast (no change)	500	10.30836	1.303592	6.68368	14.40264
Forecast (Perfect)	500	11.18054	2.973541	3.32513	20.50021
Forecast (ARMA)	500	12.24654	3.224041	3.72937	22.35133
Actual Output	513	10.48049	1.362174	6.68368	14.40264
33					
Forecast (no change)	237	9.941213	1.228445	7.39947	14.13965
Forecast (Perfect)	237	11.42215	2.083631	7.28156	17.79427
Forecast (ARMA)	237	11.47916	2.193422	6.54549	15.9955
Actual Output	245	10.0486	1.338525	6.9211	13.80835
34					
Forecast (no change)	153	10.34755	1.740283	7.29643	15.71406
Forecast (Perfect)	153	10.25179	1.710846	7.29503	15.51309
Forecast (ARMA)	153	10.25554	1.710846	7.29879	15.51685
Actual Output	137	10.25676	1.822655	6.85557	15.5483
35					
Forecast (no change)	314	11.11965	1.439693	8.23804	17.00801
Forecast (Perfect)	314	10.87426	1.496972	7.94415	16.68027
Forecast (ARMA)	314	10.88676	1.496963	7.95665	16.69277
Actual Output	301	11.16514	1.484095	8.10496	16.87518
36					
Forecast (no change)	86	10.22053	1.670429	7.57567	14.62791
Forecast (Perfect)	86	10.5531	1.862088	7.49962	15.07714
Forecast (ARMA)	86	10.58743	1.862341	7.53395	15.11147
Actual Output	89	10.36958	1.799713	6.80667	14.52532
37					
Forecast (no change)	43	12.73773	2.680316	8.0223	20.19468
Forecast (Perfect)	43	12.35188	2.666704	7.59776	19.4838
Forecast (ARMA)	43	12.36409	2.664312	7.60997	19.496
Actual Output	43	12.73761	2.241825	8.64284	17.10609
38					
Forecast (no change)	428	10.18974	1.451341	6.62825	14.69604
Forecast (Perfect)	428	7.98237	1.916162	0.14711	13.52811
Forecast (ARMA)	428	7.919932	1.451341	0.08467	13.46568
Actual Output	403	10.34386	1.350551	7.33472	14.5619

Table 5. Predicted and Actual Price Changes

	Predicted	Change
CPI	1.11266947	1.206171
Wage	1.11245466	1.23418
WPI	1.11264035	1.198117