

A Production, Distribution and Investment Model for a Multi-national Company

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Abstract

Considerable research literature exists on production planning, distribution, and investment models. In most cases they have been treated independently in an environment of low inflation rates. Unfortunately, work extending these problems to multinational companies is sparse. In this paper, we develop an integrated production planning, distribution, and investment model for a multinational firm that produces products in different countries and distributes them to geographically diverse markets. Since MNCs operate in different countries under varying exchange and inflation rates, varying opportunities for investing, and differing regulations, these factors should be included in the decision process. In our modeling, we incorporate these factors and elicit the performance of our model through an example and discuss the results. The results indicate that the exchange rates and initial capacity levels of the firms have significant effects on the production, distribution, and investment decisions, and consequently, on the profit.

1. Introduction

A multinational corporation (MNC) is a firm that engages in foreign direct investment and owns or controls value-adding activities in more than one country (Griffin & Pastay, p. 11, 2003). The MNCs influence international trade. In 2000 the total sales of world's 500 largest corporations was \$14.1 trillion (Fortune, July 23, p. F1, 2001). Of these, 185 corporations or 37% are headquartered in the United States, which underscores the importance of U.S. in the world economy. The international trade in 1995 was about \$5.5 trillion (Noori and Radford, 1995) which grew to \$7.8 trillion in 2000 (World Trade Organization website, 2002). International companies control about 25% of the \$11 trillion global output, one third of which is produced in host countries (Schary & Skjott-Larsen 2001). The revenues from abroad for American companies are now twice their export earnings. About one-fifth of the output of U.S. firms is produced overseas (Dornier et al. p. 76, 1998). The multinational companies are growing more rapidly as more and more companies are merging (e.g., Glaxo and SmithKline Beecham announcement, Wall Street Journal, February 2, 1998, p. A1), or being taken over (e.g., Britains B.A.T. Industries PLC take over of Mexico's Cigarrera La Modena, Wall Street Journal, September 30, 1997, p. A1). Or, the purchase of two youth-oriented Canadian apparel chains by

the American Eagle (American Eagle Works at Keeping Its Performance Aloft, Wall Street Journal, November 28, 2000, p. B2).

However, managing international operations presents a complex and challenging set of tasks. Unfortunately, the research on the operational modeling of MNCs is sparse. Hence, it is very difficult to ascertain the effects of changes taking place in one geographical location on the functioning of the other facilities, and on the overall performance of the MNCs. For example,

- How do the fluctuations in foreign exchange rates and inflation rates affect the functioning of not only the host facility(ies) but also all other facilities of the MNC?
- What is the optimal way of financing the operations?
- Is it better to fund these operations with direct money from U.S.? Or,
- Is it better to borrow a proportion of budgeted money from local sources? Or,
- Should they use some of the money earned through prior investments in markets? Or,
- Are the return on the investments (seed money) made are enough to sustain facilities operations?
- How do the changes in exchange rates and inflation rates affect the logistics?
- How do the changes in exchange rates and inflation rates affect the strategic role of the foreign facilities?

The integrated model developed in this paper can address these and several other related questions. The model integrates production planning, product distribution (logistics), and investment problems. Production planning decisions involve determining, for each facility, the products and their quantities to be produced. In the ensuing process of production planning, decisions regarding capacity, workforce adjustments, overtime, subcontracting, and machine capacity levels are also made for some planning horizon, usually a one year period. Logistics decisions include which facilities (suppliers) will cater to the demand of which markets (distribution centers). Financial decisions include investment opportunities, borrowing of capital, disbursing of dividends and other related decisions.

The impetus to develop an integrated model was born out of the fact that such a model is lacking in the current research literature. Mostly, the above three problems have been treated independently and perhaps is justifiable since facilities and markets considered were operating under

low inflation rates. Recognizing that the overall decisions for an MNC should consider all facilities, markets and investment opportunities, we attempt to fill the void by developing an integrated production planning, distribution, and financial investment model. Our model incorporates the effects of varying inflation rates, exchange rates, and other regulations under which a facility has to operate in a host country(ies). Exchange rates and inflation are two of the complicating macroeconomic factors in the global environment (Dornier et al., p. 224, 1998). Firms such as Komatsu take advantage of fluctuations in foreign currency to lower production costs by moving production to the facilities in countries whose currencies have depreciated (Hiezer & Render, 2000). On the other hand, firms find it difficult to operate under conditions of high inflation rate as in the case of a Turkish firm reported in Kirca & Koksalan (1996).

The results from our model indicate that the exchange rate and initial capacities of the facilities have pronounced effects on profits, capacities needed to satisfy demand, production and distribution of products, and investments needed to support facilities operations. Thus, we see the effects of the exchange rate not only on the functioning of the facility in a host country, but also on the functioning of the domestic facility. The facilities' first period operations are funded by direct funds from the U.S., and subsequent periods' operations are funded by the returns earned on the investments made in the markets. As the return on the investment is the main source of funding facilities' operations, more money is invested in the markets of facilities satisfying much of the global demand. Where it is required to borrow money from local sources, more money is borrowed when the dollar is stronger. When the dollar is weaker (low exchange rates), the U.S. facility satisfies much of the global demand, and since it is assumed to be more efficient, less capacity is consumed. Of course, more profit is made and more money is invested in the markets (since it is the main source of funding) as compared to when the dollar is stronger. **Many other findings are discussed in Section 4.**

The remainder of this paper is organized as follows. **In Section 2, we describe the growing potential of global markets and the MNC environment. In Section 3, we develop an integrated production planning, distribution, and investment model. In Section 4, we elicit the model's performance through numeric examples and discuss results. In Section 5, we present and discuss our conclusions.**

2. MNC and its Environment

Different terms abound for the multinational corporation. They are: global, world, transnational, international, supernational, and supranational corporations (Czinkota et al. 1994, p. 356). Likewise, there are various definitions for an MNC. The United Nations defines MNCs as *"enterprises which own or control production or service facilities outside the country in which they are based."* Another definition is "(MNC) is a firm that engages in foreign direct investment and owns or controls value-adding activities in more than one country" (Griffin & Pastay, p. 11, 2003). Both definitions are economist oriented (Rugman 1981). They capture both the quantitative and qualitative dimensions.

Quantitatively, for a firm to be regarded as multinational, the number of countries of operation is typically two, although the Harvard multinational enterprise project required subsidiaries in six or more nations (Vernon 1971, p 11). Another measure is the proportion of overall revenues generated from the foreign operations - 25% to 30% is the most often cited (Rugman 1976). For example, Caterpillar has 114 factories spread over five continents and almost half of its revenues was from overseas in 2001 (Griffin & Pastay, p. 120, 2003) and McDonald has stores in 103 foreign countries which contribute 59% of its total operating income (Fortune, October 13, 1997). The economic power of the world's largest entities is enormous. The 500 largest industrial corporations account for 80 percent of the world's direct investment and ownership of foreign affiliates (Stopford 1982).

Foreign direct investment (FDI) represents one component of the international business flow and includes start-ups of new operations, as well as purchases of existing companies. The other component is portfolio investment, which includes the purchase of stocks and bonds internationally. The growth of FDI is phenomenal. In 1967, it was about \$112 billion and in 1999 it was \$3.5 trillion (World Bank's World Investment Report 1999). In 1994, the world's ten industrialized countries received half of the world's foreign direct investments and accounted for two-thirds of the world's accumulated stock of foreign direct investments (Ferdows, 1997). The largest recipient was the United States and by 1994, foreign multinationals had more than \$500 billion in U.S., up from \$80 billion in 1980. FDI in the U.S. totaled \$1.2 trillion in 2000 with United Kingdom being the most important source of this FDI with \$229.8 billion and, at the same time, U.S. FDI abroad totaled \$1.2 trillion with United Kingdom receiving \$233.4 billion (Survey of Current Business, September 2001, pp. 53 and 90).

Qualitatively, for a firm to be an MNC, its management must consider it multinational and must act accordingly. In terms of the management philosophies, firms can be categorized as ethnocentric (home-market oriented), polycentric (oriented toward individual foreign market), and regiocentric or geocentric (oriented toward larger areas, even the global market place). We use the term MNC in a global context - *firms that view their domestic operations as a part of worldwide operations and direct an integrated business system*.

Why do firms choose to be multinational? Firms expand internationally for a variety of reasons. According to Ferdows (1997), these reasons include:

- Reduce direct and indirect costs,
- Reduce capital costs,
- Reduce taxes,
- Reduce logistics costs,
- Overcome tariff barriers,
- Provide better customer service,
- Spread foreign exchange risks,
- Build alternative supply sources,
- Preempt potential competitors,
- Learn from local suppliers, foreign customers, foreign competitors, and foreign research centers, and
- Attract talent globally.

These reasons can be broadly classified into marketing factors, barriers to trade, cost factors, investment climate, and general categories. Factors considered in our model include cost of production (manufacturing) and distribution (logistics), labor costs (capacity), expertise in production and distribution (efficiency), currency exchange regulations, stability of foreign exchange, opportunities in investing stocks and bonds, and local debt.

There are six strategic roles for foreign factories of MNCs (Ferdows, 1997). They are: off-shore factory, source factory, server factory, contributor factory, outpost factory, and lead factory. An off-shore factory is established to produce specific items at a low-cost and then export for further rework or for sale. The primary purpose of a source factory is also a low-cost production but gives

local managers authority over production planning, redesign, process changes, and out-bound logistics. A source factory has the same ability to produce a part as the best factory in the company's global network. A server factory supplies specific national or regional markets. It typically provides a way to overcome tariff barriers, logistics costs, and exposure to foreign exchange fluctuations. A server factory is not as developed or has powers as that of a source facility. A contributor factory also serves a national or regional market, as developed as a source factory, and has more powers to develop products, process engineering, sources of supply, and development of production capabilities. An outpost factory's primary role is to collect information. They are located where competitors, research laboratories, or customers are located. They also serve the secondary strategic role as a server or an off-shore, for example. A lead factory creates new processes, products, and technologies for the entire company. It should be noted that the choice of the factory not only influences the location, but also the operating decisions of the facility.

Managing global operations for a firm are more difficult as it has to face different cultures, values, rules, and varying degrees of business, political, and economical uncertainties. In other words, globally operating companies are faced with far more ambiguity, both internally and externally, than their domestic counterparts. There are other factors which further deter the global competitiveness of a company. Shorter product life cycles, fragmented and saturated markets, more demanding customers, consolidation and mergers of companies, and rapid advances in processes/technology always present a dynamic competitive situation. Hence, in this environment, manufacturing and operations excellence are critical factors for profitability, and globalization is an essential component of the firm's competitive strategy. Globalization means moving production facilities around to benefit from the quickest brains or the cheapest labor to position a firm competitively against its competition.

3. Model Development

Initially, a firm has to decide whether it should expand internationally. If it decides to become an MNC, then decisions related to international location(s), production strategy (mode)/strategic role, and operations have to be made.

Several studies have shown that transferring production to foreign locations is a viable alternative for lowering production costs, entry into foreign markets, and avoiding import (export) restrictions to gain competitive advantage in domestic and global markets. McDonald (1986) claims

that many manufacturing companies are willing to locate their facilities in any part of the world where they can obtain cheap labor, more reliable materials, parts, subassemblies, vendors, and governments which provide financial incentives. However, Hoch (1982) points out that many American firms fail to recognize the potential of these investments - leading to faulty facility location. The location decision is complex and involves many factors (List and Catherine, 2000). Tong et al. [22] using a questionnaire survey conducted by mail, identified thirty-two possible location variables, and then using factor analysis narrowed them down to five factors including availability of transport services, labor attitudes, proximity of markets, space for future expansion and suitable plant sites. The attempt was to try and come up with a handful of factors that could be considered when foreign firms consider locations to setup facilities. In another study Schemmer [25] talks about ten basic variables that firms looked at before deciding on locations. They include labor, climate, access to suppliers, and transportation to name a few. We would like to note that these factors continue to be relevant as reported recently in Karakaya and Canel (1998). The location factors that are relevant to the model developed in this paper include transportation costs, production costs, and labor efficiency.

Various modeling techniques ranging from capital budgeting, break-even analysis to fuzzy set theory have been used in location decisions. Mathematical modeling (Network flow models) is the most common approach used. Although considerable modeling research exists pertaining to the facilities location in domestic markets, work regarding international facilities location is limited. One of the first models of an international plant location was developed by Hodder and Jucker (1982) and was later followed by few. The recent work includes Canel and Khumawala (1993, 1996), Min & Melachrinoudis (1996), Flipo (2000), Syam (2002), and Verter (2002).

Production related strategy could be direct import, joint venture, and a wholly owned subsidiary. Kouvelis and Sinha (1994, 1995) develop a stochastic dynamic programming model that considers exchange rate, demand and pricing. For each of the production strategies they develop optimal solutions and also investigate the conditions in which each strategy dominates the others. A switching between production strategies involves switching cost, however, the time required to implement the change is assumed to be insignificant. Axarloglou et a. (1995) presented an empirical study to test the analytical results of Kouvelis and Sinha's model. They used data from the Bureau of Economic Analysis, U.S. Department of Commerce. Kogut and Kulatilaka (1994) were probably the

first to develop a stochastic dynamic programming model to this production switching flexibility. In addition, Dasu and Li (1994) and Huchzermeier and Cohen (1996) have looked into this problem as well. These models are referred as option valuation models. Option valuation models are usually formulated as stochastic dynamic programming models that seek to minimize (maximize) expected costs (profits) over a finite or infinite horizon. These models help utilize operational flexibility which is available in terms of excess capacity. By holding excess capacity in different plants, a firm can switch production among these plants to avail opportunities presented by exchange rates or counter problems related to labor, supplies, etc.

The production planning and distribution problem considered in this research is the supply chain coordination problem. Coordination of supply chain activities is a key concept for the global firm (Cohen & Mallik 1997). Network flow models provide an effective approach for modeling these supply chain coordination problems. Kogut (1984, 1985a, 1985b) was one of the first to describe qualitatively the advantages of coordination of global activities and strategies that capitalize on the comparative advantages of countries and distributed competence of international firms. However, analytical modeling in this field is relatively new (Cohen & Mallik 1997). Recent literature surveys on this topic can be found in Verter and Dincer (1992, 1996), Cohen and Kliendorfer (1993), Vidal and Goetschalckx (1997), and Cohen and Mallik (1997).

Cohen et al. (1989) develop a non-linear mixed integer programming model that lends itself to hierarchical solution process and iterative process. The model considers exchange rates, tariffs, taxes, sourcing, and taxes and maximizes profit. It assumes that sufficient capacity exists to meet each period's demand without using inventories. Dasu and Torre (1993a and 1993b) develop a game-theoretic model to study the coordination among the three affiliates of a U.S. MNC located in three Latin American countries. They conclude that a policy of collaboration, under almost all circumstances involving varying exchange rates, tariffs, inflation rates, increase group performance. In order to understand how a firm should use extra capacity to handle uncertainties in a global environment, Rosenfield (1996) proposed a series of formulations. His model determines the number of plants and production levels at each plant. The objective was to minimize the costs of production and distribution to geographically dispersed markets. The principal conclusions are that it is better to have excess capacities in multiple plants and that the costs are minimized by building plants of equal sizes.

Our model also pertains to the operations of an MNC. The model developed in this paper is a network flow optimization model. The question we address is: **What are the production, distribution, and investment decisions for an MNC over a finite planning horizon?** That is, which products will be made where, which facilities would cater to which markets, and how the funds will be obtained? The primary objective an MNC is to maximize its profits. In addition to addressing the questions raised in Introduction section, the model can address few other practical questions. For example, the model can help identify facilities requiring capacity additions and when. Is it better to expand capacity when the dollar is stronger or weaker? Is it better to dispose idle capacity or retain capacity for future use? What is the opportunity cost of meeting local regulations or marketing needs even though the facility in that market is not cost effective?

Notations

The notations used in developing our model are given in Table 1 below:

INSERT TABLE 1 JUST ABOUT HERE

Capacity requirements:

The capacity required (CAP_{ft}), to produce the products in any facility f in any given period t should be sufficient. It is a decision variable. We use an aggregate measure for capacity in the sense that it represents both labor and machine. Traditionally, in aggregate planning models labor levels are changed to meet the demand. Since each facility is different, it has a different level of expertise in producing the products. The differences stem from labor skills, training, and methods used in producing the products. This difference in efficiency is captured by the input variable e_{jf} . The capacity used in producing products should be less than or equal to the capacity available. That is,

$$\sum_j e_{jf} p_j Q_{jft} \leq CAP_{ft} \quad \forall f, t \quad (1)$$

Further, as the nonzero capacity of the previous period indicates the existence of a facility, and also as our modeling does not consider the withdrawal of facilities, we consider the capacity required in the current period to be greater than or equal to some percent of the capacity of the previous period. That is,

$$CAP_{ft} \geq \beta(CAP_{f,t-1}) \quad \forall f, t \quad (2)$$

where, $0 < \beta \leq 1$.

Capacity changing cost:

As the capacity between periods may change, an expense may be incurred. We assume that the cost per unit change in capacity (U_f) will remain the same. Of course, different costs structure for increase or decrease in capacity can be easily incorporated into the following constraint. These costs include procurement/disposition of the equipment, hiring/lay-off of workers, and other related costs. In the following constraint and other constraints (where costs are discussed), the costs are expressed in dollars by incorporating the exchange rate E_{ft} .

$$CAPCHNGCOST_{ft} = (1/E_{ft}) U_f | CAP_{ft} - CAP_{ft-1} | \quad \forall f,t \quad (3)$$

The assumption of linear function is based on how capacity planning is modeled in the literature. Traditionally, a linear function is used for capacity in the development of aggregate production planning (Nahmias 1997) and capacity planning techniques such as capacity planning using overall factors (CPOF), capacity bills, resource profiles, and capacity requirements planning (CRP) (Berry et al., 1982). Capacity has usually been expressed in terms of standard hours (Blackstone 1989). Instead of a linear function, a step function can be used but it will make the model more cumbersome.

Capacity retainment cost:

If the capacity is not completely disposed, an expense is incurred in retaining the capacity. This includes labor cost (salaries), machine maintenance cost, and other costs related directly to retaining the capacity. That is,

$$CAPRETCOST_{ft} = (1/E_{ft}) CR_{ft} CAP_{ft} \quad \forall f,t \quad (4)$$

Manufacturing and distribution cost:

In any given period t , the manufacturing and distribution cost to markets the facility f caters to is:

$$MDCOST_{ft} = (1/E_{ft}) \left(\sum_j C_{jf} Q_{jft} + \sum_j \sum_m S_{jm} Q_{jfmt} \right) \quad \forall f,t \quad (5)$$

where, the terms under first summation sign ($C_{jf} Q_{jft}$) represent manufacturing costs and terms under the second summation sign ($S_{jm} Q_{jfmt}$) represent distribution costs. We assume that the distribution cost will be borne by facility f .

Demand satisfaction:

In any given period t , the demand for product j in each market m (D_{jmt}) has to be satisfied from some or all facilities. That is,

$$D_{jmt} = \sum_f Q_{jfmt} \quad \forall j, m, t \quad (6)$$

Inventory cost:

It is possible for a firm to produce more units of a product in one period and hold it in inventory (I_{jft}) to satisfy the demand of the future period(s). The inventory held and the inventory cost incurred are,

$$I_{jft-1} + Q_{jft} = \sum_m Q_{jfmt} + I_{jft} \quad \forall j, f, t \quad (7)$$

$$IHCOST_{ft} = (1/E_{ft}) \sum_j h_{jft} I_{jft} \quad \forall f, t \quad (8)$$

Exchange rate function:

Exchange rate is a random variable. The difficulty economists have had in finding an empirically successful exchange rate theory is well documented (see, for example, Harvey 1996; Taylor 1995a, 1995b). Nonetheless, a firm has to forecast what the rate would be in the future in order to make the appropriate decisions. We will use the following linear function for the exchange rate.

$$E_{ft} = (1 + \alpha_f t) E_f \quad \forall f \quad (9)$$

where, E_f is the base exchange rate and α_f is the forecast coefficient for the exchange rate. Sensitivity analysis with respect to this value will test the robustness of the solution. A similar linear model has been developed by Harvey and Quinn (1997). Their empirical model is based on the premise that the exchange rates are a function of expectations. They used regression analysis on the data obtained from expectations surveys published by Money Market Services International and noon buying rates in New York city reported by the Federal Reserve Bank of New York. Their linear model has a constant term and a second term that reflects the change in the foreign currency price of the dollar from one period of time to another (i.e., a time function).

Budget requirements:

The budget (BUD_{ft}) required to sustain operations for any period should be sufficient. This can come directly as manufacturing funds from U.S. ($MFUND_{us-ft}$), borrowing from local markets (BOR_{ft}), and prior investment made in the local markets ($MINV_{ft-1}$). We confine ourselves to

investment in only those markets where facilities are located, however, investment in other markets can be easily incorporated. The budget should take care of the costs incurred due to manufacturing and distribution, other costs, capacity changing costs, capacity retaining costs, and inventory holding costs in each period for each facility. The following constraints capture the budgetary requirements. The $OTHERCOST_{ft}$ category includes administrative expenses and miscellaneous expenses.

$$BUD_{ft} = MDCOST_{ft} + (1/E_{ft}) OTHERCOST_{ft} + CAPCHNGCOST_{ft} + CAPRETCOST_{ft} + IHCOST_{ft} \quad \forall f,t \quad (10)$$

$$BUD_{ft} = MFUND_{us-ft} + (1/E_{ft}) BOR_{ft} + MINV_{ft-1} \quad \forall f,t \quad (11)$$

In constraint (11), we assume that money can be invested for one period and there is no penalty for early withdrawal. This is considered as in the long run, a firm may choose to take out money from the investment rather than transfer funds from U.S.

Also, firms have to operate under some foreign government regulations. For example, some part of the funds required for the budget have to be borrowed from the local sources to stimulate the local economy or, curb inflation. We consider the local source as banks and not issuing of stocks or bonds. The reason is the issuing of bonds or stocks would involve disbursing dividends and this would make the model more cumbersome.

$$(1/E_{ft}) BOR_{ft} \leq w_f BUD_{ft} \quad \forall f,t \quad (12)$$

where, w_f is the percent of budget that has to be borrowed.

Investment income from foreign country:

As stated before, a firm has the option of investing (INV_{ft}) in the market of host countries where facilities are located. We do not consider the investment opportunities in other countries to keep the model simple. A part ($MINV_{ft-1}$) of the prior period's investment (INV_{ft-1}) can be withdrawn to finance the operations of the current period and the rest can be reinvested. Also, there is an opportunity to invest funds from the U.S. in the current period (INV_{us-ft}). We do not consider separately the ploughing back of profits made from the facility of the host country towards its operations since the same money can come to the U.S. and be fed back to the host country as funds from the U.S.

$$INV_{ft} = INV_{us-ft} + (1+r_{ift}) INV_{ft-1} - MINV_{ft-1} \quad \forall f,t \quad (13)$$

Constraint (13) implies that the total investment (INV_{ft}) in the market of a host country should equal the sum of direct investment made (INV_{us-ft}), the principal and return earned on a previous investment ($((1+r_{ift}) INV_{ft-1})$), minus the amount withdrawn ($MINV_{ft-1}$) to sustain manufacturing operations.

Profit from operations:

In any period t , the factors affecting the profits include profit from the sale of the products, facilities operating costs, yields from the investments, and payback of the borrowed capital along with interest. The products are sold in different markets at different unit selling prices. Since the manufacturing and distribution costs are different as the products come from separate facilities, the unit profits will be dissimilar. Also, the yield from the funds invested in the local markets in the previous period contributes to the overall profits. Further, the profit equation should consider the amount that has been borrowed from the local sources and have to be repaid along with interest. That is,

$$\begin{aligned}
 PROFIT_t = & \sum_j \sum_m (1/E_{mt}) R_{jm} Q_{jm} - \sum_f \{MDCOST_{ft} + CAPCHNGCOST_{ft} + CAPRETCOST_{ft} + \\
 & (1/E_{ft}) OTHERCOST_{ft} + IHCOST_{ft}\} + \sum_f r_{ift-1} INV_{ft-1} - \\
 & \sum_f (1/E_{ft}) (1+r_{bft-1}) BOR_{ft-1} \quad \forall t \quad (14)
 \end{aligned}$$

We have assumed that the funds borrowed from a local market have to be paid by the next period. Of course, this assumption can be easily changed to incorporate the payment of debt at a later period.

Objective function:

To compute revenues and costs, we consider the prevailing exchange rates and interest rates, the objective function can be modeled as the maximization of future worth of profits. In the following representation of the objective function, the investment in the period prior to the last period is subtracted since we do not want enormous amounts to be invested in the prior period. This would make the problem unbounded. Of course, the inclusion of the last term should not alter the production and distribution activities.

$$\text{Maximize } \sum_t PROFIT_t - \sum_f INV_{ft-1}$$

The complete integrated production, distribution, and investment model, PDI is:

$$\text{Maximize } \sum_t \text{PROFIT}_t - \sum_f \text{INV}_{f,t-1}$$

s.t.,

$$\sum_j e_{jf} p_j Q_{jft} \leq \text{CAP}_{ft} \quad \forall f, t \quad (1)$$

$$\text{CAP}_{ft} \geq \beta \text{CAP}_{f,t-1} \quad \forall f, t \quad (2)$$

$$\text{CAPCHNGCOST}_{ft} = (1/E_{ft}) U_f * \text{CAP}_{ft} - \text{CAP}_{f,t-1} * \quad \forall f, t \quad (3)$$

$$\text{CAPRETCOST}_{ft} = (1/E_{ft}) CR_{ft} \text{CAP}_{ft} \quad \forall f, t \quad (4)$$

$$\text{MDCOST}_{ft} = (1/E_{ft}) \left(\sum_j C_{jf} Q_{jft} + \sum_j \sum_m S_{jm} Q_{jfmt} \right) \quad \forall f, t \quad (5)$$

$$D_{jmt} = \sum_f Q_{jfmt} \quad \forall j, m, t \quad (6)$$

$$I_{jft-1} + Q_{jft} = \sum_m Q_{jfmt} + I_{jft} \quad \forall j, f, t \quad (7)$$

$$\text{IHCOST}_{ft} = (1/E_{ft}) \sum_j h_{jft} I_{jft} \quad \forall f, t \quad (8)$$

$$E_{ft} = (1 + \alpha_f t) E_f \quad \forall f \quad (9)$$

$$\text{BUD}_{ft} = \text{MDCOST}_{ft} + (1/E_{ft}) \text{OTHERCOST}_{ft} + \text{CAPCHNGCOST}_{ft} + \text{CAPRETCOST}_{ft} + \text{IHCOST}_{ft} \quad \forall f, t \quad (10)$$

$$\text{BUD}_{ft} = \text{MFUND}_{us-ft} + (1/E_{ft}) \text{BOR}_{ft} + \text{MINV}_{f,t-1} \quad \forall f, t \quad (11)$$

$$(1/E_{ft}) \text{BOR}_{ft} \geq w_f \text{BUD}_{ft} \quad \forall f, t \quad (12)$$

$$\text{INV}_{ft} = \text{INV}_{us-ft} + (1+r_{ift}) \text{INV}_{f,t-1} - \text{MINV}_{f,t-1} \quad \forall f, t \quad (13)$$

$$\text{PROFIT}_t = \sum_j \sum_j (1/E_{mt}) R_{jm} Q_{jm} - \sum_f \{ \text{MDCOST}_{ft} + \text{CAPCHNGCOST}_{ft} + \text{CAPRETCOST}_{ft} + (1/E_{ft}) \text{OTHERCOST}_{ft} + \text{IHCOST}_{ft} \} + \sum_f r_{ift-1} \text{INV}_{f,t-1}$$

$$- \sum_f (1/E_{ft}) (1+r_{bft-1}) \text{BOR}_{f,t-1} \quad \forall t \quad (14)$$

$$\text{All } Q \text{'s and } I \text{'s } \geq 0 \text{ (integers) and other variables } \geq 0 \quad (15)$$

4. Numeric examples

We demonstrate the usefulness of the model through numeric examples. Table 2 shows the input parameters. The scenario considers that for a given MNC, manufacturing facilities exist in the U.S. and India. We assume that the facilities make only one type of a product. The market demand for the product exists in the U.S., Germany, and India (Figure 1). The input considers increasing exchange rates for Germany and India. Similarly, increasing interest rates are considered for both investment and borrowing in India. But, these rates are kept constant in the U.S. We consider three planning periods in our examples, and the length of each planning period is as arbitrary as the number of periods in a planning horizon.

INSERT FIGURE 1 AND TABLE 2 JUST ABOUT HERE

The unit manufacturing time in the U.S. is kept constant, whereas, this is different in India for each period to reflect the efficiency of operations. That is, this efficiency parameter can be considered as representing the learning curve, labor skills, and technology difference. Unit manufacturing cost in the U.S. is kept constant, whereas, it is taken to be different in each period for India. However, the unit revenue is kept constant in all three markets. In addition, the unit capacity retaining cost and unit capacity changing cost are kept constant in each period.

In our analysis, we consider two levels for the initial capacity and two levels for the exchange rate in India - a 2x2 matrix is considered. In the first case, an initial capacity of 0 units is considered in both countries. In the second case, initial capacities of 3000 units in the U.S. and 5000 units in India are considered. Two scenarios are considered for the exchange rates in India - increasing and decreasing. An initial investment of \$200,000 in the U.S., and \$300,000 in India are chosen. **IBM PC compatible computer and Lindo software was used to solve the model. The solution times ranged from 10 seconds to 13 seconds. Advances in computer hardware and software have not only reduced solution times, but also have increased the applicability of mathematical modeling (Schary & Skjott-Larsen 2001). The running time of one popular DSS used in designing a supply chain involving from 333 to 2066 customers, one to 23 products, and two to 23 suppliers, running on a Pentium-200 personal computer took 12 seconds to 500 seconds.** The results from the optimization model are given in Tables 3 to 6. Before discussing the effects of exchange rates and initial capacity levels, we will first list the following observations common to all four cases.

INSERT TABLES 3 - 6 JUST ABOUT HERE

- Direct funds for manufacturing are made only once in both facilities (countries).
- Besides the initial investment that was there in the markets of both countries, another investment is made in the first period in both countries.
- Funds to sustain operations (budget) in both countries come from the investments made in the markets. Only in the case of the U.S. the initial investment is consumed to sustain operations, whereas, the initial investment made in India continues to be in the market.
- Much of the direct manufacturing funds made in both facilities in the first period goes into acquiring the capacity.
- More money is invested in the markets of that facility which is producing more units. This is because the budget is being funded through the returns on the investment. The investment in the Indian market is more or less the same although we required that a minimum of 20 percent of the budget in each period should be locally borrowed for Indian operations, a higher percent is borrowed when the exchange rate is higher (stronger dollar). In all of the cases considered, the borrowing is dependent on the exchange rate and not on either the initial investment or initial capacity. A 20% of the budget is borrowed when the exchange rate is Rs31.5/\$1, 22.2% when the rate is Rs33/\$1, and 23.78% when the rate is Rs34.5/\$1.
- When the initial capacities are zero and the exchange rate is increasing (stronger \$), more capacity is added in the Indian operations than in the U.S. Indian operations satisfy the demand of markets in India and Germany and part of the U.S. demand. Capacity utilizations are 100% in India, and range from 88.5% to 100% in the U.S.
- When the initial capacities are nonzero, regardless of the exchange rate direction, more capacity is added in the U.S. than in India. The Indian facility only takes care of its demand in the first period and the other two periods demand is satisfied by the U.S. facility. However, U.S. operations satisfy the demand of both U.S. and German markets. Capacity utilizations in the U.S. are 100% and 86.5%, whereas it is 100% in the first period in India and zero percent in the next two periods. Capacity is retained, but not disposed since the cost of disposing (capacity changing cost) was higher than maintaining the capacity.

The following two tables, Table 7 and Table 8, combine the information of Tables 3-6 and report them as a summary of percent change in the performances with respect to initial capacity levels and exchange rate direction.

INSERT TABLES 7 AND 8 JUST ABOUT HERE

Effects of initial capacity when the exchange rate is increasing:

Although the demand remains the same, more profit is made when initial capacities are present (see Tables 3 & 4). It should be noted that in both cases (zero and non-zero initial capacities) revenues are the same. In the case of zero initial capacity, more capacity is created in India to meet global demand and consequently, money borrowed is paid back with interest and not much is invested in the markets. This resulted in lower total profits. On the other hand, when initial capacities are present, much of the global demand is satisfied by the U.S. facility, more money is invested in the markets earning more returns, and less is borrowed, which resulted in higher profits. Besides revenue, other factors contributing to profit are operations cost, return on the investment, and payback of borrowed sum along with interest. A ratio of profit/budget (\$ earned in profit/\$ spent), referred as profit productivity, is higher for nonzero initial capacity (0.818) than for zero initial capacity (0.77).

The effects of having nonzero initial capacities are (see Table 7): the profit increases by 88.44, the budget increases by 77.45 percent, and direct manufacturing funds in facilities increase by 15.77 percent. The direct investments in markets increase by 409.5 percent to sustain budget increase as the market investment is the primary source of funding the budget and U.S. facility is more expensive to operate. Although, fewer capacity hours are needed when there is a beginning capacity, the capacity changing cost is higher as much of the manufacturing shifts from India to the U.S. When the initial capacities are zero in both facilities, the decision calls for producing more in the Indian facility, consequently, more money is invested in the Indian market. When the initial capacities are nonzeros, much of the production takes place in the U.S. facility and no additional money is invested further in the Indian market besides the initial investment, although the return rate is much higher in the Indian market (5-7% compared to 1% in the U.S. market).

Effects of initial capacity when the exchange rate is decreasing:

Regardless of the size of the initial capacity, much of the manufacturing takes place in the U.S. facility which is more efficient but also more expensive. The above discussions hold good here as well. The profit productivity is 0.676 for zero initial capacities and 0.852 for nonzero initial capacities. When the initial capacities are nonzeros, for the same demand the profit increases by 11.67%, budget decreases by 11.39%, direct manufacturing funds decrease by 9.6%, direct investments in the market (U.S.) decrease by 9.14%, capacity changing cost decreases by 30.3%, and 6.4% fewer capacity hours are needed (see Table 7). It should be noted that besides the initial investment in the Indian market, no further investment is made, although the return rate is much higher compared to U.S. market.

Effects of exchange rate direction when the initial capacity is zero:

More profit is made when the dollar is weaker (decreasing exchange rate) than when it is stronger. This is observed in reality and the reason is that the revenues from foreign markets are higher since more dollars are bought for the same money. However, the profit productivity decreases (0.676) as compared to when the dollar is stronger (0.77). This implies that if cost cutting measures are undertaken, the productivity ratio can be increased which should lead to even more higher profits. In other words, instead of being satisfied with higher profits by virtue of a weaker dollar, more gains can be realized in this environment by cutting down costs. When the dollar is weaker, the following percent changes with respect to a stronger dollar take place (see Table 8): (1) the budget increases by 100.26% as much of the manufacturing shifts to the U.S., requiring 20.73% less hours as the U.S. facility is more efficient, (2) although the demand doesn't change, the profit increases by 75.65%, (3) borrowing from the Indian market decreases by 42.17% since not much is being produced in India, and (4) the capacity changing cost increases by 122.77% as more expensive capacity is created in the U.S.

Effects of exchange rate direction when the initial capacity is nonzero:

Regardless of the exchange rate direction, much of the production takes place in the U.S. More profit is made when the dollar is weaker. The profit productivity ratio is 0.818 for a stronger dollar and 0.852 for a weaker dollar. As before, this number (i.e., 0.852) can be further improved by taking advantage of a weaker dollar by cutting costs. As the difference in the values of profit productivity ratios is small, consequently, the effect on the measures is not as pronounced as it was before (zero initial capacity case). The budget remains unchanged (see Table 8), direct

manufacturing funds decrease by 20.99%, direct investments in the U.S. market increase by 6.5%, no money is invested in the Indian market, capacity changing costs increase by 7.92%, capacity hours needed increase by 4.33%, and the profit increases by 4.08%. Although the effects may not be pronounced, nonetheless they imply that when the exchange rate is decreasing (\$ becoming weaker), there is a potential for higher profits. This is also seen to occur in reality. For example, a recent article reports that MNCs in the U.S. earned a higher profit in the first quarter due to the weaker dollar. Earnings growth for MNCs in the first quarter of 1995 over the first quarter of 1994 has been 23%. This compares to 19% earnings growth for the Standard & Poor's 500 for all of 1994 (Daily News, April 23, 1995, p. 12-A).

Reality Checks:

Models are essential for planning the supply chain (Schary & Skjott-Larsen 2001). The only prescription where there are no guidelines for managers is to experiment (Brown & Eisenhardt 1998), testing variables to see what happens. As Schrage (2000) points out “We shape our models and they shape our perception.” Breitman and Lucas (1987) were first one report the use PLANETS, a global supply chain management model developed and used by General Motors. Lee and Billington (1993, 1995) describe the implementation of series of supply chain management models at Hewlett-Packard. Arntzen et al. report on the development and use of a global supply chain model by the Digital Equipment Corporation that saved them over \$ 100 million. Although we would like to corroborate our model with a real life application, so far we have not been successful in our attempts in securing a firm to use our model. However, our discussions with Mr. Don Vitale, ex-CEO of DESA International Corporation, Bowling Green, Kentucky, have been very encouraging. He noted our model could certainly benefit DESA Corporation. Since we were not able to apply our model in a real life setting, we would like to depend on the published qualitative research.

Here, we would like to discuss how our model results compare with the findings of Ferdows (1997). The findings of Ferdows are based on his four-year study of the role of foreign factories owned by ten large multinational manufacturing companies: Apple, Digital Equipment, Electrolux, Ford, Hewlett-Packard, Hydro Aluminum, IBM, Olivetti, Philips, and Sony. Also, his observations are based on his work as a consultant for 12 large MNC's, and on data from several surveys that he helped conduct.

- U.S. MNC's earned higher profits due to weaker dollar that our model also predicts.

- Foreign factories with low wages after adjusting for productivity and exchange rates lose their attraction. Many U.S. and European electronics manufacturer turned some of their off-shore facilities in Malaysia into server facilities. Our model also predicts this as much of the production shifts from India to U.S. when Indian facility loses its low cost advantage when exchange rates and productivity makes it more expensive.
- Fluctuations in foreign currencies turn offshore facilities into servers. In our model, the Indian facility is used more as a server facility.
- Companies shift production rapidly to keep costs down as currencies fluctuate. This is also seen in our model results.

The agreement between the reality and model results validates our model. Our future studies will address issues such as: do different exchange rate theories affect the model outcomes significantly? If the investment decision is excluded, would it affect the results significantly? What conditions will favor an off-shore facility or other facility types? When to turn an off-shore facility into other facility types?

5. Conclusions

The supply chain planning contributes to corporate planning. The role of these models is to provide a rational basis for developing and evaluating strategic options (Schary & Skjott-Larsen, 2001). The supply chain plan includes supply structure, markets, country and regional constraints including exchange rates, custom duty, capacity and transport capability, internal elements of production capacity, etc.

The production, distribution, and investment decisions are interrelated. The exchange rate direction and initial capacity levels have pronounced effects on these decisions. Investments in the markets are done to support the production and distribution activities. When the exchange rate increases, a higher percent of money is borrowed from the local market to sustain operations. The percent amount borrowed depends on the exchange rate and not on the initial capacities or demand. Changes in the exchange rate influence the activities of both U.S. and Indian facilities, and also on the investments in the markets. The potential to make higher profits depends on the initial capacity levels and the exchange rates. Both of them have pronounced effects on the profits. More profits

can be made by having nonzero initial capacities and decreasing exchange rates (\$ becoming weaker).

REFERENCES

BERRY, W.L., SCHMITT, T.G., AND VOLLMANN, T.E., . □Capacity Planning Techniques for Manufacturing Control Systems: Information Requirements and Operational Features. *Journal of Operations Management*, Vol. 3, no. 1, pp. 13-25.

BLACKSTONE, J.H., (1989) *Capacity Management*, (South-Western Publishing).

CANEL, C., AND KHUMAWALA, B., (1993) International Facilities Location: A Heuristic Solution Procedure for the Multi-period Uncapacitated Case, *Proceedings of the Decision Sciences Institute Annual Meeting*, pp. 365-367.

CZINKOTA, M.R., RONKAINEN, I.A., AND MOFFET, M.H., (1994), *International Business*, (The Dryden Press).

DAILY NEWS, (1995) Quarterly Earnings Reports Even Better Than High Expectations, *Bowling Green KY*, p. 12-A, Sunday, April 23rd.

FERDOWS, K., □ . . Making the Most of Foreign Factories. *Harvard Business Review*, pp. 73-88, March-April.

FORTUNE, What is Eating McDonald's ? ~ . October 13, p. 122-125.

HARVEY, J.T., . □An Orthodox Approaches to Exchange Rate Determination: A Survey. *Journal of Post Keynesian Economics*, 18, 567-583.

HARVEY, J.T., AND QUINN, S.F., . . Expectations and Rational Expectations in the Foreign Exchange Market. *Journal of Economic Issues*, 31 (2), 615-622.

HOCH, L.C., (1982) "Site Selection for Foreign Operations," *Industrial Development*, 151, 7-9, May-June.

KIRCA, O, AND KOKSALAN, M.M., (1994), An integrated Production and Financial Planning Model and an Application, Working Paper, Department of Industrial Engineering, Middle East Technical University, 06531 Ankara, Turkey.

KOUVELIS, P., AND SINHA, V., (1994), Production Related Strategies for Foreign Market Entry," *Proceedings of the Decision Sciences Institute Annual Meeting*, 1473-1475.

MCDONALD, A.L.,(1986), Of Floating Factories and mating Dinosaurs, Harvard Business Review, 64 (6), 82-86.

NAHMIAS, S., (1997), Production and Operations Analysis, third edition (Irwin).

NOORI, H., AND RADFORD, R.,(1995), OM-Companion to Production and Operations Management, (McGraw-Hill, Inc., New York).

RUGMAN, A.M., (1976), Risk Reduction by International Diversification, Journal of International Business Studies, 7, 75-80.

RUGMAN, A.M., (1981), Inside the Multinationals, (Croom Helm, London).

STOPFORD, J.M., (1982) The World Directory of Multinational Enterprises, (Macmillan, London).

TAYLOR, M.P., □ . The Economics of Exchange Rate. Journal of Economics Literature, 33, pp. 13-47.

TAYLOR, M.P., (1995-b)Exchange Rate Modeling and Macro Fundamentals: Failed Partnership or Open Marriage? . British Review of Economic Issues, 17, pp. 1-41.

United Nations, Multinational Corporation in World Development, (1973), (New York: United Nations).

VERNON, R., (1971), Sovereignty at Bay: The Multinational Spread of United States Enterprises, (Basic Books, New).

Wall Street Journal, "The Global Drug Industry," p. A1, Monday, February 2, 1998.

Wall Street Journal, "Foreigners Snap Up Mexican Companies; Impact is," p. A1, Tuesday, September 30, 1997.

Wall Street Journal, "U.S. Firms Preparing for Emergence of South East Asia as Consumer Market," p. A6, Thursday, July 27, 1995.

Table 1

Notation	Explanation
Input variables	
J	set of products $\{1,2,\dots,j,\dots,J\}$
F	set of facilities $\{1,2,\dots,f,\dots,F\}$
M	set of markets $\{1,2,\dots,m,\dots,M\}$
T	set of time periods $\{1,2,\dots,t,\dots,T\}$
D_{jmt}	demand for product j in period t for market m
R_{jm}	revenue/unit of product j in market m
C_{jf}	manufacturing cost/unit of product j in facility f
CR_{ft}	unit capacity retaining cost of facility f in period t
S_{fm}	unit shipping cost from facility f to market m
h_{jft}	unit inventory holding cost of product j in facility f in period t
U_f	unit capacity changing cost in facility f
β	minimum capacity level retainment
E_{ft}	exchange rate of currency of host country in period t
p_j	unit processing time of product j in U.S.
e_{jf}	efficiency of facility f in producing product j compared to U.S.
w_f	minimum percent of budget of facility f to be borrowed from the local sources
r_{jt}	interest rate earned on the investments in markets of facility f in period t
r_{bft}	interest rate paid on the funds borrowed in period t from the markets of facility f
$OTHERCOST_{ft}$	other costs incurred in the facility f in period t
Decision variables	
CAP_{ft}	capacity of facility f in period t
$CAPCHNGCOST_{ft}$	capacity changing cost of facility f in period t
$CAPRETCOST_{ft}$	capacity retaining cost of facility f in period t
$MDCOST_{ft}$	manufacturing and distributing cost of facility f in period t
Q_{jft}	quantity of product j produced in facility f in period t
Q_{jfm}	quantity of product j shipped from facility f to market m in period t
I_{jft}	ending inventory of product j in facility f in period t
$IHCOST_{ft}$	inventory holding cost of facility of f in period t
BUD_{ft}	budget requirements of facility f in period t
$MFUND_{us-ft}$	funds for manufacturing from U.S. to facility f in period t
INV_{ft}	funds invested in period t in the markets where facility f is located.
$MINV_{ft}$	funds withdrawn from the markets of facility f in period t
BOR_{ft}	funds borrowed from the markets of facility f
$PROFIT_t$	total profit in period t

Table 3: Results for zero initial capacities and increasing exchange rates.

Category	Country	Period 0	Period 1			Period 2			Period 3		
Budget	US		\$434,131			\$161,304			\$150,266		
	INDIA		\$1,095,641			\$394,876			\$410,843		
Investment	US	\$200,000	\$308,485			\$150,266			\$1,503		
	INDIA	\$300,000	\$608,090			\$328,675			\$23,007		
Borrow	US										
	INDIA		Rs. 6,847,757			Rs. 2,632,504			Rs. 2,833,403		
Direct Manufacturing Funds	US		\$234,100								
	INDIA		\$876,513								
Funds from Investments	US	\$200,000	\$161,304			\$150,266			\$1,503		
	INDIA		\$315,900			\$325,388					
Direct Investments in markets	US		\$306,485								
	INDIA		\$293,090								
Production Quantity Distribution			US	G ^C	I	US	G	I	US	G	I
	US		9.04 ^A			8.92			8		
	INDIA		0.96	14	20	3.08	8	25		14	30
Capacity	US	0	2713 Hrs. \$271,331 ^B			2713 Hrs. \$0			2713 Hrs. \$0		
	INDIA	0	20,973 Hrs. \$671,148			20,973 Hrs. \$0			20,973 Hrs. \$0		
Profits			0			\$1,134,698			\$904,707		

^A Quantities in '000s

^B Capacity changing cost in that period

^C G means Germany, and I means India

An inventory of 2055 units were carried in India in the second period.

Table 4: Results for nonzero initial capacities and increasing exchange rates.

Category	Country	Period 0	Period 1			Period 2			Period 3		
Budget	US		\$1,309,970			\$1,781,419			\$1,306,000		
	INDIA		\$219,981			\$39,942			\$39,942		
Investment	US	\$200,000	\$3,056,851			\$1,306,000			\$13,060		
	INDIA	\$300,000	\$315,000			\$309,946			\$291,129		
Borrow	US										
	INDIA		Rs. 1,374,879			Rs. 266,279			Rs. 275,461		
Direct Manufacturing Funds	US		\$1,109,790								
	INDIA		\$175,984								
Funds from Investments	US	\$200,000	\$1,781,419			\$1,306,000			\$13,060		
	INDIA		\$31,953			\$31,953					
Direct Investments in markets	US		\$3,054,851								
	INDIA										
Production Quantity Distribution			US	G ^C	I	US	G	I	US	G	I
	US		10 ^A	14	6.7	12	8	25	8	14	30
	INDIA				13.3						
Capacity	US	3000	9206 Hrs. \$620,581 ^B			15600 Hrs. \$639,400			15600 Hrs. \$0		
	INDIA	5000	7988 Hrs. \$95,628			7988 Hrs. \$0			7988 Hrs. \$0		
Profits			0			\$2,510,370			\$1,332,677		

^A Quantities in '000s

^B Capacity changing cost in that period

^C G means Germany, and I means India

Table 5: Results for zero initial capacities and decreasing exchange rates.

Category	Country	Period 0	Period 1			Period 2			Period 3		
Budget	US		\$638,348			\$2,312,369			\$1,306,000		
	INDIA		\$858,297			\$93,037			\$93,037		
Investment	US	\$200,000	\$3,582,544			\$1,306,000			\$13,060		
	INDIA	\$300,000	\$315,000			\$259,470			\$203,204		
Borrow	US										
	INDIA		Rs. 5,919,288			Rs. 620,246			Rs. 581,481		
Direct Manufacturing Funds	US		\$438,348								
	INDIA		\$686,637								
Funds from Investments	US	\$200,000	\$2,312,369			\$1,306,000			\$13,060		
	INDIA		\$74,430			\$74,430					
Direct Investments in markets	US		\$3,580,544								
	INDIA										
Production Quantity Distribution			US	G ^C	I	US	G	I	US	G	I
	US		10 ^A	3		12	8	25	8	14	30
	INDIA			11	20						
Capacity	US	0	3896 Hrs. \$389,631 ^B			15,600 Hrs. \$1,170,369			15,600 Hrs. \$0		
	INDIA	0	18,607 Hrs. \$539,614			18,607 Hrs. \$0			18,607 Hrs. \$0		
Profits			0			\$2,311,400			\$1,270,726		

^A Quantities in '000s

^B Capacity changing cost in that period

^C G means Germany, and I means India

Table 6: Results for nonzero initial capacities and decreasing exchange rates.

Category	Country	Period 0	Period 1			Period 2			Period 3		
Budget	US		\$922,000			\$1,982,000			\$1,306,000		
	INDIA		\$367,400			\$60,000			\$60,000		
Investment	US	\$200,000	\$3,255,446			\$1,306,000			\$13,060		
	INDIA	\$300,000	\$315,000			\$285,900			\$257,913		
Borrow	US										
	INDIA		Rs. 2,533,793			Rs. 400,000			Rs. 375,000		
Direct Manufacturing Funds	US		\$722,000								
	INDIA		\$293,920								
Funds from Investments	US	\$200,000	\$1,982,000			\$1,306,000			\$13,060		
	INDIA		\$48,000			\$48,000					
Direct Investments in markets	US		\$3,253,446								
	INDIA										
Production Quantity Distribution			US	G ^C	I	US	G	I	US	G	I
	US		10 ^A	14		12	8	25	8	14	30
	INDIA				20						
Capacity	US	3000	7200 Hrs. \$420,000 ^B			15600Hrs. \$840,000			15600 Hrs. \$0		
	INDIA	5000	12000 Hrs. \$203,000			12000 Hrs. \$0			12000 Hrs. \$0		
Profits			\$207,244			\$2,453,111			\$1,339,655		

^A Quantities in '000s

^B Capacity changing cost in that period

^C G means Germany, and I means India

Table 7: Effects of initial capacities on the measures.

Measures	Increasing exchange rates	Decreasing exchange rates
Profit	88.44% ^a	11.67%
Budget	77.45%	-11.39%
Direct Manufacturing Funds	15.77%	-9.69%
Borrowing	-84.43%	-53.53%
Direct Investments in Markets	409.50%	-9.14%
Capacity Changing Costs	43.83%	-30.3%
Total Capacity Hours	-34.5%	-6.4%

^a All differences are computed for nonzero initial capacities w.r.t. to zero initial capacities

Table 8: Effects of exchange rate direction on the measures.

Measures	Zero initial capacities	Nonzero initial capacities
Profit	75.65% ^a	4.08%
Budget	100.26%	0%
Direct Manufacturing Funds	1.29%	-20.99%
Borrowing	-42.17%	72.6%
Direct Investments in Markets	497.18%	6.5%
Capacity Changing Costs	122.77%	7.92%
Total Capacity Hours	-27.03%	4.33%

^a All differences are computed for decreasing exchange rates w.r.t. to increasing exchange rates