# Deriving dynamic marketing effectiveness from econometric time series models

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| Abstract | To understand the relevance of marketing efforts, it has become standard practice to estimate the long-run and short-run effects of the marketing-mix, using, say, weekly scanner data. A common vehicle for this purpose is an econometric time series model. Issues that are addressed in the literature are unit roots, cointegration, structural breaks and impulse response functions. In this paper we summarize the most important concepts by reviewing all possible empirical cases that can be encountered in practice using a prototypical model. We provide guidelines for practitioners, and illustrate these for a detailed workedout example. | |
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# Deriving dynamic marketing effectiveness from econometric time series models

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# Deriving dynamic marketing effectiveness from econometric time series models

**Abstract**

To understand the relevance of marketing efforts, it has become standard practice to estimate the long-run and short-run effects of the marketing-mix, using, say, weekly scanner data. A common vehicle for this purpose is an econometric time series model. Issues that are addressed in the literature are unit roots, cointegration, structural breaks and impulse response functions. In this paper we summarize the most important concepts by reviewing all possible empirical cases that can be encountered in practice using a prototypical model. We provide guidelines for practitioners, and illustrate these for a detailed worked-out example.

*Keywords:* Dynamic effects; marketing mix; econometric time series models

# 1 Introduction

There are many studies in marketing which examine the long-run effects of marketing instruments, see for example, Dekimpe and Hanssens (1995a), Dekimpe, Hanssens and Silva-Risso (1999) and Srinivasan and Bass (2000). Often this discussion involves matters like unit roots and impulse response functions. For example, techniques to model persistence, as suggested by Dekimpe and Hanssens (1995*b*) to assess the long-run effects of marketing actions, rely heavily on the distinction between evolving and stationary variables, which in turn are associated with decisions on unit roots.

It is important to stress here that long-run effects can also be realized in stationary markets, and hence are not unique to evolving markets. These effects can be established by also permanently changing the value of an instrument. So, if there is a unit root for sales, suggesting that the market is evolving, then a single shock, like a one-time price decrease or an advertising campaign, can change the level of sales permanently. But also, if a series is stationary, one needs to decrease the price forever to generate a permanent effect on sales.

Similar thoughts can be expressed for the use of impulse response functions (IRFs). When data are stationary, the IRF always converges to zero, due to a one-time shock. Again in this case, the sales may converge to a non-zero value, which is achieved by permanently changing the level of the marketing instrument. In this paper we elaborate more on these issues.

There is substantial empirical literature on the short- and long-run effects of temporary marketing actions, see, for example, Blattberg (1989), Dekimpe and

Hanssens (1995b) and (1999), Nijs, Dekimpe, Steenkamp and Hanssens (2001), Pauwels, Hanssens and Siddarth (2002). The dynamic effects of permanent changes in marketing variables are however less explored, see for a few exceptions Ailawadi, Lehmann and Neslin (2001) and Srinivasan, Popkowski Leszczyc and Bass (2000).

Besides enumerating the effects of temporary changes in expenditures in marketing promotions, it is also important for managers and for researchers to assess the impact of permanent changes in expenditures like a decrease or increase in regular price or a fixation of a new advertising budget. Managers are likely to be interested in assessing the sales response to temporary and to structural changes under different market conditions in order to be able to make strategic decisions about the levels of regular prices vs. tactical decisions about price discounts. Part of this learning is to realize that permanent and temporary changes in the marketing mix may have rather different effects on sales under different scenarios and that these have different consequences for profitability. Vanden Abeele (1984) already pointed out the requisite for studying responses to fundamental policy changes that are of strategic importance, and not only to tactical changes that are made in the short run.

The need for assessing the effects of permanent changes of the marketing mix is well demonstrated by the unsuccessful sustained changes in the marketing mix of Procter & Gamble. The company, based on preliminary theoretical considerations, instituted major cuts in deals and coupon activities and increased the advertising expenditures in the period from 1990 to 1996. Their objectives were to reduce operating costs and to strengthen brand loyalty (Shapiro, 1992). Unfortunately, the consumer and competitive responses to these changes resulted in a massive reduction in market shares.

In this paper we provide an extensive analysis of the short-term, intermediate-term, and long-term effects of temporary and permanent changes in marketing mix. We derive these effects with the help of a simple but comprehensive model and distinguish five important scenarios.

The paper is organized as follows. In Section 2, we discuss the prototypical model we use for our investigation. We discuss different market conditions in Section 3 and their impact on dynamic effects of the marketing mix. In Section 4, we investigate the consequences of temporary and permanent changes on profitability. We illustrate our insights by an empirical analysis of the well-known Lydia Pinkham data in Section 5. Finally, we conclude the paper in Section 6 with several remarks.

## 2 The prototypical model

Consider time series observations on $y_t$, say, sales, and a marketing mix variable $x_t$ and consider the following bivariate model

$$\begin{aligned} \triangle y_t &= \alpha \triangle x_t + \gamma y_{t-1} - \theta x_{t-1} + \varepsilon_{1,t} \qquad (1) \\ x_t &= \rho x_{t-1} + \mu I(.) + \varepsilon_{2,t}, \end{aligned}$$

where $\triangle$ denotes the first-difference operator, defined by $\triangle y_t = y_t - y_{t-1}$, $\varepsilon_{1,t}$

and $\varepsilon_{2,t}$ are mutually independent error terms of the two equations, and where $I$ is an indicator function. In the case of a temporary shock at time $t_1$, it is $I(t = t_1)$ and in the case of a permanent shift from time point $t_1$ onwards, it is $I(t \geq t_1)$. The model has a one-way causality structure, that is, $x_t$ causing $y_{t+1}$ but $y_t$ not causing $x_{t+1}$. If $\theta = \gamma\beta$, we get a so-called error correction model (ECM) as it can be written as

$$\begin{aligned} \triangle y_t &= \alpha \triangle x_t + \gamma \left( y_{t-1} - \beta x_{t-1} \right) + \varepsilon_{1,t} \\ x_t &= \rho x_{t-1} + \mu I(.) + \varepsilon_{2,t}. \end{aligned} \tag{2}$$

The expression $y_{t-1} - \beta x_{t-1}$ describes the long-run link between $x_t$ and $y_t$, and $\alpha$, in part, captures the short-run effects. The $\gamma$ parameter can be interpreted as the average speed of adjustment towards the long-run relationship. Models (1) and (2) assume that marketing expenditures may have contemporaneous effects on sales while the opposite immediate effect is precluded.

Based on (1) and (2), we distinguish the following five cases, which follow from univariate common time series properties of $x_t$ and $y_t$. We denote I($d$), $d = 0, 1$ for a time series without and with a unit root. In case I $y_t$ is I(0), $x_t$ is I(0), case II concerns when $y_t$ is I(0), $x_t$ is I(1), in case III $y_t$ is I(1), $x_t$ is I(0), in IV $y_t$ is I(1), $x_t$ is I(1), and $y_{t-1} - \beta x_{t-1}$ is I(0), while in case V $y_t$ is I(1), $x_t$ is I(1), but $y_{t-1} - \beta x_{t-1}$ is not I(0). We aim to derive short-term, intermediate-term, and long-term effects of temporary and permanent changes in $x_t$ and $y_t$, for each of the five cases.

The *immediate (short-run) effects* of promotions are reflected by the contemporaneous changes in sales. Most previous research focuses on the immediate effect of promotions and finds high own-effects (Blattberg and Neslin, 1990). The *intermediate-term (medium-term or adjustment) effects* refer to the effects of promotions in the transition period between short-term response and the resulting equilibrium, hence in the so-called dust-settling period, which can be either mean reversion or a new sales level, see Pauwels et al. (2002). Finally, *long-term effects* of marketing actions mean the difference of the after-promotion equilibrium sales from the equilibrium sales level in the absence of the promotions. If the long-run effect is different from zero, the marketing action is said to have a *persistent effect* on sales, see Dekimpe and Hanssens (1995*b*), while if it is zero, the marketing action only has a *temporary effect*.

## 3 Variations of the model

In this section, we first deal with cases I and II, as they amount to stationary sales data. In the second subsection, we deal with three cases concerning evolving markets. To indicate that differences across cases will be found to be large, we already provide results for the short-term and long-term effects in Table 1.

[TABLE 1 ABOUT HERE]

### 3.1 Stationary sales

Much empirical evidence from scanner data suggests that the performance and spending behavior of many frequently purchased consumer brands is predominantly stationary, see Bass and Pilon (1980), Dekimpe et al. (1999), Horváth, Leeflang, Wieringa and Wittink (2003), and Lal and Padmanabhan (1995). There are several theories that advocate the stationary property of markets. Ehrenberg (1988) attributes the stationarity to consumer inertia. Bass (1974) also presents evidence of stationarity and represents this through a stochastic choice process. From the stochastic choice perspective, the market is made of switchers with different probabilities of switching among brands in a category and stationarity is the steady state outcome of the stochastic process. Lal and Padmanabhan (1995) find that while promotions have an impact on the market share in the short run, market shares are unaffected by promotional expenditures in the long-run as promotional activities of competitors neutralize each other.

We demonstrate the response of stationary sales to temporary and permanent changes in a stationary and an evolving price variable in Figures 1A and 1B. We simulate series according to the data-generating processes assumed under the different scenarios and apply impulse response analysis to show the effects of temporary and permanent changes of marketing instrument on sales over time. We choose arbitrary parameters in the simulation which are in the range of the model assumptions.

From Figures 1A and 1B it is apparent that when sales is a stationary variable, a positive effect on sales in the long-term can be obtained by a permanent action, while not by a temporary shift, see Grewal et al. (2001), Dekimpe and Hanssens (1999), and Dekimpe et al. (1999). At the same time, as we will also see from the numerical derivations below, stationarity of the marketing instrument plays an important role in the mid-term sales responses and in the long-term effect of a permanent change, as in case II the long-run level is higher. In the discussion of the cases we keep the appellation of Dekimpe and Hanssens (1999) to classify the different scenarios. We note, though, that we distinguish between five cases while Dekimpe and Hanssens (1999) only consider four. We consider the evolving business practice scenario under two situations, that is, when the evolving variables are cointegrated and when they are not. In the appendix we give full derivations of the dynamic effects for each scenario.

[FIGURES 1A AND 1B ABOUT HERE]

**Case I. Business as usual (both $y_t$ and $x_t$ are $\mathbf{I}(0)$)**

In this case a temporary marketing effort of size $\mu$ results in an immediate effect of size $\alpha\mu$. Hence, the instantaneous effect is a function of the size of the promotion and of the parameter, measuring, say, price elasticity and it depends on the signs of $\alpha$ and $\mu$. The medium-term effects of a temporary marketing action can be expressed as

$$IRF(t+k) = \sum_{i=0}^{k-1} (1+\gamma)^i \rho^{k-1-i} (\alpha\rho - \alpha - \gamma\beta) \mu + (1+\gamma)^k \alpha\mu,$$

where $IRF(t+k)$ expresses the $k$-period effect of an action. As in this case

$y$ and $x$ are both stationary, that is, $\gamma < 0$ and $\rho < 1$ in (2), the impact of additional marketing-mix expenditures diminishes over time.

A permanent change in performance can be achieved by altering marketing expenditures irrevocably. After an immediate effect of size $\alpha\mu$, the medium-term effects can then be expressed as

$$IRF(t+k) = \sum_{j=1}^{k-1}\sum_{i=0}^{j}(1+\gamma)^i \rho^{j-1-i}(\alpha\rho - \alpha - \gamma\beta)\mu + \sum_{i=0}^{k}(1+\gamma)^i \alpha\mu.$$

In the long-term, this converges to $\frac{\beta\mu}{(1-\rho)}$, which is not zero if $\beta \neq 0$.

This case illustrates the following. The larger the long-run equilibrium parameter, the larger the long-run effect on sales. And the larger the autoregressive parameter in the $x_t$ equation, the larger the effect. It is important to see that a permanent increase in $x_t$ may result either in an increase or a decrease in $y_t$ in the long run, depending on the signs of $\beta$ and $\mu$. If $\beta$ and $\mu$ have the same sign, we obtain an upward level shift in sales in the long term. Hence, for positive $\beta$, a permanent increase in the level of the marketing variables would lead to a sustained sales increase, while for a negative $\beta$ permanent downward shifts would lead to such a favorable situation. If $\beta$ is zero, even a permanent change in price cannot arrive at a persistent effect on sales. The marketing variables will reach a new level in the long run, that differs from its original level with $\frac{\mu}{(1-\rho)}$.

There are several examples of long-run effects of permanent changes in marketing variables. A study, conducted by the United States Department of Health and Human Services, confirms that substantial permanent increase in prices of cigarettes would encourage some people to quit smoking. If a proportion of them succeed, the number of smokers would reduce, resulting in lower cigarette sales in the long-term. Companies in mature frequently purchased consumer markets seem to have realized that for long-term superiority, permanent changes are important. Albert Heijn, a grocery chain reigning throughout The Netherlands, for example, in addition to their usual bonus offerings, started to reduce the price of some of their products permanently.

**Case II. Escalation ($y_t$ is $\mathbf{I}(0)$, $x_t$ is $\mathbf{I}(1)$)**

In this case of escalation, where $\beta = 0$ and $\rho = 1$, temporary marketing actions do not have a long-term impact on performance. A one-time marketing action may, however, have enduring consequences on the level of the expenditures. Hence, long-term effects may be achieved by permanent changes but this, due to the non-stationarity of $x_t$, would not be sustainable in the long run, as a permanent change of the marketing variable may result in escalating behavior.

After a significant instantaneous effect of size $\alpha\mu$, the subsequent $k$-period impact of a temporary action is

$$IRF(t+k) = (1+\gamma)^k \alpha\mu,$$

which starts to diminish as we assume stationarity of $y$, that is $\gamma < 0$ in (2). However, the mid-term effect of a permanent change in the level of marketing effort $x$ can be expressed as

$$IRF(t+k) = \sum_{i=0}^{k} (1+\gamma)^k \alpha\mu.$$

This expression converges to the non-zero value $-\frac{\alpha\mu}{\gamma}$ as $k$ grows if $\alpha \neq 0$. Interestingly, if $\gamma < -1$, the action will have an alternating effect on sales, while if $-1 < \gamma < 0$ the mid-term effects will have the same sign as the immediate effects. This does not hold when we include further lags and account for feedback effects in the model.

In our special case, the sign of the long-run effect of permanent policy change only depends on the immediate effect and the direction of the change, and thereby, its sign will be the same as the sign of the immediate effect. In terms of size, the larger the permanent change and the immediate effect, the larger the long-run effect. And the slower the adjustment, the larger the long-run effect.

## 3.2 Evolving sales

The environments in which marketing decisions are made may be evolving due to, for example, changes in technology, consumer preferences, and/or competition, see Dekimpe and Hanssens (1995a) and Dekimpe et al. (1999). Simon (1997) discusses and provides several empirical cases when temporal factors such as price cuts may permanently affect a company's performance. He also provides possible explanations for such a phenomenon. The most important ones are (1) that a temporary stimulus may attract new customers who then remain loyal, (2) that there is inertia in consumer choice, which means that once a consumer switches to a new product, he or she is not likely to return to the old product, (3) that there is communication in industries where repeat-buying does not occur, namely, a consumer attracted by the temporary stimulus may convince new customers to make a purchase, and (4) the fact that in the period of a temporary stimulus, consumers may store information in their long-term memory.

We demonstrate the response of evolving sales to temporary and permanent changes in a stationary and an evolving price variable in Figures 2A, 2B, and 2C. We simulate time series data in the same way as we did for Figures 1A and 1B. The figures clearly show that when sales is an evolving variable, a temporary marketing action is enough to induce a permanent effect on sales, see also Grewal et al. (2001), Dekimpe and Hanssens (1999), and Dekimpe et al. (1999). At the same time, as to be shown below, the intermediate-term dynamics as well as the long-run equilibrium of a temporary action depend on the stationary property of the marketing instrument and on the long-run relationship between the sales and the marketing expenditures. In the case of evolving sales, a permanent action may induce a permanent increase in sales. However, this might not be tenable in the long-run, due to, for example, physical considerations, maximum size of the category and/or retaliatory competitive moves triggered by the successful performance of the brand.

Suresh (1996) is concerned that the effects of sustained advertising on India's consumption patterns may be unsustainable. He points out that as a result of aggressive advertising and the permeation of the "buy now and pay later" culture, even poor Indians are buying various consumer goods at increasing scale and thrift, which is hardly custom among middle class Indians. These consumption patterns move slowly towards unsustainable levels, while resources like domestic savings diminish. As a result, in 2001, United Nations Division for Sustainable Development in Agenda 21 named increasing awareness for sustainable consumption as one of the points to tackle for India.

[FIGURES 2A, 2B, AND 2C ABOUT HERE]

**Case III. Hysteresis ($y_t$ is $\mathbf{I}(1)$, $x_t$ is $\mathbf{I}(0)$)**

Let us consider the reaction to a temporary marketing action. Given the non-stationary properties of the sales variable, immediate effects are of size $\alpha\mu$ and the medium-term effects of size

$$IRF(t+k) = \sum_{i=0}^{k} \rho^i \left(\alpha\rho - \alpha - \theta\right)\mu + \alpha\mu.$$

In the end of the dust-settling period, sales approach a level that differs from the equilibrium level before the promotion with $\frac{\theta\mu}{\rho-1}$.

**Case IV. Evolving business practice (both $y_t$ and $x_t$ are $\mathbf{I}(1)$ and are cointegrated)**

The immediate effect of a one-time marketing action is $\alpha\mu$, just like in all other cases and its subsequent $k$-period impact on sales is

$$IRF(t+k) = \sum_{i=0}^{k-1} (1+\gamma)^i \left(-\gamma\beta\right)\mu + (1+\gamma)^k \alpha\mu.$$

In a cointegrated system the effect of a temporary shock converges to the long-run equilibrium value, hence the long-run effect of a shock of size $\mu$ is $\beta\mu$.

**Case V. Evolving business practice (both $y_t$ and $x_t$ are $\mathbf{I}(1)$ but are not cointegrated)**

In this case the initial change carries on for the sales as well as for the marketing variables. The short-term, medium-term, and long-term effects of a one-time shock on sales is $\alpha\mu$ and the marketing variable arrives at a new level, which is higher or lower than the original level with $\alpha\mu$, depending on the sign of $\alpha$.

## 4 Consequences for profit

The temporary and permanent changes of marketing expenditures in the five cases discussed above have very different consequences for the long-term profitability of marketing efforts. These consequences of, say, a temporary/permanent price decrease on sales can be illustrated through the following calculations where we use

$$(S + \Delta S)(P - \Delta P) \gtreqless SP,$$

where $S$ and $P$ denote sales and price levels before the marketing action and $\Delta S$ and $\Delta P$ represent the changes in sales and price levels in the long run (say, the difference between the equilibrium value before and after the action). A marketing action is profitable if the profit has increased after the changes, which means that the left hand-side of this equation is larger than the right hand-side.

After rearranging we get

$$P\Delta S \gtreqless (S + \Delta S)\Delta P, \tag{3}$$

which, in the case of a long-term sales effect (and if $\Delta S > 0$) can be further written as

$$\frac{P}{(S + \Delta S)} \gtreqless \frac{\Delta P}{\Delta S} \tag{4}$$

If we have a linear model, the short-, medium, and long-run effects are independent of the original (equilibrium) levels of sales and prices. This implies for two brands, with the same long-run price and sales effect of a price reduction, that the action is likely to be more profitable for the one with higher original price and lower initial sales. Also, for brands with similar sizes and price levels, the price reduction is more profitable for the brand with a smaller level shift in price and higher expansion of sales.

**Case I.** In the case of the most prevalent "business as usual scenario", a one-time change in $P$, results in no permanent effects. Both $\Delta P$ and $\Delta S$ will be zero in the long-run, hence the two sides of (3) are equal. In this case, temporary actions imply no long-run profitability. But, they might have temporary effects on profitability. Therefore, profitability measures of temporary action require the implementation of a cost-benefit analysis based of short- and intermediate-term effects. This involves the calculation of $\sum_{t=0}^{T} P\Delta S \gtreqqless \sum_{t=0}^{T}(S + \Delta S)\Delta P$, where $T$ refers to the end of the dust-settling period. The conclusion may be that market response and profit margins are sufficient or insufficient to cover marketing costs, see Dekimpe and Hanssens (1999) and Dekimpe et al. (1999).

A permanent shift in prices will affect both the sales and the price level in the long run, with $\frac{\beta\mu}{(1-\rho)}$ and $\frac{\mu}{(1-\rho)}$, respectively. This suggests that the higher $\beta$, the larger the profitability of the action.

**Case II.** In the case of escalation, the profitability of a temporary price cut grows to minus infinity, as, although the effect on sales dies out, the change in price carries over to the new periods and will have a new and lower level. An example of such a case is when, after a firm cuts its price, a series of retaliatory price reductions are launched by competitors as no one wants to lose consumers, volume, or market share. Subsequently, the initiator firm has to act again, in order to retain its position on the market. This action, however, may be followed by further competitive moves, and so on. This agitated environment may result in a different (lower) price level than before the initiative action, while the market returns to the primal structure, eroding profits from the market. Such behavior have been observed in the airline industry, computer software, automobile tires, and many other markets. In such an environment, managers should consider increasing the price to arrive at more profitable situation.

A permanent expenditure expansion starts to escalate, resulting in a long-run sales effect, but this grows slower than the expenditures. Hence, this marketing step is also not profitable in this case.

**Case III.** In hysteresis, the long-term profitability of a price cut might be either infinitely positive or negative, depending on the sign of $\theta$. This is because a one-time shock to price will die out over time, while it will have a permanent effect on sales of size $\frac{\theta\mu}{\rho-1}$.

The profitability of a permanent price reduction will have the same size. However, the effect of such a marketing action on sales keeps increasing, and this might not be tenable in the long run.

**Cases IV and V.** In the two distinguished cases of the evolving business practise scenario, the profitability of a temporary action might be either positive or negative, depending on the relative size of the long-run effect of the action on levels of sales and expenditures.

## 5 Empirical illustration

We aim to provide an empirical illustration of the notion that different assumptions on the parameters of the models of (1) and (2) provide different results on the dynamic effects of advertising for the annual Lydia Pinkham's vegetable compound data in this section. In other words, decisions on unit roots and cointegration determine the managerially relevant outcomes.

Lydia Pinkham's medicine was patented in 1873 as a remedy for menstrual pain and menopausal malaise and has been on the market long time after. The annual data cover the period of 1907−1960 and the history of the company is described in detail in Palda (1964). A large court case made the company database public. These data are considered to be very suitable for advertising-sales studies due to lack of competitors, exclusivity of advertising as the company's marketing effort, with all sales handled by distributors, and the availability of detailed data.

As the data are publicly available and have several unique characteristics, they have been used by several researchers for various purposes. Palda (1964) introduced the first empirical evidence of the advertising carryover effect on sales using these data by estimating several versions of the Koyck model.

In our empirical illustration, we track the effect of 100 dollars (temporary and permanent) expansions of the advertising budget. This means an increase of about 10% in advertising, as the mean of the advertising expenditures is about 935 dollars. We choose for a lag structure of order 2 for the model in all the five cases in order to allow for a fair focus on only the effects of differences in parameter assumptions while capturing autocorrelation. We aim to build a model that is close to available marketing applications, so we also consider performance feedback and allow advertising to have an immediate effect on sales, while we do not allow for the opposite immediate effect, consistent with the prototypical model.

**Case I.** Stationary assumptions on the sales and advertising variables require a two-dimensional VAR(2) model in levels. Figure 3 shows that a temporary increase in the advertising budget dislodges both sales and advertising expenditures from their original equilibrium, but after a short period both variables return to their original level. Interestingly, both advertising expenditures and sales reduce after the high initial effects. After five years, the point estimates show that they will even reach a value that is lower than the initial one. However, these effects are not significant, as can be observed from the 95% confidence bounds.

[FIGURE 3 ABOUT HERE]

A permanent increase in advertising expenditures may (as Figure 4 shows) have a long-run effect. According to the point estimates, the advertising budget of the company would increase with about 106 dollars, while sales would drop with about 124 dollars in the long term. This suggests that a permanent expansion in advertising has unfavorable long-term consequences with respect to sales and profitability. However, due to the wide confidence intervals, we cannot draw distinct conclusions about the long-term effects of permanent expansion of the advertising budget under the assumptions of case I.

[FIGURE 4 ABOUT HERE]

**Case II.** Under the assumption of escalation, a VAR model is to be built with sales in levels and advertising in first differences (DA in the graph). The

IRF for the variables is shown in Figure 5A. We see that the effects of a temporary change in the change in advertising die out over time. However, the first graph measures the effects on the first differences of advertising. We can calculate the effects of a temporal change on the level at time $t$ by summing up the IRFs up until this period. These sequences are represented in Figure 5B. So, a temporary initial change in advertising does not have a permanent effect on sales, but will result in significantly (about 66 dollars) higher overall yearly advertising expenditures. This suggests that, if we adopt the assumptions of case II, a temporary increase in advertising has unfavorable profitability consequences for the company.

[FIGURES 5A AND 5B ABOUT HERE]

**Case III.** If we have a market under hysteresis, a VAR model should to be built with sales in first differences and advertising in levels. As sales are defined in first differences (Figure 6A), the impact of the increase in advertising on the level of sales at time $t$ can be computed as the sum of responses of the differences in sales up to $t$. Figure 6B shows that the temporary increase in advertising leads to lower sales in the long run. So, under the assumptions of case III, we conclude that a temporary increase in advertising leads to lower sales, and invariable price level, in the long-term, that is not a profitable move.

[FIGURES 6A AND 6B ABOUT HERE]

**Case IV.** If the two non-stationary variables are cointegrated, we have to incorporate long-run stationary relations into the model. The model with the assumption of a long-run relationship between the evolving variables predicts that a one-time increase in advertising expenditures carries over, and after fluctuations, will reach a new (about 56 dollars higher) level and that the sales will expand with about 78 dollars in the long-run, see Figure 7. We need to compute the values in (4) in order to assess the long-run profitability consequences of extra advertising. Using the mean values as initial levels for the sales (1829) and advertising (935), we get $\frac{1829}{935+78}$ ($\approx 1.81$) $>$ $\frac{56}{78}$ ($\approx 0.72$). So, under the assumptions of case IV, we predict that extra advertising increases sales and profits of the firm, in the long run.

[FIGURE 7 ABOUT HERE]

**Case V.** When there would be no cointegrating relationship between the two nonstationary variables, a VAR model is to be built that includes the variables in first differences. Figures 8A and 8B show the IRF results for the Lydia Pinkham data under the assumptions of this case. We see that although the IRF of the differences series returns to zero, the initially one-time increase in advertising expenditures carries over (just like in case IV) and reaches a new (about 70 dollars higher) level and that the sales will expand with about 44 dollars in the long run. In this case, the calculations according to Equation (4) will be $\frac{1829}{935+44}$ ($\approx 1.87$) $>$ $\frac{70}{44}$ ($\approx 1.59$). Therefore, when adopting the assumptions of case V, the conclusions are the same as in case IV, however, the sales and profitability expansion is predicted to be much lower. So, it is interesting to note how the long-run relation assumption makes the difference for the effects of a temporary increase in advertising. In case IV, where we assumed a cointegrating relationship, the advertising expenditures were expected to rise with 56 dollars yearly, while the sales were predicted to expand with about 78 dollars yearly, in the long run. When no long-term relationship is accounted for, these numbers change to 70 and 40 dollars, respectively, changing the ratio on the right hand-side of Equation (4), and hence, profitability in the long-term remarkably.

[FIGURES 8A AND 8B ABOUT HERE]

The results for the Lydia Pinkham data show that completely different results can be obtained from different, but closely related, models. Depending on the assumptions on stationarity and cointegration, one can obtain lower or higher levels of long-run sales and, due to feedback of advertising.

It is now interesting to examine what tests for unit root and cointegration for these data entail. When we apply the familiar Dickey-Fuller and Johansen tests, we find evidence that model V comes closest to an adequate description of the data, with IV as a close competitor. These results suggest that a temporary expansion in advertising would have favorable consequences on the sales and the profitability of the firm.

# 6 Conclusion

Now, what does the exercise in this paper tell us? The formal analysis, but foremost the empirical analysis of the Lydia Pinkham data, seem to point towards the one and only conclusion. This is that one needs a proper econometric time series model to understand the dynamic effects of marketing mix instruments. This may seem a trivial finding, but it might not be. Indeed, depending on the model, marketing instruments can be seen to have either a positive or a negative long-run effect.

In this paper, we did not want to tell marketing researchers that tests for unit roots and cointegration are important by outlining how all these tests should be implemented in practice. Instead, we decided simply to illustrate that different assumptions lead to markedly different, and managerially important, outcomes. So, to understand if one's marketing effort exercise any long-run effects, one should start with modeling the historical data with the proper model. There is an enormous literature on methods to make the proper decisions on unit roots and cointegration. This literature does not amount to an aberration of econometricians. In contrast, it should help marketing managers to understand and forecast the dynamic consequences of their own efforts.

# Appendix

| | |
|---|---|
| Case I | temporary change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(\alpha\rho-\alpha-\gamma\beta)\,\mu+(1+\gamma)\,\alpha\mu$ |
| $t+2$ | $[(1+\gamma)+\rho]\,(\alpha\rho-\alpha-\gamma\beta)\,\mu+(1+\gamma)^2\,\alpha\mu$ |
| $t+3$ | $\left[(1+\gamma)^2+(1+\gamma)\,\rho+\rho^2\right](\alpha\rho-\alpha-\gamma\beta)\,\mu+(1+\gamma)^3\,\alpha\mu$ |
| $t+k$ | $\sum_{i=0}^{k-1}(1+\gamma)^i\,\rho^{k-1-i}\,(\alpha\rho-\alpha-\gamma\beta)\,\mu+(1+\gamma)^k\,\alpha\mu$ |
| $t+\infty$ | $0$ |

| | |
|---|---|
| Case I | permanent change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(\alpha\rho-\alpha-\gamma\beta)\,\mu+[1+(1+\gamma)]\,\alpha\mu$ |
| $t+2$ | $[(1+\gamma)+\rho+1]\,(\alpha\rho-\alpha-\gamma\beta)\,\mu+\left[1+(1+\gamma)+(1+\gamma)^2\right]\alpha\mu$ |
| $t+3$ | $\left[(1+\gamma)^2+(1+\gamma)\,\rho+\rho^2+(1+\gamma)+\rho+1\right](\alpha\rho-\alpha-\gamma\beta)\,\mu$ |
| | $+\left[1+(1+\gamma)+(1+\gamma)^2+(1+\gamma)^3\right]\alpha\mu$ |
| $t+k$ | $\sum_{j=1}^{k-1}\sum_{i=0}^{j}(1+\gamma)^i\,\rho^{j-1-i}\,(\alpha\rho-\alpha-\gamma\beta)\,\mu+\sum_{i=0}^{k}(1+\gamma)^i\,\alpha\mu$ |
| $t+\infty$ | $\frac{\beta\mu}{(1-\rho)}$ |

| | |
|---|---|
| Case II | temporary change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(1+\gamma)\,\alpha\mu$ |
| $t+2$ | $(1+\gamma)^2\,\alpha\mu$ |
| $t+3$ | $(1+\gamma)^3\,\alpha\mu$ |
| $t+k$ | $(1+\gamma)^k\,\alpha\mu$ |
| $t+\infty$ | $0$ |

| | |
|---|---|
| Case II | permanent change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $[1+(1+\gamma)]\,\alpha\mu$ |
| $t+2$ | $\left[1+(1+\gamma)+(1+\gamma)^2\right]\alpha\mu$ |
| $t+3$ | $\left[1+(1+\gamma)+(1+\gamma)^2+(1+\gamma)^3\right]\alpha\mu$ |
| $t+k$ | $\sum_{i=0}^{k}(1+\gamma)^k\,\alpha\mu$ |
| $t+\infty$ | $-\frac{\alpha\mu}{\gamma}$ |

| | |
|---|---|
| Case III | temporary change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(\alpha\rho-\alpha-\theta)\,\mu+\alpha\mu=(\alpha\rho-\theta)\,\mu$ |
| $t+2$ | $(1+\rho)\,(\alpha\rho-\alpha-\theta)\,\mu+\alpha\mu$ |
| $t+3$ | $\left(1+\rho+\rho^2\right)(\alpha\rho-\alpha-\theta)\,\mu+\alpha\mu$ |
| $t+k$ | $\sum_{i=0}^{k}\rho^k\,(\alpha\rho-\alpha-\theta)\,\mu+\alpha\mu$ |
| $t+\infty$ | $\frac{\theta\mu}{\rho-1}$ |

| | |
|---|---|
| Case III | permanent change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(\alpha\rho - \alpha - \theta)\,\mu + 2\alpha\mu$ |
| $t+2$ | $(2+\rho)\,(\alpha\rho - \alpha - \theta)\,\mu + 3\alpha\mu$ |
| $t+3$ | $\left(3+2\rho+\rho^2\right)(\alpha\rho - \alpha - \theta)\,\mu + 4\alpha\mu$ |
| $t+k$ | $\sum_{i=0}^{k-1}(k-i)\rho^i\,(\alpha\rho - \alpha - \theta)\,\mu + (k+1)\alpha\mu$ |
| $t+\infty$ | $\infty$ |

| | |
|---|---|
| Case IV | temporary change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(-\gamma\beta)\,\mu + (1+\gamma)\,\alpha\mu$ |
| $t+2$ | $[(1+\gamma)+1]\,(-\gamma\beta)\,\mu + (1+\gamma)^2\,\alpha\mu$ |
| $t+3$ | $\left[(1+\gamma)^2 + (1+\gamma) + 1\right](-\gamma\beta)\,\mu + (1+\gamma)^3\,\alpha\mu$ |
| $t+k$ | $\sum_{i=0}^{k-1}(1+\gamma)^i\,(-\gamma\beta)\,\mu + (1+\gamma)^k\,\alpha\mu$ |
| $t+\infty$ | $\beta\mu$ |

| | |
|---|---|
| Case IV | permanent change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $(-\gamma\beta)\,\mu + [1+(1+\gamma)]\,\alpha\mu$ |
| $t+2$ | $[(1+\gamma)+2]\,(-\gamma\beta)\,\mu + \left[1+(1+\gamma)+(1+\gamma)^2\right]\alpha\mu$ |
| $t+3$ | $\left[(1+\gamma)^2 + 2\,(1+\gamma) + 3\right](-\gamma\beta)\,\mu + \left[1+(1+\gamma)+(1+\gamma)^2+(1+\gamma)^3\right]\alpha\mu$ |
| $t+k$ | $\sum_{i=0}^{k-1}(k-i)\,(1+\gamma)^i\,(-\gamma\beta)\,\mu + \sum_{i}^{k}(1+\gamma)^i\,\alpha\mu$ |
| $t+\infty$ | $\infty$ |

| | |
|---|---|
| Case V | temporary change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $\alpha\mu$ |
| $t+2$ | $\alpha\mu$ |
| $t+3$ | $\alpha\mu$ |
| $t+k$ | $\alpha\mu$ |
| $t+\infty$ | $\alpha\mu$ |
| Case V | permanent change |
| $t$ | $\alpha\mu$ |
| $t+1$ | $2\alpha\mu$ |
| $t+2$ | $3\alpha\mu$ |
| $t+3$ | $4\alpha\mu$ |
| $t+k$ | $(k+1)\alpha\mu$ |
| $t+\infty$ | $\infty$ |

# Table

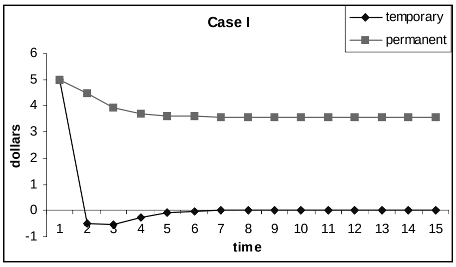
Table 1: A summary of the short-and long-term effects of temporary and permanent changes of marketing instruments on sales

| Cases | model on level parameters | | | temporary short | temporary long | permanent short | permanent long |
|---|---|---|---|---|---|---|---|
| Case I | $\rho < 1$<br>$\beta \neq 0$<br>$\gamma < 0$ | in Eq. (2) | $y_t$ is I(0)<br>$x_t$ is I(0) | $\alpha\mu$ | 0 | $\alpha\mu$ | $\frac{\beta\mu}{(1-\rho)}$ |
| Case II | $\rho = 1$<br>$\beta = 0$<br>$\gamma < 0$ | in Eq. (2) | $y_t$ is I(0)<br>$x_t$ is I(1) | $\alpha\mu$ | 0 | $\alpha\mu$ | $-\frac{\alpha\mu}{\gamma}$ |
| Case III | $\rho < 1$<br>$\theta \neq 0$<br>$\gamma = 0$ | in Eq. (1) | $y_t$ is I(1)<br>$x_t$ is I(0) | $\alpha\mu$ | $\frac{\theta\mu}{\rho-1}$ | $\alpha\mu$ | $\infty$ |
| Case IV | $\rho = 1$<br>$\beta \neq 0$<br>$\gamma < 0$ | in Eq. (2) | $y_t$ is I(1)<br>$x_t$ is I(1)<br>$y_{t-1} - \beta x_{t-1}$ is I(0) | $\alpha\mu$ | $\beta\mu$ | $\alpha\mu$ | $\infty$ |
| Case V | $\rho = 1$<br>$\gamma = 0$ | in Eq. (2) | $y_t$ is I(1)<br>$x_t$ is I(1)<br>$y_{t-1} - \beta x_{t-1}$ is not I(0) | $\alpha\mu$ | $\alpha\mu$ | $\alpha\mu$ | $\infty$ |

# Figures

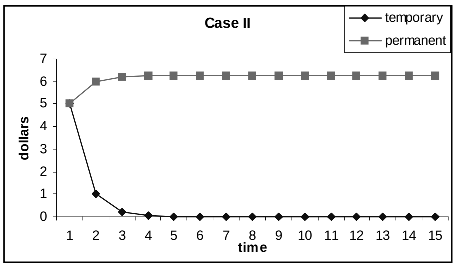
Figure 1: The responses of sales to temporary and permanent price changes in cases I and II

A




$\rho = 0.3$
$\beta = 2.5$
$\gamma = -0.8$ in Eq. (2)
$\alpha = 5$
$\mu = 1$

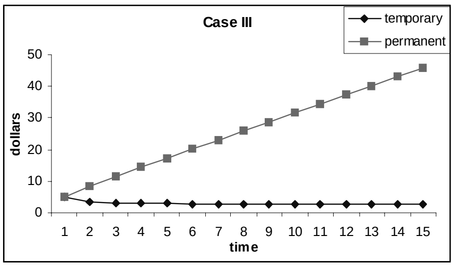
B




$\rho = 1$
$\beta = 2.5$
$\gamma = -0.8$ in Eq. (2)
$\alpha = 5$
$\mu = 1$

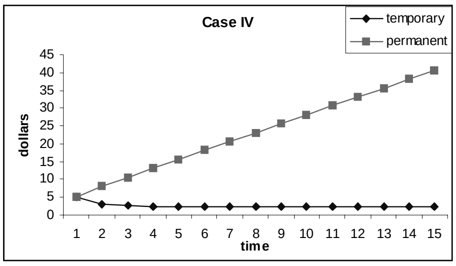
Figure 2: The responses of sales to temporary and permanent price changes in cases III, IV, and V

A



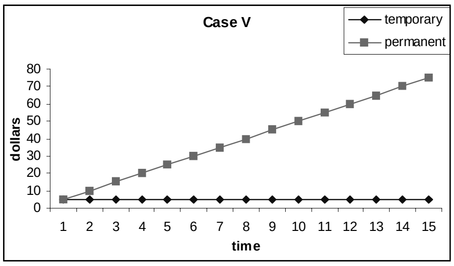

$\rho = 0.3$
$\theta = 2$
$\alpha = 5$
$\mu = 1$
in Eq. (1)

B



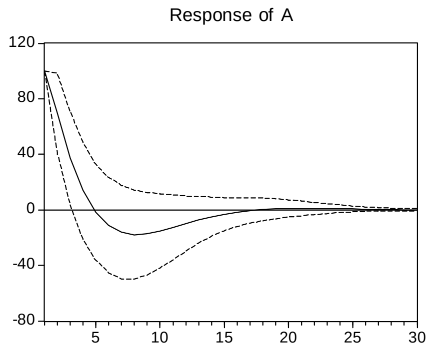

$\rho = 1$
$\beta = 2.5$
$\gamma = -0.8$
$\alpha = 5$
$\mu = 1$
in Eq. (2)

C




$\rho = 1$
$\gamma = 0$
$\alpha = 5$
$\mu = 1$
in Eq. (2)

Figure 3: Responses to a temporary change in A



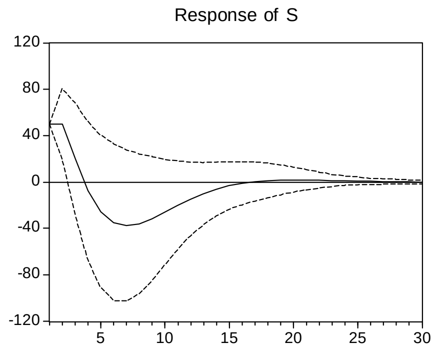



Figure 4: Responses to a permanent change in A

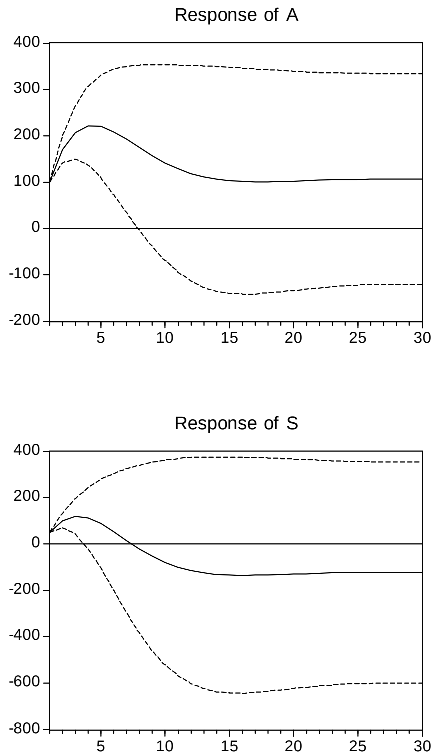
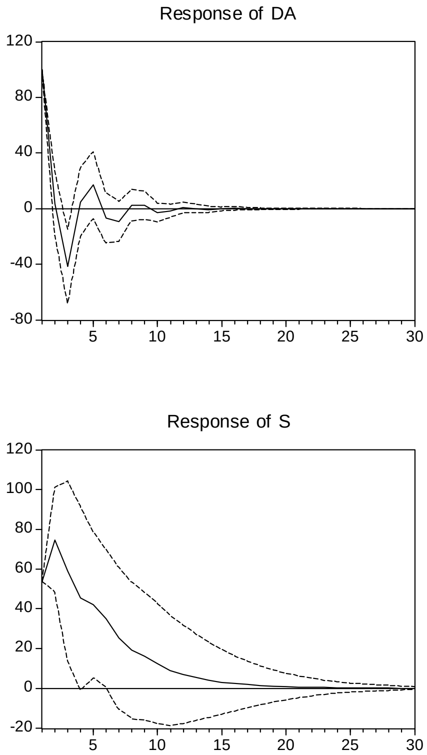


Figure 5: Responses to a temporary change in A

A




B

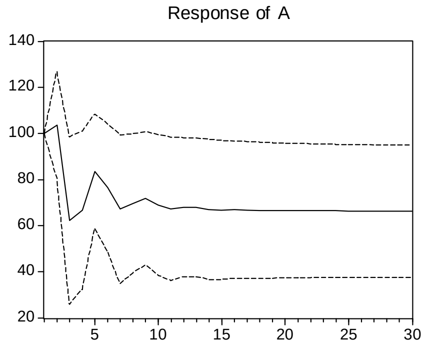


Figure 6: Responses to a temporary change in A

A B

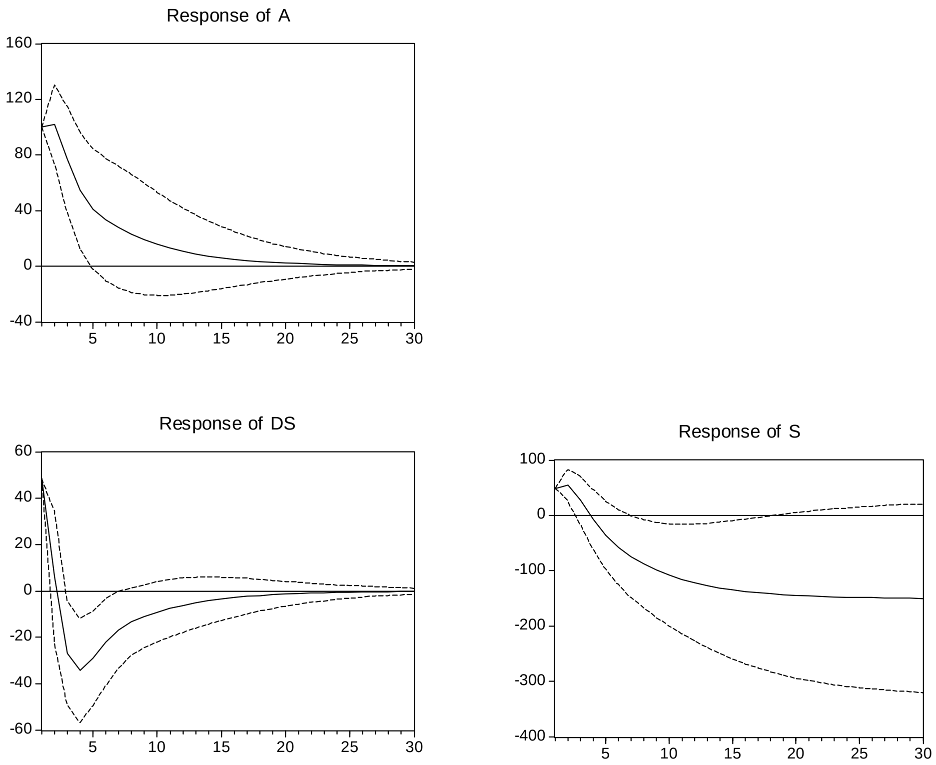


Figure 7: Responses to a temporary change in A

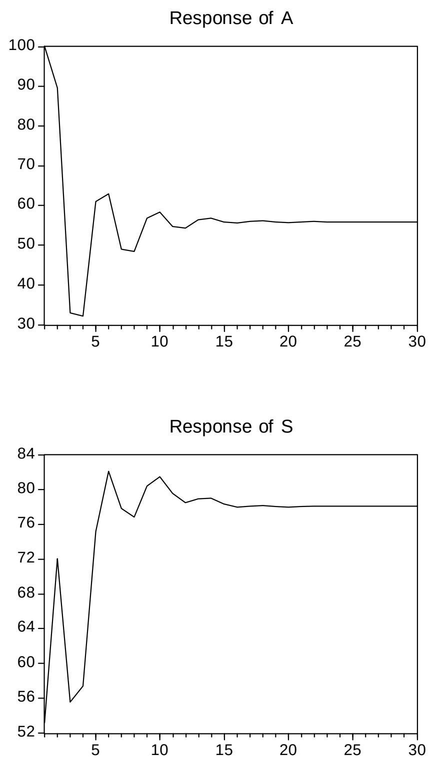
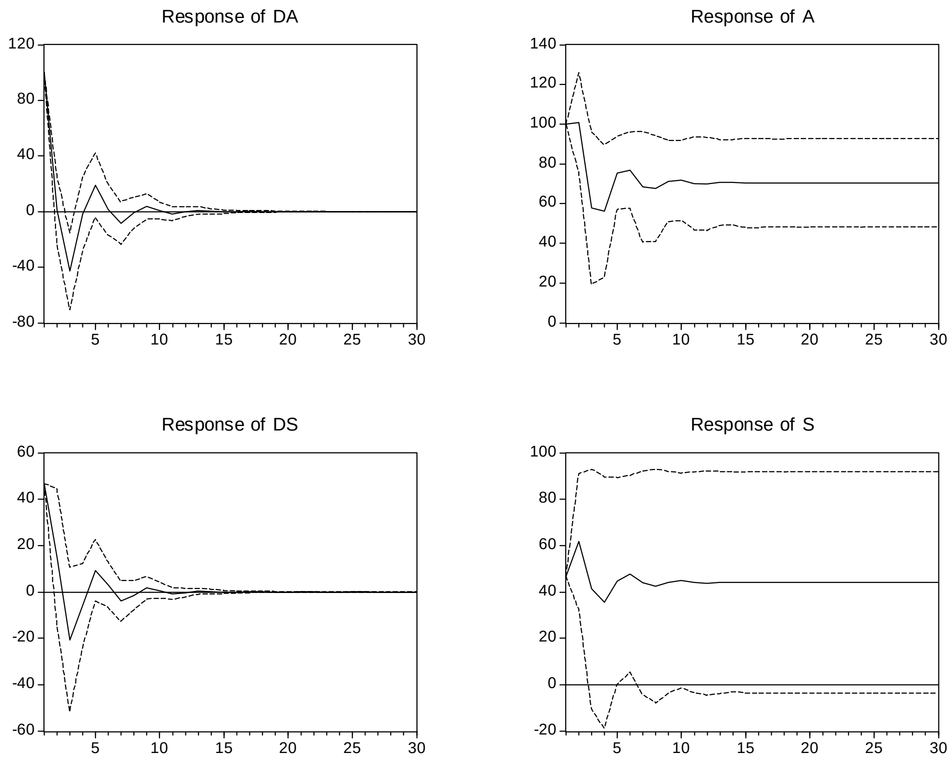


Figure 8: Responses to a temporary change in A

A B



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