

# Time-to-build and interrelated investments and labour demand under rational expectations : applications to six OECD countries

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## CHAPTER 6

### SUMMARY, CONCLUSIONS AND SHORTCOMINGS

#### 6.1 Summary

Main theoretical results can be summarized for each chapter as follows.

In the *overview* it was shown that gestation lags are periods of time that occur between the placement of orders and the delivery of capital goods. In comparison with other economic factors that directly influence economic growth, a lagging behind or leading ahead of capital growth over the business cycle exists as a consequence of gestation lags. An illustration of the business cycle by Kalecki (1935) clearly shows this.

Several studies in the literature, mentioned in *chapter 1*, bring the occurrence of gestation lags up for discussion. Different aspects are discussed by Kalecki (1935), Jorgenson (1963), and Kydland and Prescott (1982,1988).

*Chapter 2* empirically scrutinizes the process of, literally put, the 'capital construction' of houses and plants. This process consists of the designing of plans, the acquisition of building permits, the placement of orders and the start and completion of projects. Construction lags obviously apply to construction projects like houses and plants. Apart from these construction lags, delivery lags can be distinguished as being another 'lead time'. A delivery lag is defined as a lead time where investments fully occur at the beginning *or* at the end of the lead time, whereas the delivery of the capital good occurs at the end. These kinds of lags most logically exist for equipment which is customly made or affected by transportation lags.

An empirical foundation for the existence of lead times is also given by Mayer and Sonenblum (1955) and Mayer (1960). Abel and Blanchard (1988) give statistical information on delivery lags. From their results and the results presented in chapter 2, it follows that construction lags seem longer than delivery lags and are more evidently underpinned by the descriptive statistics presented.

The 'time-to-build' specification of Kydland and Prescott (1982) encompasses both kinds of gestation, being construction lags and delivery lags. In subsequent chapters, 'construction lags' and 'time-to-build' are used interchangeably. The occurrence of delivery lags is further not investigated.

The difference between an investment series subject to a multi-period construction lag and a series subject to a delivery lag is shown in chapter 2 to be a difference in serial correlation. Much more correlation is present in the former as a consequence of the

stagewise investment scheme. The specification of Kydland and Prescott is used to calculate physical capital stock series with the different assumptions about gestation. Calculations of the capital growth rates obtained by assuming a multi-period construction period and a multi-period delivery lag highlight the difference of fluctuations and autocorrelation. These two growth rates also differ from a series with a one period time-to-build, being the 'Perpetual Inventory Method', that is very often used by Central Bureaus of Statistics.

Physical capital stock series that take into account the construction lags entail a stagewise investment in current projects, like the multi-period time-to-build of Kydland and Prescott (1982), are unfortunately not available. For this reason it is emphasized that in order to test the existence of dynamics resulting from time-to-build, economic models should be formulated in terms of gross investments.

*Chapter 3* analyses a neoclassical intertemporal linear-quadratic model in which the inclusion of a multi-period time-to-build is investigated. Intertemporality in these kinds of models is usually explained by adjustment costs. This adjustment costs theory assumes that production factors can be changed within one period. But particularly large physical capital stock projects, called 'structures', need a relatively long period to be built, according to the findings in chapter 2. Instantaneous changes seem thus to be impossible for structures, even if high compensations would be possible.

In the model, the three production factors structures, equipment and labour are distinguished. For structures, a multi-period time-to-build is specified while adjustment costs are specified for structures, equipment and labour.

The closed form derived from this model is a trivariate VARMAX-model with non-linear cross equation restrictions. As a consequence of the time-to-build in the structures equation, a high order moving average parts results. A first principle result is that time-to-build can be identified from adjustment costs. Time-to-build is associated with the moving average (MA-) part, the prices (X-) part and, in case of adjustment costs of gross investments, also the autoregressive (AR-) part. As was already well-known from other factor demand studies, adjustment costs without time-to-build only entail an autoregressive part.

The VARMAX-model could be estimated by Full Maximum Likelihood. However, estimation unfortunately turns out to be very complicated. Interrelations between the three production factors together with the high order moving average parts, make convergence to optimum values wretchedly slow. For this reason the existence of a multi-period time-to-build model for structures is imposed, fixing the parameters of the moving average part at a priori selected values. Maximum Likelihood estimates are then obtained for the other structural parameters in the model, although convergence is still not fast.

A major difference between this model and the model investigated by Palm, Peeters and

Pfann (1993) is that the latter only takes into account interrelations in the contemporaneous disturbances of prices and technology shocks. Estimation of the time-to-build parameters is then possible, but no interrelations in the autoregressive part exist. The model of chapter 3 takes into account interrelations in the autoregressive part of the technology process that turn out to be highly significant. For this reason this model is more appealing from an economic point of view.

Unfortunately, interrelations in the production function and adjustment costs function are not taken into account. For these specifications the model solution would become very tricky because of the time-to-build in combination with the adjustment costs in the trivariate setting.

*Chapter 4* focuses on interrelations between both the production function (in the factor part) and the adjustment costs function. In this way the marginal productivity of, for example, structures stocks can depend both on equipment stocks and the number of working hours of employees. Relations in the opposite direction also hold. Interrelations in the adjustment costs account for costs associated with simultaneous changes of both the capital stock and labour force. Apart from this economic interpretation of interrelated adjustment costs, it is important that allowances in dynamics are modelled.

The model here is more general than the model of chapter 3, and obviously more appealing from an economic point of view. The main drawback is that a closed form, like the model solution in chapter 3, is cumbersome to derive theoretically, let alone to manage empirically. For this reason an instrumental estimation method is used, the General Method of Moments. Transversality conditions are in this case not satisfied by estimation. Furthermore, these instrumental methods are always less efficient than estimation by Full Information Maximum Likelihood, where information concerning marginal processes is taken into account. In addition, for the model under investigation in this chapter, a lot of efficiency is lost because high order moving averages that are only implicitly estimated appear in all disturbance terms.

As in chapter 3, time-to-build specified for structures remains to be identified as a consequence of transforming the first order conditions into terms of gross investments. Gross investment data, instead of productive capital stock data, that do not exist (see chapter 2, section 2.6), can be used in this way for estimation.

Contrary to chapters 3 and 4, *chapter 5* takes into account inventory stocks. If producers do not instantaneously sell their production, inventory stocks accumulate. Vice versa, if inventory stocks exist, producers need not increase production to meet demand increases. Inventories stocks are included in chapter 5, among others, in a similar factor demand model such as the model analyzed in chapter 3 and 4.

Three main differences with models of chapter 3 and 4 exist. First, a cost minimizing approach is adopted. In this way the main focus is on costs of inventories, labour, and capital stock. Revenue specifications that are more difficult to model, need not be

chosen. Secondly, aggregate instead of structures and equipment investments are modelled. Thirdly, a multi-period time-to-build is imposed instead of tested. This is justified by the fact that time-to-build already turned out to be significant in chapters 3 and 4. A three quarter time-to-build is assumed for the aggregate physical capital stock. With these capital stock data, more flexible production functions or cost functions, can easily be specified and maintained in the econometric analyses.

In this chapter, three inventory models are investigated: an Error Correction Model, a production smoothing model, and a factor demand model with inventories. The first model is estimated using Least Squares regressions, while the last two structural models are estimated by the General Method of Moments. The impact of inventories, entailing costs for entrepreneurs and their possible interrelation with capital stock and labour, is investigated.

From an economic point of view, one can conclude that the factor demand model with inventories is more appealing than the very often used production smoothing model. Costs associated with the level of production as well as costs associated with 'adjustment costs' seem more appropriately specified in the factor demand model. Also interrelations among physical capital stock, labour and inventories seem more appropriately specified.

From an econometric point of view, a similar conclusion holds. More structure concerning parameters and variables are imposed by the factor demand model with inventories. For this reason, the estimation results are more efficient.

From the factor demand model, price and sales elasticities are derived and calculated, thus making the dynamics resulting from adjustment costs and time-to-build apparent. Flexible accelerator models are often directly associated with models with adjustment costs. The inclusion of a multi-period time-to-build calls for the use of difference equations of a higher order and thus a more 'stagewise' flexible accelerator model.

In comparison to the models of chapter 3 and chapter 4, the factor demand model with inventories presented in chapter 5 is a more general model. Bearing in mind that inventories certainly exist on aggregate levels, as demand almost never coincides with supply, theoretically this model must be an improvement of the former models. A major difficulty is however the specification of inventory costs and their implications to production. Until now literature has not reached a consensus on the role of inventories such as, for example, the specifications of adjustment costs of capital stock and/or employment.

## 6.2 Conclusions from empirical results

Main empirical results can be summarized for each chapter as follows.

In *chapter 2* data for plants and houses from the Dutch and French building industry, 1986.I-1991.IV and 1980.I-1992.IV respectively, illustrate the existence of time-to-build, preconstruction or construction lags. With quarterly data from the Netherlands on reconstruction, expansions, and new plants for projects from Dfl. 50.000 onwards, an average time-to-build ranging from 10 to 17 quarters is found. The 'average' time-to-build for plants is about one year. This is however difficult to indicate exactly, because of a changing time-to-build over the business cycle and the lack of detailed data for all (plant) projects. Nevertheless, the existence of a multi-quarter time-to-build seems evident.

As a consequence of these findings, *chapter 3* investigates a multi-period time-to-build for structures of three, four, and five quarters. Although the main focus is on structures, interrelations between the three production factors can not be denied according to simple, non-structural, analyses presented in the appendix of chapter 1.

The empirical analyses, using manufacturing industry data from the United States and the Netherlands, show that the existence of adjustment costs for structures within the model with interrelation between equipment and labour, seems to be unpersuasive. This does not seem surprising from an economic point of view, because adjustment costs besides time-to-build for structures, are difficult to interpret.

As a result of the many (cross equation) restrictions in the model, and the very high dynamics (including high order moving averages) and the ensuing difficulty in estimation, only adjustment costs other than time-to-build for structures are tested. At first sight the results indicate that in an interrelated model adjustment costs are not significant besides time-to-build, for both structures in the United States and in the Dutch manufacturing industry.

The reverse case, which is imposing adjustment costs and testing for time-to-build, is only carried out using a non-nested hypotheses test. This test indicates that for the United States, as well as for The Netherlands, none of the pure models (adjustment costs *or* time-to-build) is accepted. This might also indicate that other features in the multivariate model are not quite well specified.

In line with the model analyzed in Palm, Peeters, and Pfann (1993), where few interrelations are taken into account, the result that both adjustment costs and time-to-build for structures are significant is thus upheld.

In *chapter 4*, a highly interrelated model is estimated. As estimation is less cumbersome here than in chapter 3 because of the instrumental estimation method used, the model is applied to data from six industrial countries. The rejection of adjustment costs for structures other than time-to-build is not confirmed. Both adjustment costs and time-to-

build parameters are estimated. The time-to-build parameter estimates are within proper ranges and are highly significant. This significance is however at least partly due to the high restrictions on these parameters.

In the model under investigation a distinction is made between internal and external adjustment costs. The former are costs that are incurred within the firm, the latter are costs incurred at the capital good markets. As in chapter 3, internal adjustment costs seem important. This, in particular, holds for equipment and labour. A peculiar result is that, unlike the presumptions of the theoretical model, internal adjustment costs are not convex for two countries. France and West-Germany show negative and concave, instead of convex costs. This contradicts the objective function of profit maximising behaviour. It could indicate that production bunching may occur.

The presence of external adjustment costs seems to be confirmed for West-Germany. According to these results, the German manufacturing industry is able to influence its investment prices. West-Germany is however the country for which adjustment costs turned out negatively, both in a model with and a model without interrelations. As these latter results are peculiar, and a clear reason for these findings is not on hand, other results for this country must be interpreted with some caution.

An important result is, that for all six countries, investigated time-to-build parameters are highly significant. Interrelations are highly significant too, particularly in the adjustment costs function.

In *chapter 5*, the existence of inventories and their high volatility is confirmed, especially in French agricultural, transport equipment, and in the consumer sector. Simple analyses further show that inventories increase (decrease) when sales decrease (increase), except in the intermediate goods sector. The objective of entrepreneurs of having inventory stock in line with sales, as specified by Holt et al. (1960) and often thereafter, is not confirmed in an Error Correction Model for the French sectors. This objective supposes that sales and inventory stock cointegrate. Assuming sales as given, an entrepreneur is then supposed to gear inventory stocks to sales. This result is clearly not overall confirmed by the estimation results.

In a structural factor demand model applied to four French investment sectors and one consumption sector, the significance of this objective is only confirmed for the transport equipment sector. Interrelations between inventory changes, physical capital stock, and labour are confirmed to be important in the restricted cost function that is specified. The hypothesis that inventories do not exist, implying that sales and output always coincide, is rejected. This finding casts doubt on studies in which inventories are not mentioned and a clearing goods market is assumed.

The major difference with this factor demand inventory model in comparison with the models of chapter 3 and 4, is that far less restrictions are imposed and significance levels consequently decrease. It can be concluded, however, that the inclusion of

inventories in the production function seems important from an economic point of view and is found significant in econometric modelling. The inventory objective specified by Holt et al. (1960), which is used very often in the literature, is not confirmed.

### 6.3 Shortcomings

The analyses summarized above can be criticised in many different ways. Some shortcomings concerning specification, econometric, and data issues are mentioned here.

In all analyses the time-to-build specification of Kydland and Prescott (1982) is used. This specification is restricted to investment projects that, once started, are completed. Evidence shows that cancellations certainly occur, see for example Lee (1992), although the percentage of cancellations in comparison with the total amount of started projects seems small.

But apart from these cancellations, changes during construction are in reality always possible. For entrepreneurs who start building large projects and foresee profitable sales opportunities, high compensations may exist that accelerate construction. The opposite is also true; slow down possibilities can exist. Allowing for these changes in projects that are under construction would result in a so called 'multi-period adjustment cost' model (see Park (1984)). In this case, entrepreneurs not only decide on capital projects to be started, but also decide on all projects that are under construction. This last statement already indicates the difficulty in solving the optimization problem of the entrepreneur. For example, a model where a three period time-to-build is assumed for structures entails three decision rules that need to take into account the fact that changes made in a certain period can be revised in subsequent periods. This issue is addressed by Park (1984), who solves his specified model with the use of Riccati methods.

Another assumption in the time-to-build specification which could be criticized is the constancy of the depreciation rate. Depreciation is, among other things, subject to the level of capital utilization and the maintenance of capital. Maintenance outlays can lead to improvements of the productivity of capital goods, capital goods that during recession or depression periods would be depreciated. Periods of prosperity might lead to higher utilization, instead of extending the actual capital stock, and at the same time keep depreciation low. Therefore, a difference between economical and technological decay of capital goods should be made (see for example Nickell (1975)). Here again, more realistic modelling of depreciation is restrained by the difficulty of conceiving a suitable model.

The models adopted in chapter 3 and 4 can be criticized more broadly. For example,

the often made assumption of price taking by entrepreneurs on the output and factor input markets seems appropriate on a microeconomic level but is difficult to defend at an aggregate level. A major problem is that choosing a more general model leads to identification problems. If, for instance, monopolistic competition is assumed on the output market, parameters in the production function are difficult to disentangle from the parameters in the price setting equation.

The efforts made in chapter 4, in order to assume causal relationships from investment demand to investment prices when the representative entrepreneur is the aggregate manufacturing industry, are steps in the right direction. After all, investment prices can be influenced by a large demander like the manufacturing industry. Again, the econometric drawback applies as this more realistic way of modelling is hampered by identification and estimation issues.

Assumptions that are made concerning stochastic technology shocks in chapter 3 and 4 seem to be very important because they also entail dynamics, as confirmed in Real Business Cycle studies. The main problem with technological developments is that the impact of innovations is observable, but the source and nature is hard to identify. Hence, modelling the process of technology remains a guess. Unfortunately, a trade off seems to exist between the modelling of dynamics, or persistence, induced by technology innovations and time-to-build. A higher persistence in technology shocks can lead to the same dynamics that are described by a multi-period time-to-build, and vice versa. But as the empirical evidence in chapter 2 showed, the time-to-build dynamics for structures are very well-founded.

Another not yet mentioned feature is the negligence by all models is the financial structure of firms. Investments depend on available equity or the possibility of acquiring financial means. In all analyses made in this thesis, it is assumed that no financial restrictions occur, an assumption that on a microeconomic level is certainly not upheld, but seems less serious on aggregate levels.

An empirical econometric issue concerning the structural models adopted in chapters 3, 4, and 5 is the non-stationarity of the time series used in the analyses. These time series are mostly non-stationary and are assumed to cointegrate in the structural models in which they appear. If cointegration did not hold, the structural models would be unusual from an economic point of view. Cointegration seems to be a necessary condition because, for example, investment and employment together with their prices can not differ widely, and be at the same time the most important variables in the linear-quadratic criterium function to be optimized (see for example Nickell (1985) and Dolado, Galbraith and Banerjee (1991)).

Long term stationary relationships obtained when Error Correction Models are estimated should coincide with the estimation results obtained when using the structural

model as a vantage point. A verification of both estimation results seems important in order to test both models. It is important because two different approaches are used, one that takes theory (the structural model) and the other (the ECM) taking data to start from. The fact that these different approaches can have very different results, follows from chapter 5 where both kind of models are adopted. A very thorough comparison is however in this thesis not given.

All analyses carried out here, could be simplified and improved by the availability of data that are more in line with theory. Examples are the physical capital stock data, which do not exist, at least not using a multi-period time-to-build. If these data would exist, the estimation of the very complicated model in chapter 3 would become much easier. After all, less dynamics result if the solution in productive capital stock could be estimated directly.

A drawback when using the investment data is that some interpolations are necessary. Although these interpolations are carried out by the 'Ginsburgh' method, allowing for mimicking fluctuations of closely associated series by a method that does not cause serial correlation, some caution is necessary.

Another data improvement could be achieved in the inventory analyses of chapter 5. Inventories highly fluctuate, thus making the use of data at a high frequency important. Also, the use of rough data instead of seasonally adjusted inventory data would be much better in these inventory analyses.

#### 6.4 Overall conclusions and some policy implications

Overall insights that are gained can be summarized as follows.

Intertemporal modelling of inventories, investments, and labour together with their interrelations is appealing both from a theoretical and an empirical point of view. Interrelations certainly exist, as already emphasized for labour and capital by Nadiri and Rosen (1969) or Brechling (1975). Dynamics are also very important, as the use of the adjustment costs specification in many factor demand studies already have emphasized.

The question whether investment gestation lags are important or not, the major question addressed here, can be answered in the affirmative. Firstly, data on the construction of houses and plants from the Netherlands and France show that a considerable construction period exists. Secondly, the dynamics induced by gestation lags turn out to be identified in factor demand models with investments. Earlier, gestation lags were mentioned in univariate studies, like Jorgenson (1963), or in general equilibrium models, like Kydland and Prescott (1982). As turns out here, gestation lags are another

source of dynamics besides, the often used, capital adjustment costs dynamics. Thirdly, from an economic point of view long gestation lags for large investment projects seem to be more plausible than adjustment costs. These latter costs are in the literature unclearly referred to as 'scrappage' and 'installation' costs whereas, as said before, time-to-build investments are well-founded. Fourthly, from the econometric analyses it follows that time-to-build is statistically significant.

Drawbacks certainly remain. Analyses with time series on employment (number of hours worked), capital stock investments, and inventory investments show that these three factors are increasing in degree of volatility. Consequently, it is increasingly difficult to find a specification by which they are well explained. The average number of hours worked remains relatively stable in time, causing the theory of adjustment costs that results in a model where labour is autoregressive of first order, to be almost trivially upheld (see also appendix 1). On the contrary, series on inventory stocks are for most industries very volatile, making the formation of an economic explanation much more difficult. A consensus about the explanations of fluctuations of capital stock and inventory investments seems as yet unreached (see for example Chirinko (1993), Christiano (1982)). As interrelations among factors exist and can not be neglected, models become even more complicated.

No one can doubt the occurrence of adjustment costs (at least for labour), the existence of long time-to-build periods for large investment projects, or the existence of inventory stocks. To what extent they are of importance in econometric modelling is a question that can only be answered by making simplifying assumptions. As shown here, despite slight differences, the specified and estimated dynamically interrelated multivariate models can be said to be relatively robust across countries (chapter 3 and 4) and across industrial sectors (chapter 5).

The concept of gestation lags and the associated irreversibility of investments, is here only applied to large investment projects. They could however even be extended to small investment projects and/or labour.

Many equipment investments may gestate more rapidly than structures investments. Nevertheless, delivery lags or other lags resulting from delays in the acquisition of specific capital goods certainly exist. An entrepreneur's decision to invest or delay investments, can also for particular goods be of major importance. For example, Dixit and Pindyck (1994) pay attention to these kind of investment decisions. The impact of the irreversibility -in particular along with lead times- or delay -in the case of waiting- on aggregate investments is, however, hard to overlook.

Also labour, the human capital that is an input for production, can have gestation lags. For specific kinds of labour an entrepreneur may need time to find a person able to fulfil his requirements, see also Smolny (1993) on this point. The gestation of human

capital, i.e. the gaining of required job skills, seems even more evident. Each person that is hired needs a certain period to do 'on-the-job-training' or an 'apprenticeship', during which job specific skills are acquired. This is a period where human capital gestates, but from an entrepreneur's point of view, costs (search costs, wage costs and possibly training costs) are incurred. During this period no optimal productivity is obtained. Both Schultz (1961) and Spence (1973) compare investments in human capital with investments in capital goods, although Schultz is reasoning more from an employee's point of view. Spence states that: ... *The job may take time to learn. ... The fact that it takes time to learn an individual's productive capabilities means that hiring is an investment decision. The fact that these capabilities are not known beforehand makes the decision one under uncertainty...* (page 356). From an entrepreneur's point of view, hiring costs are sunk costs and thus irreversible and spent before the on-the-job-training period.

Individual firms are usually driven by increasing profits and depend to a great extent on (uncertain) sales potentials. As the acquisition of capital and labour takes time, along with the time needed to obtain the optimal productivity from new recruitments, entrepreneurs or firm management may need long periods before optimal 'profits' are obtained. Firms should therefore not base policy decisions only on current developments, but forecast future events while accounting for the long gestation of capital and labour during firm set-ups or capacity extensions ('upturns').

When sales are low for a long time, firms' revenues may become lower than costs. In order to reduce costs, the actual capital stock may become idle, may even be scrapped and employees may be fired. In the worst case, complete firm shut downs could follow. For individual firms, these 'downturns' will generally occur much more suddenly and more quickly than the constructive 'upturns'. After all, capital scrapping can be much faster than capital construction and installation. Hiring or better stated, the acquisition of human capital that is optimally productive, seems also to be a longer phase than the firing phase. Of course these phases depend highly on associated costs and regulations.

A government's policy concerning investments and labour subsidies should be concerned with the possibly long 'time-to-build' and relatively quick 'time-to-destruct' phenomena. Governments that want to establish high economic growth and at the same time high incomes, might take investment funds into consideration in order to stimulate quicker investments during upturns. Such investment funds were used, for example, during the late 1950s and 1960s in Sweden, see Taylor (1982) who also takes into account time-to-build considerations according Kydland and Prescott (1982). Investment fluctuations can be destabilized by the existence of such funds, although this result is not fully proven by Taylor's analyses for the Swedish system. Concerning labour, bearing in mind the enormous unemployment rates of today, governments could stimulate starting firms and subsidize hiring and wages in order to compensate for the

relatively long unproductive periods of employees, which can be very costly for an entrepreneur.

The results in the previous chapters emphatically indicate that structures investment gestation periods are rather long. Unfortunately, attention was paid to neither equipment nor labour gestation during these 'constructive phases' of firms, nor to the opposite 'destructive phases'. Empirical evidence on these issues (on micro, let alone on macro levels) is probably harder to find, but might be of similar importance to the occurrence of the construction lags observed for structures.