An Application of the Loop Diagram to the Forward Market Efficiency
การประยุกต์ใช้แผนภูมิวงรอบกับความมีประสิทธิภาพของตลาดล่วงหน้า

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บทคัดย่อ

บทความวิชาการนี้มีวัตถุประสงค์เพื่ออธิบายความเชื่อมโยงระหว่างสมมติฐานต่างๆ ที่เกี่ยวข้องกับความมีประสิทธิภาพของตลาดล่วงหน้า สมมติฐานดังกล่าวประกอบด้วย ความไม่มีอคติของอัตราล่วงหน้า ความคาดหวังอย่างมีเหตุมีผล ความคาดหวังที่ไม่แตกต่างกัน และความเป็นกลางกับความเสี่ยง ตำราเรียนทางการเงินจะแสดงความสัมพันธ์ระหว่างสมมติฐานเหล่านี้ด้วยสมการทางคณิตศาสตร์ที่ซับซ้อนและเข้าใจยากสำหรับผู้เรียน ด้วยเหตุนี้ ผู้เขียนจึงคิดค้นแผนภูมิวงรอบเพื่อใช้ประกอบการเรียนการสอนเรื่อง ความมีประสิทธิภาพของตลาดล่วงหน้า แผนภูมิวงรอบเป็นเครื่องมือการเรียนรู้ทางสายตาที่จะส่งเสริมให้ผู้เรียนสามารถวิเคราะห์ความเชื่อมโยงระหว่างสมมติฐานต่างๆ ได้ง่ายกว่าวิธีที่ใช้ในตำราเรียนโดยทั่วไป

คำสำคัญ: ความมีประสิทธิภาพของตลาดล่วงหน้า ความคาดหวังอย่างมีเหตุมีผล ความคาดหวังที่ไม่แตกต่างกัน ความเป็นกลางกับความเสี่ยง

Abstract

The objective of this academic paper is to shed light on the linkages among several hypotheses associated with the forward market efficiency: the forward rate unbiasedness, the risk neutrality, the rational expectations and the homogeneous expectations. In finance textbooks, the relationships among these hypotheses are demonstrated by sophisticated mathematical equations, thus making it difficult for students to understand. With that in mind, the author has invented the loop diagram to supplement the conventional teaching method of the forward market efficiency. The loop diagram aims to provide a visually-oriented learning method for students and enable them to analyze the interconnection among hypotheses in a less complicated manner than what they typically see in textbooks.

Keywords: Forward Market Efficiency, Risk Neutrality, Rational Expectations, Homogeneous Expectations

Introduction

One of the most important theories in finance is the forward market efficiency hypothesis which postulates that the forward rate is an unbiased estimator of the future spot rate.[1] The test of the forward rate unbiasedness hypothesis involves the following regression equations (Fama, 1984: 325-327; MacDonald and Torrance, 1990: 547-548; Mishkin, 1988: 310-312).

$$r_{t+k} - r_t = \alpha_1 + \beta_1(f_{t,k} - r_t) + \varepsilon_{1,t+k} \qquad (1)$$

$$f_{t+k} - r_{t+k} = \alpha_2 + \beta_2(f_{t,k} - r_t) + \varepsilon_{2,t+k} \qquad (2)$$

where f_{t+k} denotes the forward rate at time t for delivery in k-periods ahead, r_t denotes the current spot rate at time t, r_{t+k} denotes the future spot rate at time $t+k$, $(r_{t,k} - r_t)$ denotes the realised spot rate change, $(f_{t,k} - r_t)$ denotes the forward rate bias, $(f_{t,k} - r_{t+k})$ denotes the forward premium, and $\varepsilon_{1,t+k}$ and $\varepsilon_{2,t+k}$ denote the disturbance terms. Following most studies surveyed in this paper, all variables in regression equations are expressed as natural logarithms. Note that equations (1) and (2) are complementary regressions where $\alpha_1 = \alpha_2$, $\varepsilon_{1,t+k} = \varepsilon_{2,t+k}$ and $\beta_1 = 1 - \beta_2$. This implies that the interpretation from either equation provides the same conclusion. The null hypothesis of the forward rate unbiasedness is that $\alpha_1 = 0$ and $\beta_1 = 1$ ($\alpha_1 = 0$ and $\beta_2 = 0$). Nonetheless, the earlier literature mainly tests the restriction that $\beta_1 = 1$ ($\beta_2 = 0$) and finds that β_1 s significantly different from unity (β_2 is

[1] Since the loop diagram can be applied to both interest rates and foreign exchange rates, the terms "forward rate" and "spot rate" used in this paper can imply the interest rates or the foreign exchange rates.

significantly different from zero) (Batchelor, 1995: 237-238; Froot, 1989: 290-291; Hamburger and Platt, 1975: 195-197; Mankiw and Miron, 1986: 217-219; Shiller, Campbell, and Schoenholz, 1983: 190-192).

The forward rate unbiasedness hypothesis can be regarded as a joint hypothesis that market participants comply with risk neutrality and rational expectations.[2] Hence the departure of β_1 from unity (β_2 from zero) could imply the existence of a time-varying risk premium and/or the failure of rational expectations. An aggregate measure of survey expectations, the so-called consensus forecast, can be used as a proxy for market expectations to shed more light on the comparative impact of both factors. As a consequence, the risk neutrality and rational expectations can be tested separately by the following regressions (Batchelor, 1995: 236-239; Frankel and Froot, 1989: 153-158; Froot, 1989: 294-296).

$$r^s_{t,k} - r_t = \alpha_3 + \beta_3(f_{t,k} - r_t) + \varepsilon_{3,t,k} \quad (3)$$
$$f_{t,k} - r^s_{t,k} = \alpha_4 + \beta_4(f_{t,k} - r_t) + \varepsilon_{4,t,k} \quad (4)$$
$$r_{t+k} - r^s_{t,k} = \alpha_5 + \beta_5(f_{t,k} - r_t) + \varepsilon_{5,t+k} \quad (5)$$

where $r^s_{t,k}$ is the consensus forecast of the future spot rate made at time t for k-periods ahead, $(r^s_{t,k} - r_t)$ is the consensus expected spot rate change, $(f_{t,k} - r^s_{t,k})$ is the consensus risk premium, $(r_{t+k} - r^s_{t,k})$ is the consensus expectations error, and $\varepsilon_{3,t+k}$, $\varepsilon_{4,t+k}$ and $\varepsilon_{5,t+k}$ are the disturbance terms. In the literature, the consensus mean or median forecast can be used as the consensus forecast.

The risk neutrality hypothesis can be examined by equations (3) and (4) which are complementary regressions, i.e., $\alpha_3 = \alpha_4$, $\varepsilon_{3,t+k} = -\varepsilon_{4,t+k}$ and $\beta_3 = 1 - \beta_4$. The null hypothesis of the risk neutrality is that $\alpha_4 = 0$ and $\beta_4 = 0$ ($\alpha_3 = 0$ and $\beta_3 = 1$). The deviation of β_4 from zero (β_3 from one) implies the existence of a time-varying risk premium. The rational expectations hypothesis is tested by equation (5). If market participants are rational, one would expect $\alpha_5 = 0$ and $\beta_5 = 0$ cannot. In other words, the consensus forecast of market participants already includes the information available in the forward premium. Equation (2) can be derived by subtracting equation (5) from equation (4), thereby implying that the relative contributions of the time-varying risk premium and irrational expectations to the rejection of forward rate unbiasedness are measured by the estimates of β_4 and β_5 respectively.

Using the consensus forecasts to test for risk neutrality and rationality of expectations in equations (3) to (5) assumes the representative

[2] In the context of interest rates, the risk neutrality assumption is generally known as the pure expectations hypothesis of the term structure of interest rates (pure EHTS). The pure EHTS states that the forward interest rate equals the expected future spot interest rate. In other words, the pure EHTS requires a zero term premium.

agent model in which agents' expectations are homogeneous. However, an increasing number of recent studies have raised considerable doubt about the homogeneity of expectations on both theoretical and empirical grounds. Moreover, the aggregate measures of survey expectations may conceal heterogeneous expectations among individual agents. The homogeneity of expectations can be tested by the following regression (Chortareas, Jitmaneeroj, and Wood, 2012: 214-215; Elliott and Ito, 1999: 439-441; Ito, 1990: 441-442; MacDonald and Marsh, 1996: 674-679).

$$r^e_{i,t,k} - r^s_{t,k} = \alpha_{6i} + \beta_{6i}(f_{t,k} - r_t) + \varepsilon_{6i,t,k} \qquad (6)$$

where $r^e_{i,t,k}$ is forecaster i's prediction for the future spot rate made at time t for k-periods ahead, $(r^e_{i,t,k} - r^s_{t,k})$ is the deviation of the individual forecast from the consensus mean forecast, and $\varepsilon_{6i,t,k} = 0$ is the disturbance term. The null hypothesis of homogeneous expectations is that $\alpha_{6i} = 0$ and $\beta_{6i} = 0$. It is worth noting that the derivation of the homogeneity test in equation (6) is based on the consensus mean forecast, not the consensus median forecast. (see Ito, 1990; MacDonald and Marsh, 1996). To integrate the homogeneity test, as shown in equation (6), into the same testing framework of equations (1) to (5), in what follows the term "consensus forecast" means the consensus mean forecast only.

Due to the increasing concerns about the deviation from homogeneous expectations, the tests for the rational expectations and risk neutrality should be conducted by the individual forecasts rather than the consensus forecasts (Batchelor and Dua, 1991: 698-701; Ito, 1990: 435-438; MacDonald and MacMillan, 1994: 1077-1081; MacDonald and Marsh, 1996: 671-673). To our knowledge, none of the previous studies demonstrates the role of the homogeneity test as the connection between the consensus forecast and the individual forecast approaches. Adding equation (6) to equation (3), subtracting equation (6) from equation (4), subtracting equation (6) from equation (5) and rearranging equations, we obtain the following equations corresponding to equation (3), (4) and (5) respectively.[3]

$$r^e_{i,t,k} - r_t = \alpha_{7i} + \beta_{7i}(f_{t,k} - r_t) + \varepsilon_{7i,t,k} \qquad (7)$$

$$f_{t,k} - r^e_{i,t,k} = \alpha_{8i} + \beta_{8i}(f_{t,k} - r_t) + \varepsilon_{8i,t,k} \qquad (8)$$

$$r_{t+k} - r^e_{i,t,k} = \alpha_{9i} + \beta_{9i}(f_{t,k} - r_t) + \varepsilon_{9i,t+k} \qquad (9)$$

where $(r^e_{i,t,k} - r_t)$ denotes the individual expected spot rate change, $(f_{t,k} - r^e_{i,t,k})$ denotes the individual risk premium, $(r_{t+k} - r^e_{i,t,k})$ denotes the individual expectations error, and $\varepsilon_{7i,t,k}$, $\varepsilon_{8i,t,k}$ and $\varepsilon_{9i,t,k}$ denote the disturbance terms.

[3] The previous studies derive equations (7) to (9) by replacing the consensus forecast ($r^s_{t,k}$) in equations (3) to (5) with the individual forecast ($r^e_{i,t,k}$). However, doing so will not show the homogeneity test as the linkage between the consensus forecast and the individual forecast approaches.

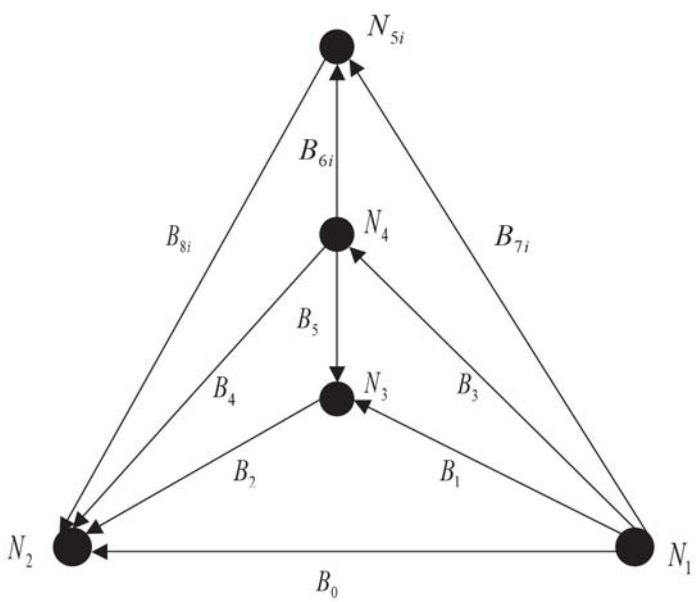
The interpretations of equations (7) to (9) are similar to those of equations (3) to (5). Equations (7) and (8) are complementary regressions where $\alpha_{7i} = \alpha_{8i}$, $\varepsilon_{7i,t,k} = -\varepsilon_{8i,t,k}$ and $\beta_{7i} = 1 - \beta_{8i}$. The null hypothesis of risk neutrality of individual forecaster i is that $\alpha_{8i} = 0$ and $\beta_{8i} = 0$ ($\alpha_{7i} = 0$ and $\beta_{7i} = 1$). According to equation (9), the null hypothesis of rationality of individual forecaster i is that $\alpha_{9i} = 0$ and $\beta_{9i} = 0$ if the forecast of individual forecaster i is rational. Based on the individual forecasts, the relative importance of the time-varying risk premium and irrational expectations to the rejection of the forward rate unbiasedness is measured by the estimates of β_{8i} and β_{9i} respectively.

Thus far, a set of regression equations for testing the forward market efficiency hypothesis as well as its associated hypotheses has been presented. Different from the earlier literature, this paper aims to demonstrate the relationships between these hypotheses through the estimates of betas from equations (1) to (9). By adapting the concept of electrical circuit analysis, we develop a loop diagram to demonstrate the linkages among these hypotheses. The loop diagram has various configurations depending on a given set of betas. Furthermore, the loop diagram aims to provide beginning and intermediate students with a powerful and convenient tool for formulating the regression equations and for visualising the interconnections between the aforementioned hypotheses in a less complicated manner.

The Concept of a Loop Diagram

This section defines a number of terms that will be used in a loop diagram. As will be the approach throughout this paper, examples will be given to illustrate the concept and define the key terms of a loop diagram. A loop diagram illustrated in Figure 1 will serve as a basis to describe the terms *node*, *branch*, *beta* and *loop*.

A *node* (N) is represented by the black dot which is exaggerated for clarity. The nodes simply mean the individual variables in equations (1) to (9). The loop diagram contains five nodes: N_1, N_2, N_3, N_4 and N_{5i} which represent r_t, $f_{t,k}$, r_{t+k}, $r^s_{t,k}$ and $r^e_{i,t,k}$ respectively. Note that the subscript i in the loop diagram indicates that it depends on the individual forecaster i in the survey panel.



Node	Node's description	Branch	Branch's description
$N_1 = r_t$	Current spot rate	$B_0 = f_{t,k} - r_t$	Forward premium
$N_2 = f_{t,k}$	Forward rate	$B_1 = r_{t+k} - r_t$	Realised spot rate change
$N_3 = r_{t+k}$	Future spot rate	$B_2 = f_{t,k} - r_{t+k}$	Forward rate bias
$N_4 = r^s_{t,k}$	Consensus forecast	$B_3 = r^s_{t,k} - r_t$	Consensus expected spot rate change
$N_{5i} = r^e_{i,t,k}$	Individual forecast	$B_4 = f_{t,k} - r^s_{t,k}$	Consensus risk premium
		$B_5 = r_{t+k} - r^s_{t,k}$	Consensus expectations error
		$B_{6i} = r^e_{i,t,k} - r^s_{t,k}$	Heterogeneous expectations error
		$B_{7i} = r^e_{i,t,k} - r_t$	Individual expected spot rate change
		$B_{8i} = f_{t,k} - r^e_{i,t,k}$	Individual risk premium
		$B_{9i} = r_{t+k} - r^e_{i,t,k}$	Individual expectations error

Figure 1 The Loop Diagram

Notes: Branch B_{9i} is not explicitly shown since it lies exactly on branches B_5 and B_{6i}. We can imagine that branch B_{9i} starts from node N_{5i} and points toward node N_3. We select this figure as a basis to explain the concepts of the loop diagram because this configuration of the loop diagram shows the maximum number of branches without any crossover between branches.

A *branch* (B) is defined as the directional difference between any two nodes. The loop diagram has a total of 10 branches, that is, 4 branches exit or enter each node. It can be clearly seen that branches are the regressors and regressands of equations (1) to (9). In accordance with the expressions of regressors and regressands, the branch is represented by an arrow with the arrow's head located at the minuend node and the arrow's tail located at the subtrahend node. As an example, branch is computed by subtracting node N_1 from node N_2, i.e., $B_0 = N_2 - N_1 = f_{t,k} - r_t$. Thus the direction of branch B_0 is pointing from node N_1 toward node N_2. We define branch B_0 as the reference branch since it is the common regressor to all regression equations.

A *beta* (β) is defined as a measure of association between any branch B_j and the reference branch B_0, that is, $\beta_j = \frac{Cov(B_j, B_0)}{Var(B_0)}$; where j stands for arbitrary branch index, $Cov\ (B_j, B_0)$ is a covariance between branches B_j and B_0, and $Var(B_0)$ is a variance of branch B_0. The loop diagram contains 10 betas corresponding to 10 branches. As $\beta_0 = \frac{Cov(B_0, B_0)}{Var(B_0)} = 1$, β_0 is defined as the reference beta. For the remaining betas, their values equal the OLS estimates of the slope coefficients in the corresponding regression equations.

A *loop*, also called a closed path, is a connection of branches which traverses each branch only once and which begins and ends at the same node. Figure 1 illustrates several loops. For example, a loop $B_0 - B_4 - B_5 - B_1$ begins at node N_1, moves to node N_2 and then node N_4, drops to node N_3 and returns to node N_1.

The Laws of a Loop Diagram and Their Application

Given the previous concept of a loop diagram, we are now in a position to introduce two laws of a loop diagram. These laws are quite simple but extremely important for examining the interdependence among betas estimated from equations (1) to (9).

The first law is the *loop diagram's branch law* which states that *"the algebraic sum of the branches around any loop is zero"*. The mathematical representation of the loop diagram's branch law is

$$\sum_{j=1}^{M} B_j = 0 \qquad (10)$$

where Σ represents summation, B_j represents the j^{th} branch in a loop, and M represents the number of branches in the loop. The term "algebraic" simply means paying attention to the directions of branches as branches are added or subtracted in the equation.

To demonstrate the application of the loop diagram's branch law, we firstly define a loop of investigation. For example, we consider the loop $B_0 - B_4 - B_5 - B_1$ in Figure 1. Then, we start at node N_1 and traverse the loop in a clockwise direction. If any branch in the loop has the same (opposite) direction in which the loop is traversed, the algebraic sign of such a branch is positive (negative). Applying the loop diagram's branch law yields

$$B_0 - B_4 - B_5 - B_1 = 0 \quad (11)$$

Note that if we had traversed the loop in a counter-clockwise direction, we would obtain

$$B_1 - B_5 - B_4 - B_0 = 0 \quad (12)$$

Multiplying equation (12) by -1 yields equation (11). This illustrates that the application of the loop diagram's branch law is independent of the direction in which the loop is traversed.

The second law is the *loop diagram's beta law* which postulates that *"the algebraic sum of the betas associated with any loop is zero"*. In the mathematical form, the loop diagram's beta law can be written as

$$\sum_{j=1}^{M} \beta_j = 0 \quad (13)$$

where β_j denotes the beta of the j^{th} branch in a loop containing M branches. This expression is analogous to the loop diagram's branch law. Thus it implies that the linear combination of branches in equation (10) can be directly transformed to the linear combination of corresponding betas in equation (13). To show that the loop diagram's beta law can be derived from the loop diagram's branch law, we impose the formula of beta on both sides of the equation (11).

$$\frac{Cov[(B_0 - B_4 + B_5 - B_1), B_0]}{Var[B_0]} = \frac{Cov[0, B_0]}{Var[B_0]}$$

$$\frac{Cov[B_0, B_0]}{Var[B_0]} - \frac{Cov[B_4, B_0]}{Var[B_0]} + \frac{Cov[B_5, B_0]}{Var[B_0]} - \frac{Cov[B_1, B_0]}{Var[B_0]} = 0$$

$$\beta_0 - \beta_4 + \beta_5 - \beta_1 = 0 \quad (14)$$

Alternatively equation (14) can be directly obtained by applying the loop diagram's beta law, that is, traversing the loop $B_0 - B_4 - B_5 - B_1$ in the clockwise direction. If any branch in the loop has the same (opposite) direction in which the loop is traversed, the algebraic sign of the corresponding beta is positive (negative). Like the loop diagram's branch law, the loop diagram's beta law is independent of the direction in which the loop is traversed. Therefore equation (14) can be also obtained by traversing the loop $B_0 - B_4 - B_5 - B_1$ in the counter-clockwise direction.

The most important benefit of the loop's diagram beta law is that it provides a shorthand method for examining relationships between betas estimated from regression equations (1) to (9). Although various relationships between betas will be apparent upon investigation of possible areas of application, the list below highlights some of the most important relationships.

First applying the loop diagram's beta law to the loop $B_0 - B_4 - B_5 - B_1$ and replacing the value of the reference beta, β_0 = 1, yield

$$\beta_1 = 1 - \beta_4 + \beta_5 \quad (15)$$

Alternatively, considering the loop $B_2 - B_4 - B_5$ and applying the loop diagram's beta law obtain

$$\beta_2 = \beta_4 + \beta_5 \quad (16)$$

Based on the consensus forecasts, the relationships between betas in equations (15) and (16) are widely used in the literature to investigate the relative contribution of β_4 and β_5 to the deviation of β_1 from one (or the deviation of β_2 from zero). In other words, the rejection of forward rate unbiasedness may be due to a time-varying risk premium (β_4), irrational expectations (β_5), or some combination of both.

Second, the individual forecasts can be used to shed more light on the relative importance of the time-varying risk premium (β_{8i}) and irrational expectations (β_{9i}) for individual agents. Considering the loop $B_0 - B_{8i} - B_{9i} - B_1$, applying the loop diagram's beta law and replacing β_0 = 1 obtain

$$\beta_1 = 1 - \beta_{8i} + \beta_{9i} \quad (17)$$

Alternatively, applying the loop diagram's beta law to the loop $B_2 - B_{8i} - B_{9i}$ yields

$$\beta_2 = \beta_{8i} + \beta_{9i} \quad (18)$$

Finally, we will demonstrate the impact of heterogeneous expectations on interpretations about the time-varying risk premium and irrational expectations. Applying the loop diagram's beta law to the loop $B_5 - B_{6i} - B_{9i}$ yields

$$\beta_2 = \beta_{8i} + \beta_{9i} \quad (19)$$

Equation (19) shows that the interpretation in regard to irrational expectations from the consensus forecast (β_5) may be misleading about irrational expectations of the individual forecasters (β_{9i}) due to the presence of heterogeneous expectations (β_{6i}). For instance, if β_{6i} and β_{9i} of forecasters have comparable magnitude but opposite signs, putting an interpretation on the irrational expectations from the consensus forecast conceals the irrational behavior of individual forecasters since the effects from β_{6i} and β_{9i} are totally offsetting. In a similar manner, considering the loop $B_0 - B_{8i} - B_{9i}$ and applying the loop diagram's beta law yield

$$\beta_4 = \beta_{6i} + \beta_{8i} \quad (20)$$

Similar to equation (19), equation (20) demonstrates that heterogeneous expectations (β_{6i}) may mislead inferences about the individual time-varying risk premium (β_{8i}) from the consensus time-varying risk premium (β_4). In summary, equations (19) and (20) suggest that if β_{6i} has the opposite sign to (the same sign as) β_{8i} and β_{9i}, heterogeneous expectations will offset (reinforce) the time-varying risk premium and irrational expectations of individual forecasters respectively.

The Construction of a Loop Diagram

This section explains the construction of loop diagram for a given set of betas. The deviation of β_1 from one (β_2 from zero) represents the violation of the forward rate unbiasedness hypothesis. For the consensus forecast, the deviation of β_3 from one (β_4 from zero) implies the failure of a risk neutrality hypothesis and the deviation of β_5 from zero suggests the rejection of the rational expectations hypothesis. The hypothesis of homogeneous expectations holds true if β_{6i} does not significantly deviate from zero. For the individual forecast, the deviation of β_{7i} from one (β_{8i} from zero) implies the rejection of the risk neutrality hypothesis and the deviation of β_{9i} from zero suggests the violation of the rational expectations hypothesis. Before looking at the procedures to draw the loop diagram, we introduce a few general characteristics of the configuration of the loop diagram as depicted in Figure 2.

First, all forecasters in the survey panel share the common nodes N_1, N_2, N_3 and N_4 but node N_{5i} varies from individual to individual. Second, the loop diagram has a hierarchical structure composed of 4 levels: level 0 (the reference level) for nodes N_1 and N_2, level 1 (the non-forecast level) for node N_3, level 2 (the consensus forecast level) for node N_4 and level 3 (the individual forecast level) for node N_{5i}. Third, the loop diagram has a dynamic structure in which nodes are allowed to move horizontally on their situated levels but their exact positions depend on the estimates of the relevant betas. Finally, since betas are the measures of association between their corresponding branches and the reference branch, betas can be presented as the horizontal projections of their corresponding branches. Like branches, betas have both magnitude and direction components. It is important to note that the direction of each beta is consistent with the direction of its corresponding branch and that if the beta is positive (negative), its direction will be in the same (opposite) direction of the reference beta β_0.

Assuming the estimates of betas as shown in Figure 2, the step-by-step procedures to construct the loop diagram are described as follows: First nodes N_1 and N_2 will be drawn on the same horizon labeled as level 0 and the distance between them is defined as 1 unit length. The reference branch B_0 is depicted as an arrow pointing from node N_1 toward node N_2. Since the reference branch lies on the horizon, its horizontal projection equals itself, that is, $\beta_0 = B_0 = 1$ unit. The magnitudes of the remaining betas are measured in proportion to the magnitude of the reference beta β_0.

Next the remaining nodes N_3, N_4 and N_{5i} will be situated on level 1, level 2 and level 3 respectively. The gaps between these levels do not matter for investigating the relationships among betas because betas are represented by the horizontal projections of their corresponding branches. For simplicity, the gap between two adjacent levels is specified to be $\frac{1}{3}$ unit so that the gap between level 0 and level 3 equals 1 unit. The positions of nodes N_3, N_4 and N_{5i} are located by the estimates of the relevant betas. For example, the position of node N_3 can be located by the estimate of β_1 or β_2, the position of node N_4 can be located by the estimate of β_3 or β_4, and the position of node N_{5i} can be located by the estimate of β_{7i} or β_{8i} . Branches can be easily drawn between nodes with the directions of branches defined in accordance with the directions of the relevant betas.

Concluding Remarks

In an introductory or intermediate finance course, students deal with several variables and regression equations in testing the forward market efficiency hypothesis and its associated hypotheses: the forward rate unbiasedness, the rational expectations, the risk neutrality and the homogeneous expectations. With that in mind, we have invented the loop diagram which systematically represents all of these hypotheses within a single diagram. The loop diagram can be applied to interest rates and foreign exchange rates as well as other asset classes such as equity and commodity. Due to its hierarchical and dynamic structure, the loop diagram allows students to visualise the linkages among these hypotheses in such a way that cannot easily be recognised from a set of regression equations. We also establish two laws of a loop diagram which are condensed methods used to examine the relationships between betas across regression equations. Furthermore, visualising the loop diagram provides students with a powerful and convenient tool for formulating the regression equations. The loop diagram has various configurations depending on the estimates of betas. Visualising the configurations of a loop diagram enables students to compare the deviation of individual forecasters from the rationality of expectations, the homogeneity of expectations and the risk neutrality.

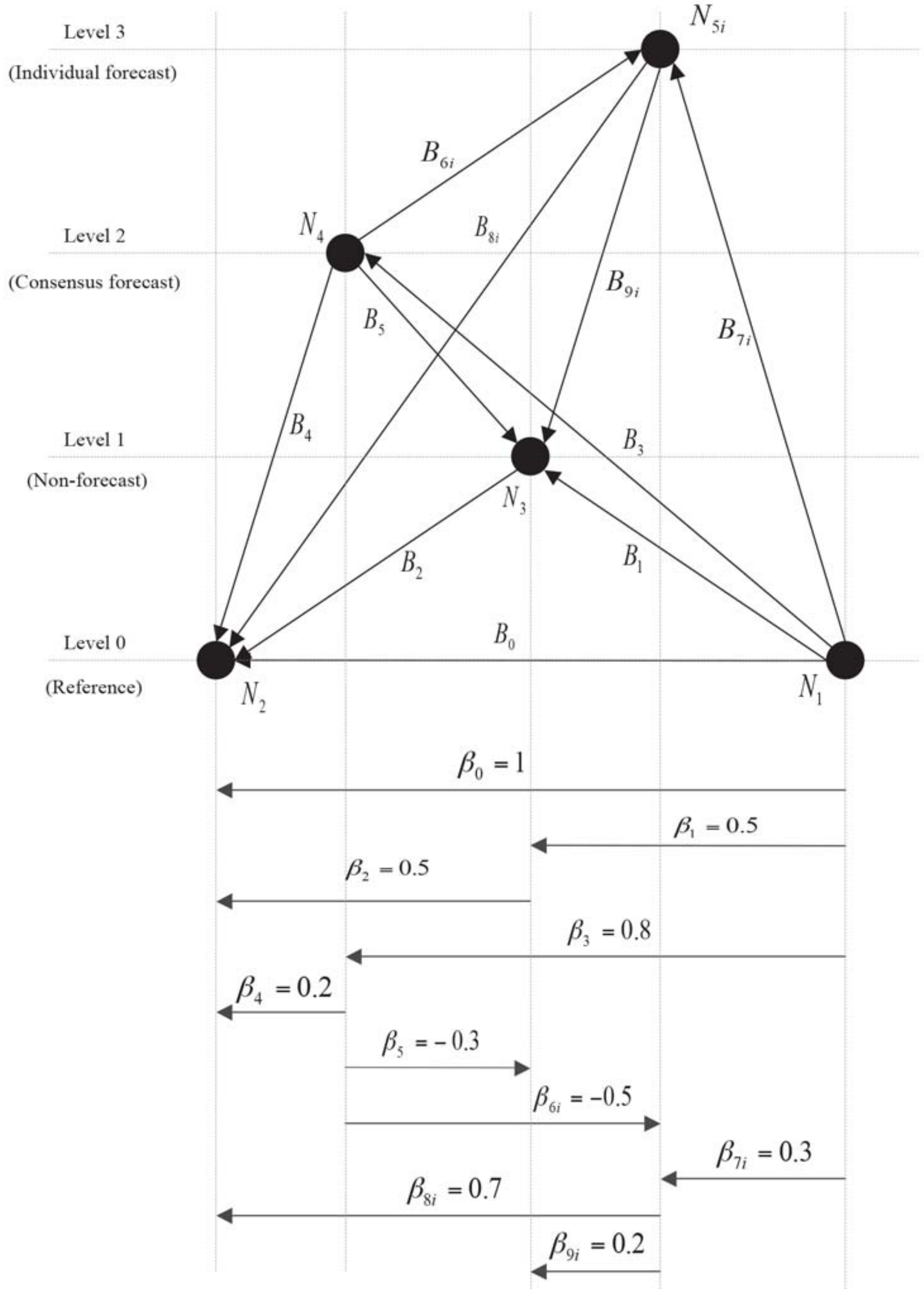


Figure 2 The Construction of the Loop Diagram

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