Investment gestation lags: The difference between time-to-build and delivery lags

Peeters, Marga

Universite Catholique de Louvain

1996

Applied Economics, 1996, **28**, 203–208

Investment gestation lags: the difference between time-to-build and delivery lags

MARGA PEETERS

IRES, Université Catholique de Louvain, Place Montesquieu, 3, 1348 Louvain-La-Neuve, Belgium

The timing of investment and capital stock accumulation can differ as a result of time-to-build and/or delivery lags. In this paper simple (calibration) methods are used to illustrate the differences in these sources of gestation lags.

I. INTRODUCTION

Investment is said to gestate since it bears potential profit or utility possibilities by the creation of capital goods. A characteristic of certain types of capital good is that the gestation period is rather long; much time passes before the capital good is 'constructed' and/or 'delivered'. Consequently, much time passes before the good becomes available for the purpose for which it was intended. The demand for capital in these cases differs from investment demand. Investment precedes capital stock, at lags that increase if the delivery and/or time-to-build lags increase. Jorgenson (1963) stated that 'each period new projects are initiated until *the backlog of uncompleted projects* is equal to the difference between desired stock and actual capital stock'.

Physical capital stock and investment dynamics have received much attention in both empirical general equilibrium and intertemporal factor demand studies because of their high explanatory power. A consensus about the different gestation lag specifications and terminology is therefore desirable. The main aim of this paper is to compare time-to-build and delivery lags, two kinds of gestation. Both types of gestation lag are investigated, empirical evidence is summarized and attention is paid to the consequences and problems of modelling these phenomena.

II. TIME-TO-BUILD AND DELIVERY LAGS

Kydland and Prescott (1982) modelled the accumulation process of capital stock as

$$K_t = K_{t-1} - D_{t-1} + S_{1,t} \qquad (2.1a)$$

$$I_t = \sum_{j=1}^{J} \delta_j S_{j,t} \qquad (2.1b)$$

$$\sum_{j=1}^{J} \delta_j = 1 \text{ with } 0 \leqslant \delta_j \leqslant 1 \qquad (2.1c)$$

and

$$S_{j,t} = S_{j+1,t-1} \quad \text{for} \quad j = 1, 2, \ldots, J-1 \qquad (2.1d)$$

and called this specification 'time to build'. Productive capital at the end of period t is represented by K_t and obsolescence or depreciation by D_{t-1}. $S_{j,t}$ represents the expenditure of the capital project that is j periods from completion at period t, J represents the construction time or time to build. According to Equation 2.1b, at each moment (at most) J current capital projects $S_{j,t} (j = 1, 2, \ldots, J)$ exist that can be characterized by their production stage j. The capital project finished at the end of period t, $S_{1,t}$, is added to the productive capital stock K_t (Equation 2.1a). Gross investment during period t, I_t, consists of the sum of the values-put-in-place $\delta_j S_{j,t}$ $(j = 1, 2, \ldots, J)$, being expenditures for projects under construction during period t. Neither the time to build (J) nor the investment scheme during the construction period change in time (see Equation 2.1c). The last equality (Equation 2.1d) states that the total expenditure on the projects j periods from completion at time t, is the same as the total expenditure on the projects that needed $j+1$ periods to be built in the previous period. For this reason specification 2.1 is called a 'fixed investment plan specification'.[1]

---

[1] As should be noted, no confusion among vintage models and time-to-build models can arise. Vintage models focus on a heterogeneous capital stock, K_t, to distinguish the productivity potential of capital goods from different vintages. Time-to-build concentrates on capital stock projects under construction, $S_{1,t}$, $S_{2,t}$, $S_{j,t}$.

0003–6846

Park (1984) generalizes the specification of Kydland and Prescott. He specifies a 'flexible investment plan specification' by modifying Equation 2.1d into

$$S_{j,t} = S_{j+1,t-1} + \Delta_{j,t} \quad \text{for} \quad j = 1,2,\dots,J-1 \qquad (2.1\text{d})^*$$

The revisions in current project during period t, $S_{j,t}$, are represented by $\Delta_{j,t}$. If $\Delta_{j,t} < 0$, the current project j periods from completion is decreased in size and possibly cancelled. This project is increased in size if $\Delta_{j,t} > 0$.

As can easily be verified, the time-to-build specification (Equation 2.1) boils down to the often used capital accumulation equation:

$$K_t = K_{t-1} - D_{t-1} + I_t \qquad (2.2)$$

if $J = 1$ and as a consequence $\delta_1 = 1$. In this equation gross investment, I_t, adds to productive capital stock, K_t, instantaneously.

Delivery lags for capital stock exist if new capital stock cannot be delivered immediately. For example, if it takes L periods to have new capital delivered and investment needs to be made at the beginning of the L periods, the accumulation process of capital is to be specified as

$$K_t = K_{t-1} - D_{t-1} + I_{t-L+1} \qquad (2.3)$$

If, on the other hand, investment occurs at the moment of delivery, specification 2.2 holds, and the delivery lag becomes observationally equivalent to time-to-build lags with $J = 1$. As follows from comparing Equations 2.1 and 2.3, both specifications coincide if and only if $\delta_J = 1$ and $J = L$ and consequently $\delta_j = 0$ for $j = 1,2,\dots,J-1$.

From an investor point of view, it may not seem to matter whether lags are due to time-to-build (see Equation 2.1) or to delivery (according to Equation 2.3). In both cases investiment is irreversible because sunk costs exist at the beginning of the lead time. The fact that lead times are important, in particular when uncertainty and opportunity costs of delay are high, is emphasized in Majd and Pindyck (1987). If demand is uncertain, both types of gestation lags may increase the costs of waiting-to-invest and hence induce investors to invest more quickly as lead times lengthen (see Bar-Ilan *et al.*, 1993). Construction in the electric utility industry and the aircraft and mining industry are among the examples given in these studies.

By time to build according to Equation 2.1, though, more serial correlation exists than by delivery lags according to Equation 2.3. After all, Equation 2.1d gives

$$S_{1,t} = S_{j,t-j+1} \quad \text{for} \quad j = 1,2,\dots,J-1$$

Assuming depreciation to be a constant percentage (κ) of capital stock, that is $D_{t-1} = \kappa K_{t-1}$, and using Equations 2.1a and 2.1b yields

$$I_t = \sum_{j=0}^{J} \varphi_j K_{t+j-1} \qquad (2.4)$$

with $\varphi_1 = \delta_1(\kappa - 1)$, $\varphi_j = \delta_j + \delta_{j+1}(\kappa - 1)$ for $j = 1,2,\dots,J-1$ and $\varphi_J = \delta_J$. The richer dynamics in gross investment for time-to-build (i.e. $J > 1$) over deliver lags ($J = 1$) then follow from identity 2.4. I_t depends on $I_{\tau-1}$, $I_{\tau-2},\dots,I_{\tau-J+1}$, only if $\delta_j \neq 0$ for all $j \in \{1,2,\dots,J\}$.

III. EVIDENCE FOR TIME-TO-BUILD AND DELIVERY LAGS

The existence of lead times is endorsed empirically by information gathered by Mayer and Sonenblum (1955). They find evidence for construction and equipment of 108 sectors in the United States during World War II and the Korean period. For each sector the average estimated and actual lead time is given and a total lead time for a plant, including its equipment, is calculated. Evidence for lead times for plants as a whole is also found in Mayer (1960), who surveyed 110 companies in 1954–55. Averages are calculated by summing individual project lead times weighted by the costs of the projects. The construction period of both new plants and large additions to existing operating plants is found to be 11 months on average (unweighted). Unfortunately neither study mentions the moment of investment; without this it is not possible to identify whether the lead time is a delivery lag or a time-to-build lag.

Some statistical evidence for delivery lags for different types of capital goods is given by Abel and Blanchard (1988). With annual data of 1967 and 1972 for the United States, they calculate delivery lags of on average 2, 2, 3 and 0 quarters for the delivery of fabricated metals, non-electrical machinery, electrical machinery and motor vehicles respectively. These averages are calculated using data on the unfilled orders and mean shipments of the supplying industry. Along with this, they calculate construction lags of 3–5, 3–6 and 4–8 quarters for industrial structures, commerical structures and other structures respectively, with direct evidence from the construction of structures projects.

Delivery lags for equipment seem to be the most obvious case. After all, custom-made machinery installation that is not often demanded or which needs to be transported long distances will be subject to delivery lags. The lead times for construction, given by Mayer and Sonenblum (1955) and Mayer (1960), may thereby presumably be a time-to-build according to Equation 2.1.

While statistical evidence for delivery lags according to Equation 2.3 for the different types and/or the aggregate of capital goods does not exist, an exception being the study of Abel and Blanchard (1988), evidence for time-to-build is available for building projects. The evidence given here is for the construction of residential buildings and plants. The gestation process is subdivided in two consecutive stages: the stage when designer's plans are made and building permits are obtained (the pre-construction stage) and the construction stage.

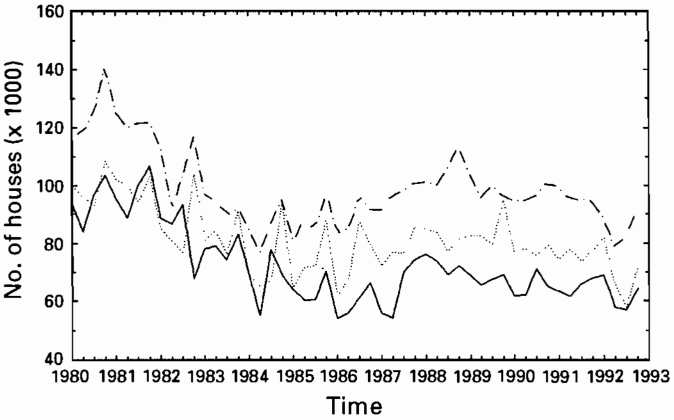

Fig. 1. *Construction of houses in France* (— · — · –) *building permits issued*, (· · · · ·) *projects started*, (——) *projects completed*

Source: SICLONE, Ministry of Equipment, Transport and Tourism, Paris

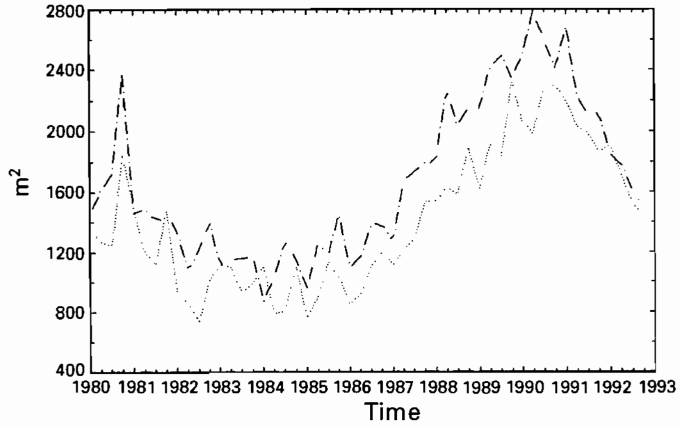

Fig. 2. *Construction of manufacturing industry plants in France* (– · – · –) *building permits issued*, (· · · ·) *projects started*

Source: See Fig. 1

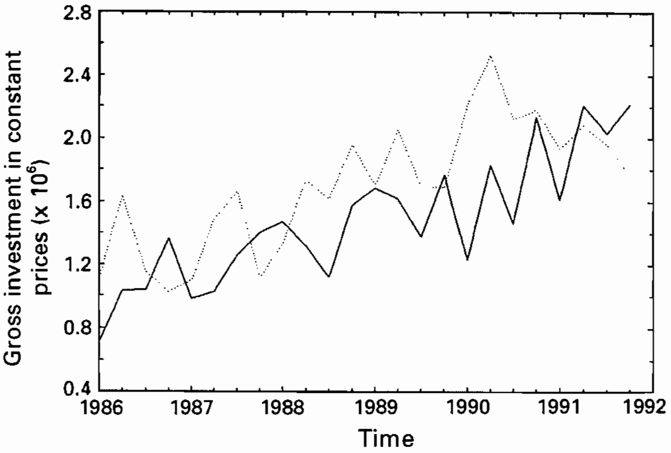

Fig. 3. *Construction of plants in the Netherlands* (· · · ·) *projects started*, (——) *projects completed*

Source: Afdeling Bouwnijverheid, Central Planning Bureau, Den Haag, The Netherlands

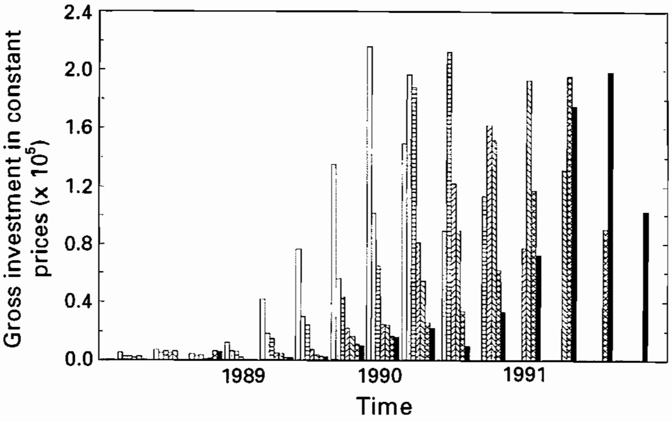

Fig. 4. *Reconstruction, expansions and new plants in the industry: distributions of investment 1990:2–1991:4*, (□) 1990:2, (⊟) 1990:3, (⊟) 1990:4, (▨) 1991:1, (▧) 1991:2, (⊠) 1991:3, (■) 1991:4

Source: Afdeling Bouwnijverheid, Central Planning Bureau, Den Haag, The Netherlands

Figure 1 shows the series of the number of houses for which 'building permits' were issued, and the number of housing projects 'started' and 'finished' in France during 1980:1–1992:4. The figure indicates that the first series clearly precedes the second, and the second clearly precedes the third at the end of the same period. This order is even more apparent in Figs. 2 and 3 concerning the construction of plants (in square metres) during 1980:1–1992:4 in France and plant investment during 1986:1–1991:4 in the Netherlands.[2]

The lag of the 'started' series after 'building permits issued' is to be interpreted as a lead time during the pre-construction period. The time between started and completed projects is the construction period, or literally the time to build. The level differences between the series refers to projects not yet started on the building site or cancellations (when specification 2.1d* becomes appropriate). A crossing of lines refers to a lagging behind and catching up of projects.

Figure 4 highlights the investment schemes. These vintage data that distinguish the different vintages of construction projects are even less easily available from central bureaux

---

[2] Unfortunately, for plant construction the series of projects completed and building permits issued are not available quarterly for France and the Netherlands respectively.

of statistics than the data in Figs. 1–3. For this reason only a short period is illustrated.

Figure 4 shows the time to build during 1990:2–1991:4 for new plants in the Dutch industry. For example, investment in 1991:4 involves projects that were started from 1988:3 onwards. The time to build is thus even more than two years. As the number of projects is not known, nothing can be said about the 'average' time to build. The investment scheme shows that most investment takes place in projects recently started or started one quarter previously.

For the modelling of housing construction, Alphen and Merkies (1976) used similar vintage data (1965:1–1972:3). They find with these data that the Pascal distribution is best to estimate the investment scheme during gestation (δ_j for $j = 1, 2, \ldots, J$ in Equation 2.1b). In Merkies and Steyn (1994) attention is paid to the contractionary and expansionary effect of the time to build period (J) during recession and recovery periods, which are termed the 'accordion effect'.

Unfinished housing or plant projects do not belong to *productive* capital stock. For this reason, and considering quarterly periods, the specification 2.1 is appropriate for the construction period since a multiperiod time to build exists for plants (see Fig. 4). Moreover, and the major divergence from the delivery specification 2.3, investment occurs during the whole gestation period (so $\delta_j \neq 0$ for $j = 1, 2, \ldots, J - 1$, see 2.4).

IV. THE IMPORTANCE OF LEAD TIMES AND THE LITERATURE

Kalecki (1935) made it theoretically clear that the lag between investment and capital stock accumulation, as a consequence of time to build and/or delivery lags of capital goods according to 2.1 and 2.3, considerably alters during different phases of the business cycle. Kydland and Prescott (1982), with the introduction of Equation 2.1, emphasize the serial correlation in macroeconomic time series due to these lags. In their view, fluctuations of macroeconomic variables are caused by persistent pure real shocks, such as technology and productivity shocks, and the existence of time to build thereby induces much more serial correlation.

Macroeconomically, the existence of time to build indeed seems important, as OECD publications on flows and stocks of fixed capital indicate, national gross investment includes mainly large construction projects (structures). These structures are subject to long lead times and stagewise investment during gestation, according to the findings in the previous section.

In their real business cycle study, Kydland and Prescott (1982) are, however, not consistent. They intend to use the time-to-build specification 2.1. By contrast, instead of using productive capital stock series (K_t) as defined by 2.1a, the series used are calculated according to 2.2. This method is used by Central Bureaux of Statistics and known as the perpetual inventory method (PIM); a benchmark is used for capital stock K_0, gross investment is added and depreciation is subtracted. Hence a one-period time to build is assumed (see 2.2).

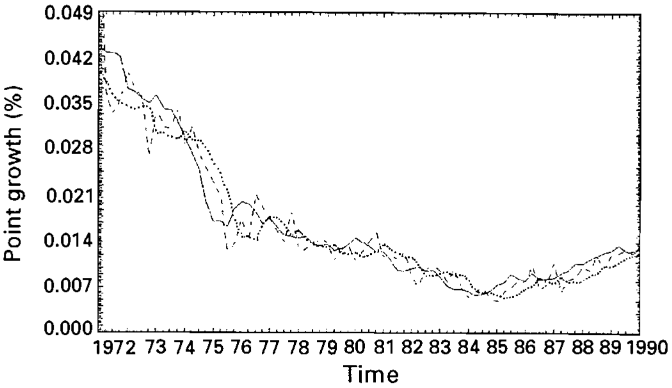

Fig. 5. *Growth of physical capital stock* (——) *standard* (---) *time-to-build* (····) *delivery lags*

Source: Databank OECD

In Fig. 5 the error is illustrated by the comparison of the growth rate of three calculated capital stock series. A benchmark of French national physical capital stock for 1970, a depreciation rate of 5% and French quarterly investment series (in constant prices of 1980 from the national accounts) are used. It is further assumed that $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0.25$. The first capital stock series is then calculated according to Equation 2.2. The second series is according to 2.1, where $J = 4$ and $S_{1970,1} = S_{1970,2} = S_{1970,3} = S_{1970,4} = I_{1970}$. The third series is according to Equation 2.3, with $L = 4$.

The figure shows that the fluctuations in the first and third capital series are similar, except for the delivery lag of four quarters. The time to build series does not replicate fluctuations of one of these series and is much more erratic. This is of course due to the investment scheme that was previously assumed to be uniform. The time-to-build series falls in between the standard series and the delivery lags series.

The inconsistency in the Kydland and Prescott study (1982) also committed by Rouwenhorst (1991, see footnote 4, p. 246), among others. He uses the same national capital stock series as Kydland and Prescott and analyses the importance of time to build in explaining fluctuations. The fact that the investment scheme during gestation (δ_j for $j = 1, 2, \ldots, J$) is calibrated instead of estimated and that a significant serial correlation is neglected by using data according to 2.2 instead of 2.1 casts much doubt on his main result that time to build does not cause persistence.

The difference in serial correlation also follows from the calculation of the autocorrelations and partial correlations

Table 1. *Correlations growth rate capital stock*

	Autocorrelations			Partial correlations		
Order	Standard	Time to build	Delivery lags	Standard	Time to build	Delivery lags
1	0.94 (0.11)	0.79 (0.11)	0.95 (0.11)	0.94	0.79	0.95
2	0.89 (0.19)	0.75 (0.17)	0.90 (0.19)	– 0.05	0.32	– 0.08
3	0.82 (0.23)	0.73 (0.21)	0.86 (0.24)	– 0.08	0.20	0.02
4	0.76 (0.27)	0.70 (0.24)	0.81 (0.27)	– 0.05	0.12	– 0.02

Notes: Values between brackets are standard errors. The standard error for the partial autocorrelations is 0.2.

of the three series in Fig. 5, as given in Table 1. The results indicate that autocorrelations of the growth rate of the time-to-build series is much lower than for the other two series. The partial correlations are significant up to the third order for time to build capital stock series.

Like Kydland and Prescott (1982), Wolfson (1993), who disaggregates manufacturing capital stock into structures and equipment, is confusing on lead times. He speaks in terms of time to build while modelling delivery lags as in 2.3 for both types of capital. In addition, he almost certainly uses capital stock data according to 2.2. In his partial modelling of the firm's demand for structures and equipment another point of economic interpretation is side stepped. Adjustment costs for both structures and equipment, usually referred to as 'installation' and 'scrappage costs' (in increasing and decreasing regimes $\Delta K_t > 0$ and $\Delta K_t < 0$ respectively), are specified to occur one year before the delivery. As capital is delivered at the end of a delivery lag, chosen in Wolfson to be two years for both structures and equipment (see p. 139), this specifiction of adjustment costs is difficult to interpret. Essential dynamics in structures and equipment demand seem not correctly specified. Moreover, the existence of adjustment costs for structures can also be questioned.

The existence of adjustment costs can be of importance in describing dynamics, but the difference from time to build and the identification of both sources of dynamics are not trivial. As well as the resulting adjustment cost specification (in first-order conditions) being an autocorrelation representation, the time to build specification is identified as a moving average in Peeters (1995, Chapter 3). To describe the dynamics of the structures and equipment capital stock specification, Equations 2.1 and 2.2 are used respectively. The problem of non-existent appropriate data of productive capital stock for structures is circumvented by transforming equations that are linear in K_t into gross investment using 2.4. In this way gross investment series rather than capital stock can be used, an avenue also chosen in Park (1984) and Altug (1989) in general equilibrium models. Altug distinguishes structures and equipment and estimates the investment scheme like Park (1984) and Peeters (1995, Chapter 4). In all three studies the time to build parameters (δ_j for $j = 1, 2, \ldots, J$) differ significantly from zero. This indicates that time to build is important.

V. CONCLUSIONS

The main points can be summarized as follows.

Two kinds of gestations lag can be distinguished, construction and delivery lags. Buildings obviously take time to build, with a stagewise investment. Equipment is most probably subject to delivery lags. The specification of Kydland and Prescott (1982) seems suitable to formalize the construction process of capital projects. It also nests the delivery lags specification. As shown here, existing capital stock series are inconsistent with the time to build specification. To be consistent and in order to identify lead times *empirically, gross investment instead of capital stock data* should be used.

Macroeconomically, it is important to take account of time to build since a large proportion of national investment is connected with construction projects. These projects, mainly consisting of residential buildings, need long construction periods and entail a high serial correlation. Factor demand studies are often applied only to the manufacturing industry. The aggregation problem of buildings and equipment and thus of different lead times is thus less transparent, since equipment plays the major part. In these studies, it is furthermore important to consider time to build as a source of dynamics that is different from adjustment costs.

ACKNOWLEDGEMENTS

I gratefully acknowledge the Netherlands Organisation for the Advancement of Pure Research (NWO, The Hague), the Centre de Recherche en Economie et Statistique (CREST, Paris) and the IRES (Louvain-La-Neuve). I thank Franz Palm for helpful comments.

REFERENCES

Abel, A. B. and Blanchard, O. J. (1988) Optimal investment under uncertainty, *American Economic Review*, **73**, 228–33.

Alphen, J. H. and Merkies, A. H. Q. M. (1976) Distributed lags in construction: an empirical study, *International Economic Review*, **17**, 411–30.

Altug, S. (1989) Time-to-build and aggregate fluctuations: some new evidence, *International Economic Review*, **30**, 889–920.

Bar-Ilan, A., Sulem, A. and Zanello, A. (1993) Time-to-build and capacity choice, International Monetary Fund, Washington, D.C. 20431, USA, paper presented at European Economic Association conference in Helsinki 1993.

Jorgensen, D. W. (1963) Capital theory and investment behavior, *American Economic Review*, **53**, 47–56.

Kalecki, M. (1935) A macrodynamic theory of business cycles, *Econometrica*, **3**, 327–44.

Kydland, F. E. and Prescott, E. C. (1982) Time to build and aggregate fluctuations, *Econometrica*, **50**, 1343–70.

Majd, S. and Pindyck, R. S. (1987) Time to build, option value, and investment decisions, *Journal of Financial Economics*, **18**, 7–27.

Mayer, T. (1960) Plant and equipment lead times, *The Journal of Business*, **33**, 127–32.

Mayer, T. and Sonenblum, S. (1955) Lead times for fixed investment, *Review of Economics and Statistics*, **37**, 300–4.

Merkies, A. H. Q. M. and Steyn, I. J. (1994) Modelling changing lag patterns in Dutch construction, *Journal of Economic Dynamics and Control*, **18**, 499–509.

OECD (Organisation for Economic Co-operation and Development) (various issues) *Flows and Stocks of Fixed Capital*, Paris.

Park, J. A. (1984) Gestation lags with variable plans: an empirical study of aggregate investment, Dissertation, Carnegie–Mellon University.

Peeters, Marga (1995) *Time-to-build: Interrelated investment and labour demand with applications to six OECD countries*, Lecture Notes in Economics and Mathematical Systems, Springer-Verlag, 420.

Rouwenhorst, K. G. (1991) Time-to-build and aggregate fluctuations: a reconsideration, *Journal of Monetary Economics*, **27**, 241–54.

Wolfson, P. (1993) Compositional change, aggregation, and dynamic factor demand *Journal of Applied Econometrics*, **8**, 129–48.