



## Polynomial regressions with three dimensions and application of the response surface analysis (RSA)

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This technique as polynomial regression with three dimensions and response surface analysis (RSA) has been applied in two of my recent, not yet published studies. One paper was with Kashif Ahmed titled as: “Forerunners, Laggards, Walkers, and Talkers: Impact of (In)congruent Internal–External CSR Strategies on Market Performance”. The other paper where this technique has been written with Robert Goehlich and is titled as: “Pilots’ Desire to be Future Space Tourism Pilots: Polynomial Regression Using Response Surface Analysis”.

### Methodology of the polynomial regression with three dimensions and RSA-analysis

It is worth noting that almost all empirical studies applying regressions investigate associations between independent and dependent variables in only in two dimensions. However, a lot of information is lost by this procedure. Furthermore, conclusions based on two dimensional models can be misleading when raw variables are transformed into the sum or the gap (Edwards, 2002). That is to say, the internal–external CSR gap and market performance has not been employed for response surface analysis using polynomial regression (Al-Shammari et al., 2022; Hawn & Ioannou, 2016). Polynomial regression with response surface analysis enables the examination of a curvilinear relationship among three variables in a three-dimensional space (Schönbrodt et al., 2018). Consequently, response surface graphic derived from polynomial regression provide more accurate and detailed information compared to linear models (Humberg et al., 2019). For example, consider the study with Robert Goehlich: extrinsic and intrinsic motivation and desire to become a space pilot:

$$Desire = b0D + b1DXIM + b2DYEM + b3DXIM2 + b4DXIMYEM + b5DYEM2 + eD \quad (1)$$

The equations include linear, quadratic, and interaction terms, besides the error terms  $eD$ . The polynomial regression parameters  $b0$ – $b5$  that define the characteristic of the surface were used to determine the response surface parameters  $a1$ – $a4$  in Equation 2 to 5 (Shanock et al., 2010):

- $a1 = b1 + b2$  (2)
- $a2 = b3 + b4 + b5$  (3)
- $a3 = b1 - b2$  (4)
- $a4 = b3 - b4 + b5$  (5)

Two different lines exist. The line of congruence (LOC) goes from low extrinsic and low intrinsic to high extrinsic and high intrinsic. In contrast, the line of incongruence (LOIC) goes from high extrinsic and low intrinsic to how extrinsic and high intrinsic (See Table 1). In the following, we adjusted the questions a1–a4 to motivation:

- *a1: Slope of LOC. Does the match of motivation on higher levels have a different outcome on desire than on lower levels?*
- *a2: Curvature of LOC. Does the match of motivation on extreme levels have a different outcome than a match on midrange levels?*
- *a3: Slope of LOIC. Does a mismatch of intrinsic versus extrinsic motivation in one direction ( $X > Y$ ) lead to a higher outcome than the other way around ( $X < Y$ )?*
- *a4: Curvature of LOIC. Does a match of intrinsic and extrinsic motivations lead to a different outcome from a mismatch?*

### **Application at both studies**

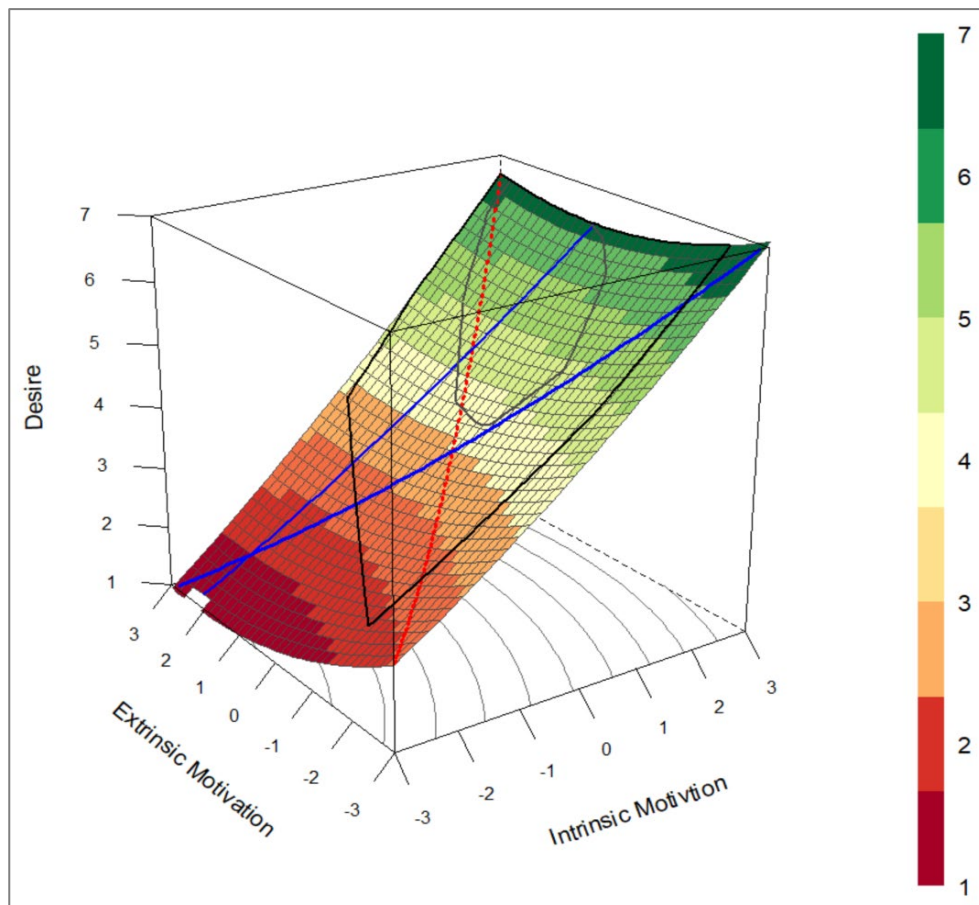
The first study with Kashif Ahmed draws on the resource-based view theory and the new stakeholder theory. This study investigates the effect of (in)congruent internal–external CSR strategies on market performance. We classify a sample of almost 40,000 firm-year observations covering the period 2010 to 2019 and place firms into four quadrants based on the level of internal and external CSR activities: forerunners (both high), laggards (both low), walkers (high internal, low external), and talkers (high external, low internal). Through polynomial regression and three-dimensional response surface, our findings reveal that the positive effect of congruent internal–external CSR activities on market performance is stronger for forerunners compared to laggards. That is, investors reward the CSR actions of forerunners to a greater extent compared to laggards. Additionally, for firms with aggregated internal and external CSR activities in the mediocre range, the market value is higher for walkers compared to talkers. Contrary to the traditional perspective that emphasizes the significance of external stakeholder satisfaction for firms, our study demonstrates that investors prefer firms that prioritize workforce well-being.

Also at the study with Robert Goehlich, we applied polynomial regression analysis with RSA that allows us to enhance the correlations into a three-dimensional space. In corroborating previous literature, we found that highly motivated people (as a higher match of intrinsic and

extrinsic motivation) correlated positively with performance. Our findings provided support for our introduced hypothesis that desire was explained by intrinsic motivation. It shows that pilots who are high on intrinsic motivation have a higher desire to become space pilot; extrinsic motivation does not play an important role for desire to become a space pilot.

#### Example figure of the Goehlich-Bebenroth paper

Response surface plot of participants' congruent and incongruent lines of intrinsic and extrinsic motivations correlating with desire to become space pilot



Note. Line of congruence (LOC) = red dotted

Line of incongruence (LOIC) = blue thick

Ridge line = blue thin

Bag plot = black lines