**MASCEM: A Multiagent System that Simulates Complex Energy Markets**

**GECAD: Knowledge Engineering and Decision Support Group**

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**CASE STUDY:** MASCEM-2010-09

**GOAL**: The main goal is to compare the performance of Seller 2 in the day-ahead spot market, using three distinct strategies: A Neural Network; a statistical approach - regression on the data of the last 5 business days; and the proposed strategy for bid definition, based on reinforcement learning for choosing the method to apply in each situation. The comparison will be evaluated based on the profits obtained by Seller 2 using each of the strategies.

**GENERAL DESCRIPTION:** In order to compare the performance of the three strategies, we present three simulations, referring to the same 14 consecutive days, starting from Wednesday, 29th October, 2009. The data used in this case study has been based on real data from the Iberian market, extracted from OMEL – Iberian electricity market.

The group of agents that take part in the simulations were assigned different criterions for defining their bids, which will remain constant for the three simulations. Seller 2, on the other hand, will use a different strategy, each of the three referred ones, in each simulation.

**Simulations Definition**

The simulations involve 7 buyers and 5 sellers (3 regular sellers and 2 VPPs). This group of agents was created with the intention of representing the Spanish reality, reduced to a smaller summarized group, containing the essential aspects of different parts of the market, in order to allow a better individual analysis and study of the interactions and potentiality of each of those actors.

In the first simulation Seller 2 will use the Neural Network as strategy for the bid definition. In the second it will use a statistical approach, a regression on the data of the last 5 business days. Finally, in the third simulation, it will use the proposed strategy for bid definition. The selected reinforcement learning algorithm for this simulation has been the revised Roth-Erev, with equal value of the algorithms weight, and a past experience weight W value of 0.4, a small value to grant higher influence to the most recent results, so that it can quickly learn and catch new tendencies, since the market is always changing fast. This agent's power supply will remain constant at 550MW for each period throughout the simulations.

The other players' bids are defined as follows:

Buyer 1 – This buyer buys power independently of the market price. The offer price is 18.30 c€/kWh (this value is much higher than average market price)
Buyer 2 – This buyer bid price varies between two fixed prices, depending on the periods when it really needs to buy, and the ones in which the need is lower. The two variations are 10.00 and 8.00 c€/kWh
Buyer 3 – This buyer bid price is fixed at 4.90 c€/kWh
Buyer 4 – This buyer bid considers the average prices of the last 4 Wednesdays
Buyer 5 – This buyer bid considers the average prices of the last 4 months
Buyer 6 – This buyer bid considers the average prices of the last week (considering only business days)
Buyer 7 – This buyer only buys power if market prices are lower than average market price
Seller 1 – This seller needs to sell all the power that he produces. The offer price is 0.00 c€/kWh
Seller 3 – This seller bid considers the average prices of the last 4 months with an increment of 0.5 c€/kWh
VPP 1 – Includes 4 wind farms and offers a fixed value along the day. The offer price is 3.50 c€/kWh
VPP 2 – Includes 1 photovoltaic, 1 co-generation and 1 mini-hydro plants; the offer price is based on generation costs of co-generation and on the total forecasted production.

**Simulations Results**

Since the reinforcement learning algorithm treats each period of the day as a distinct case, we have to analyse the development of the performance in each period individually. Next we present the comparison of the results obtained by using each of the three strategies along the 14 considered days, in each of the 24 periods of the day.

*Period 1*

**Figure 1** – Profits obtained by Seller 2 in the first period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
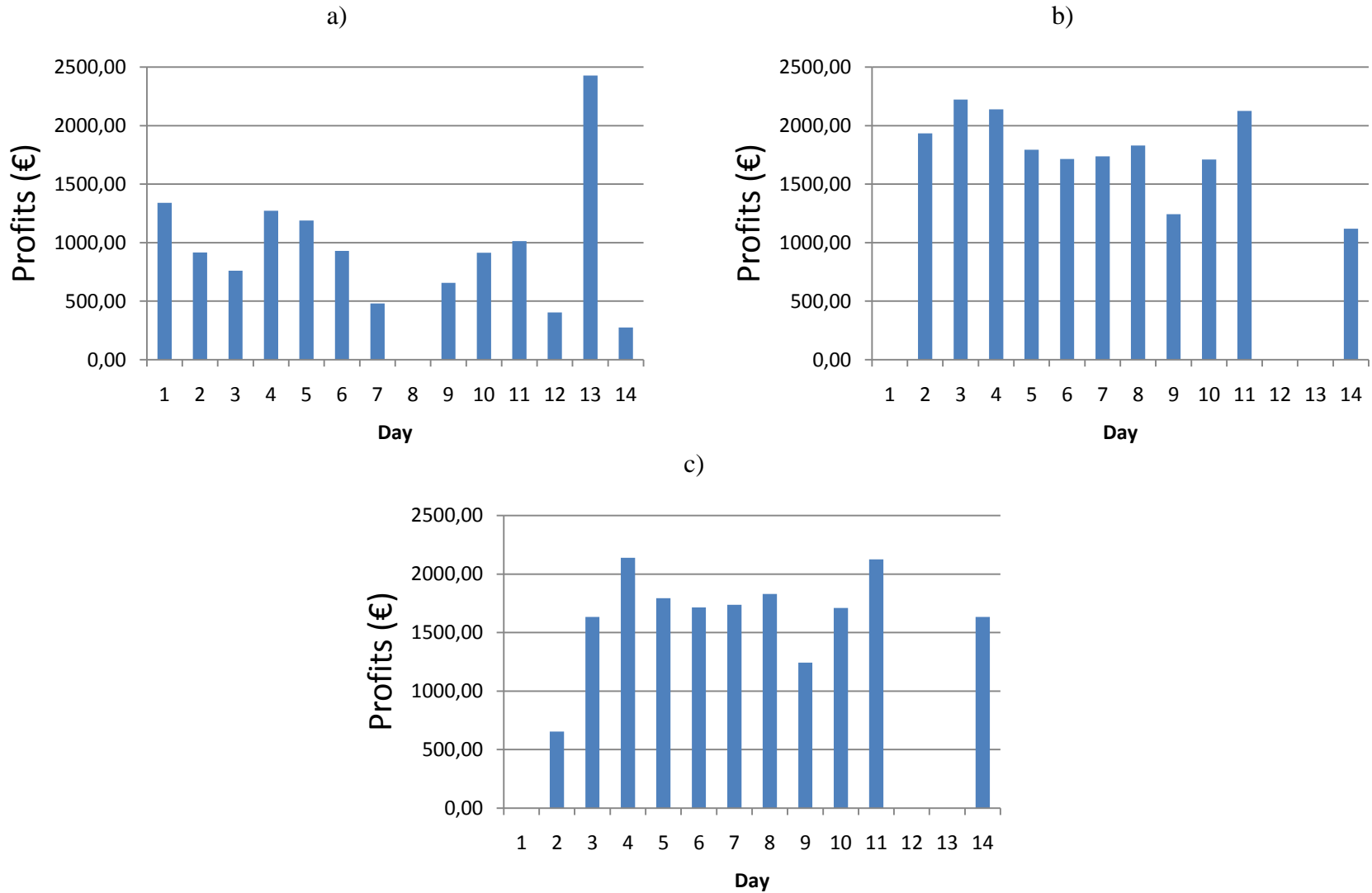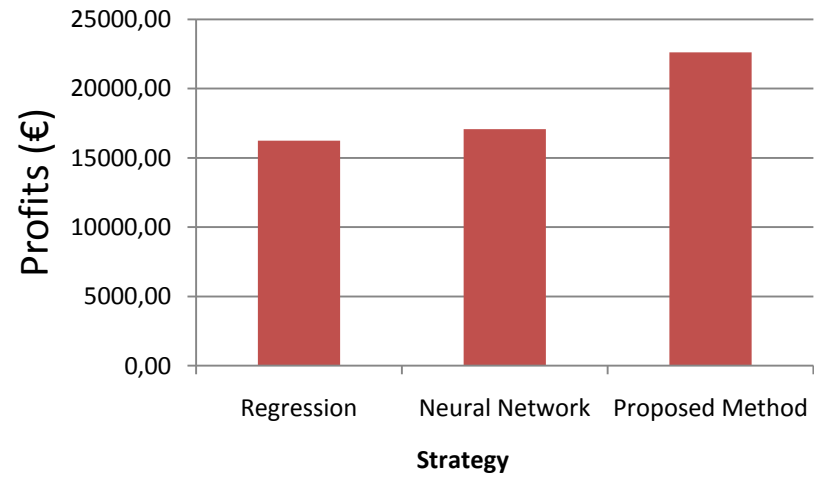
c)
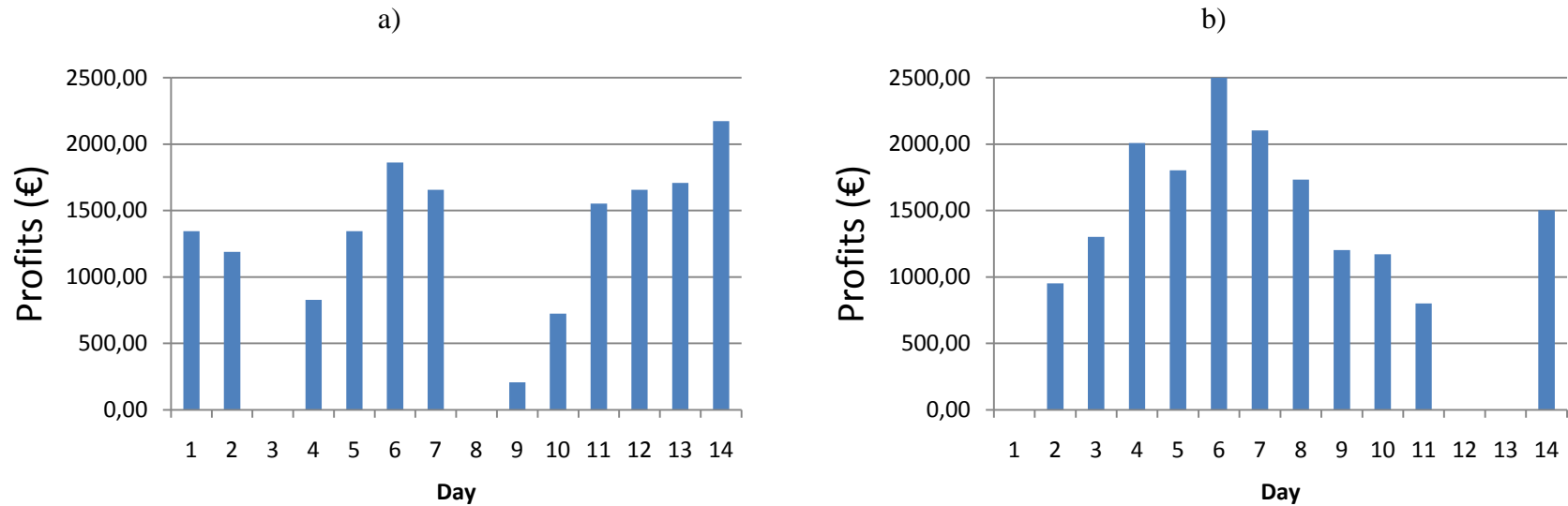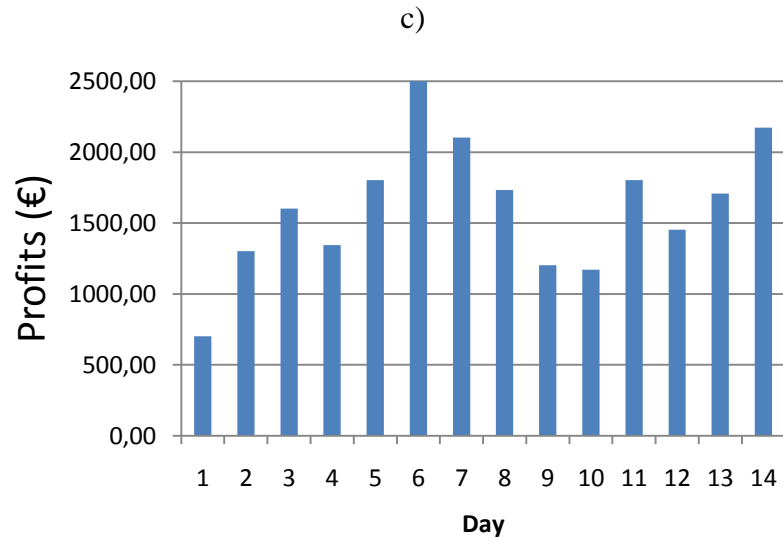


**Figure 2** – Comparison of the total profits obtained by Seller 2 in the first period of the considered 14 days
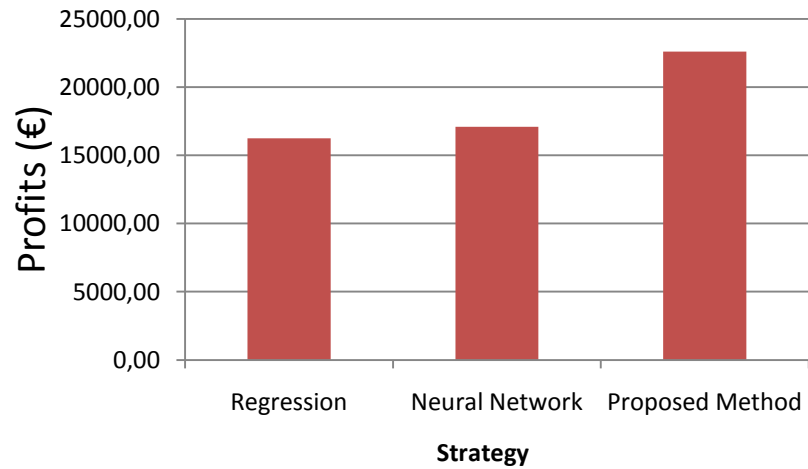
*Period 2*

**Figure 3** – Profits obtained by Seller 2 in the second period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
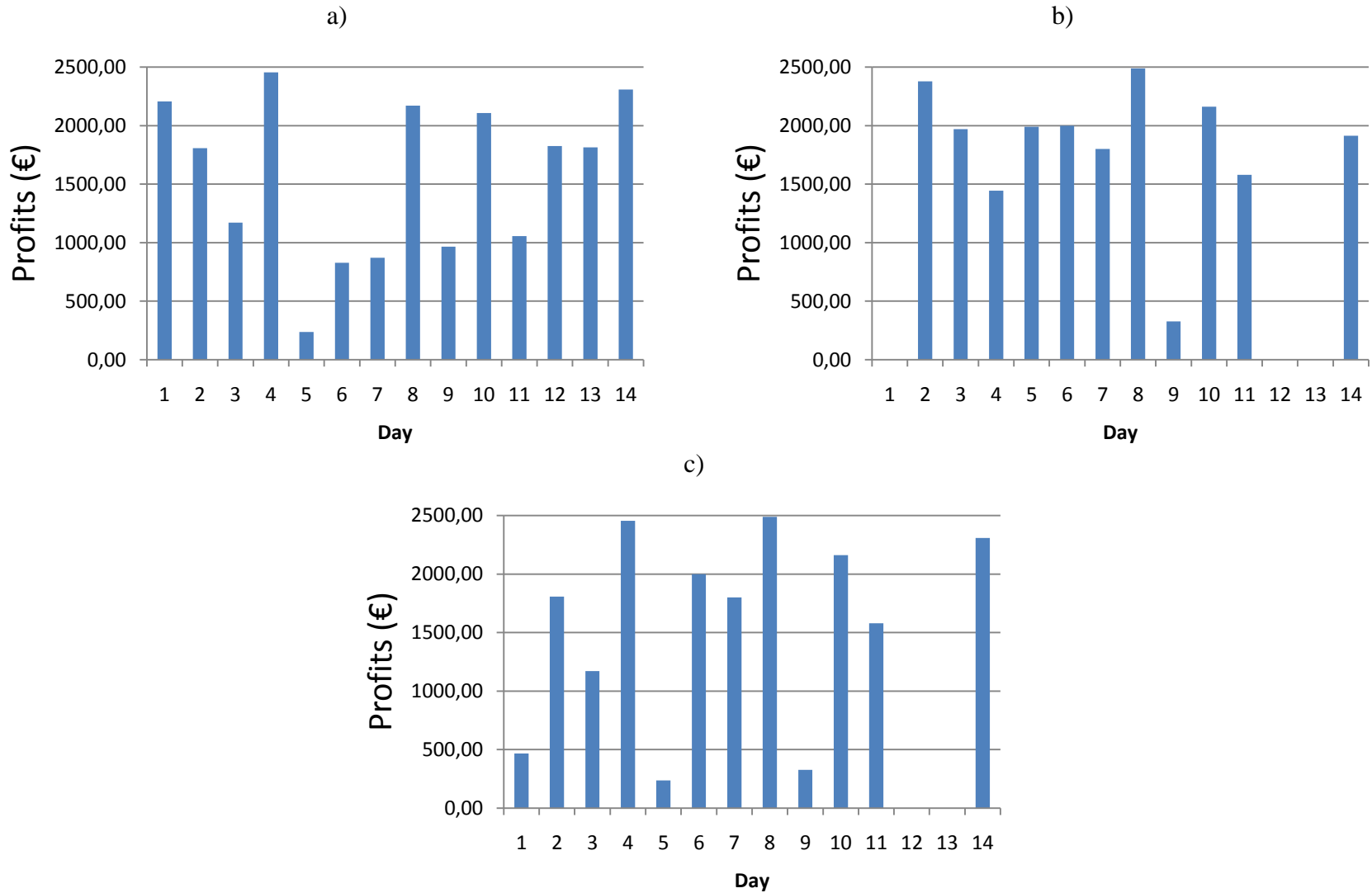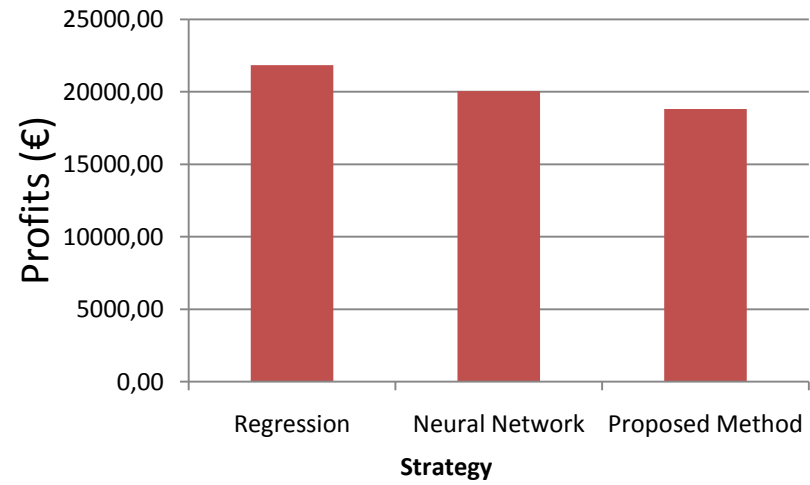
a)

b)



c)
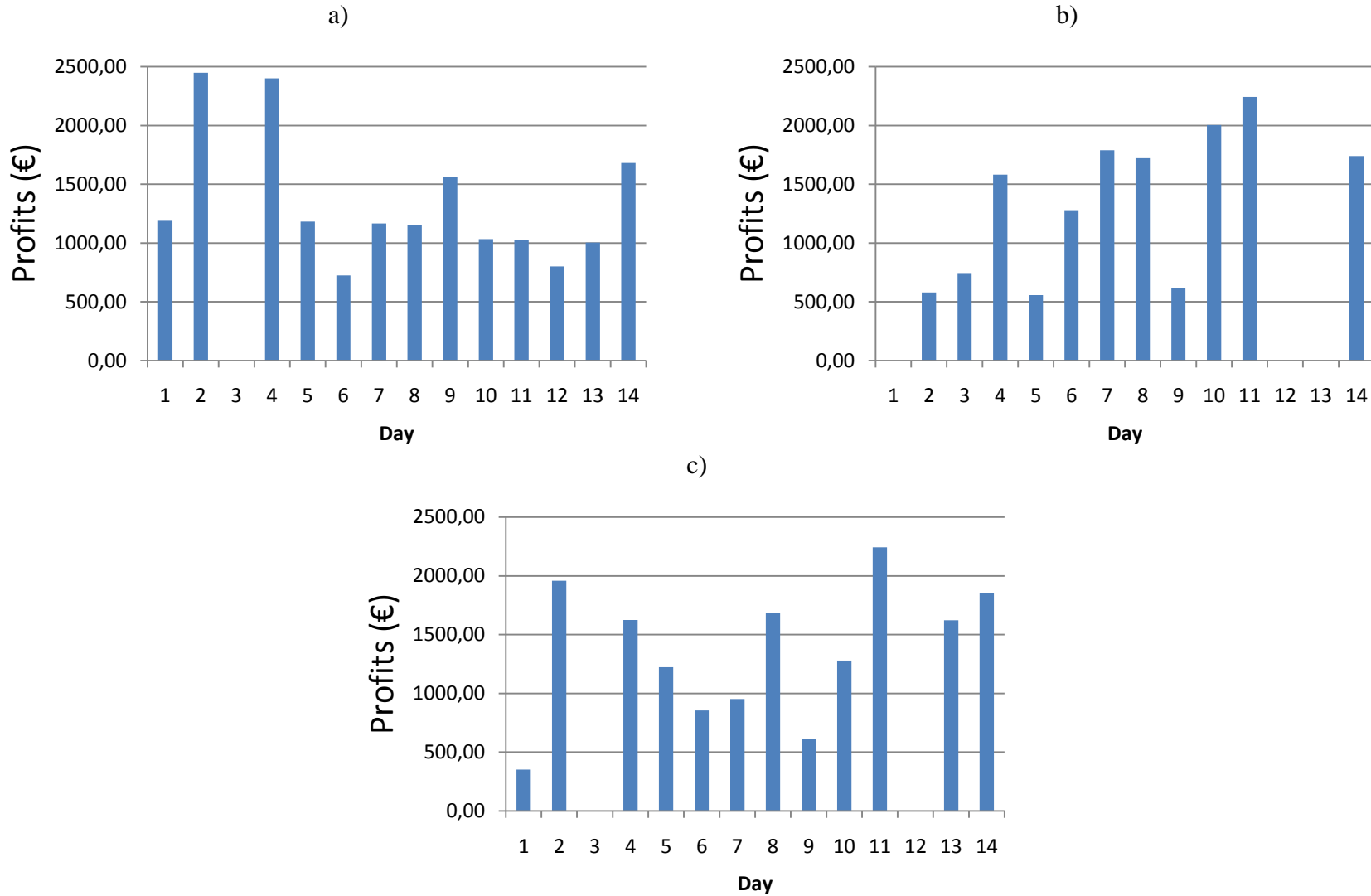
**Figure 4** – Comparison of the total profits obtained by Seller 2 in the second period of the considered 14 days
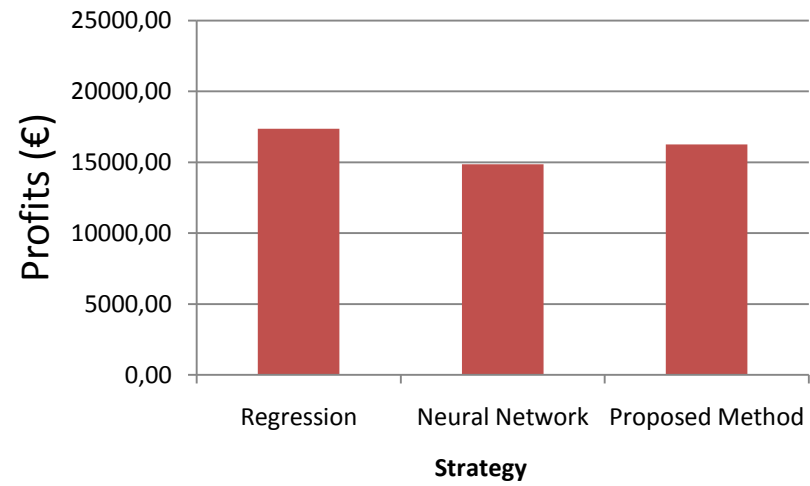
*Period 3*

**Figure 5** – Profits obtained by Seller 2 in the third period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
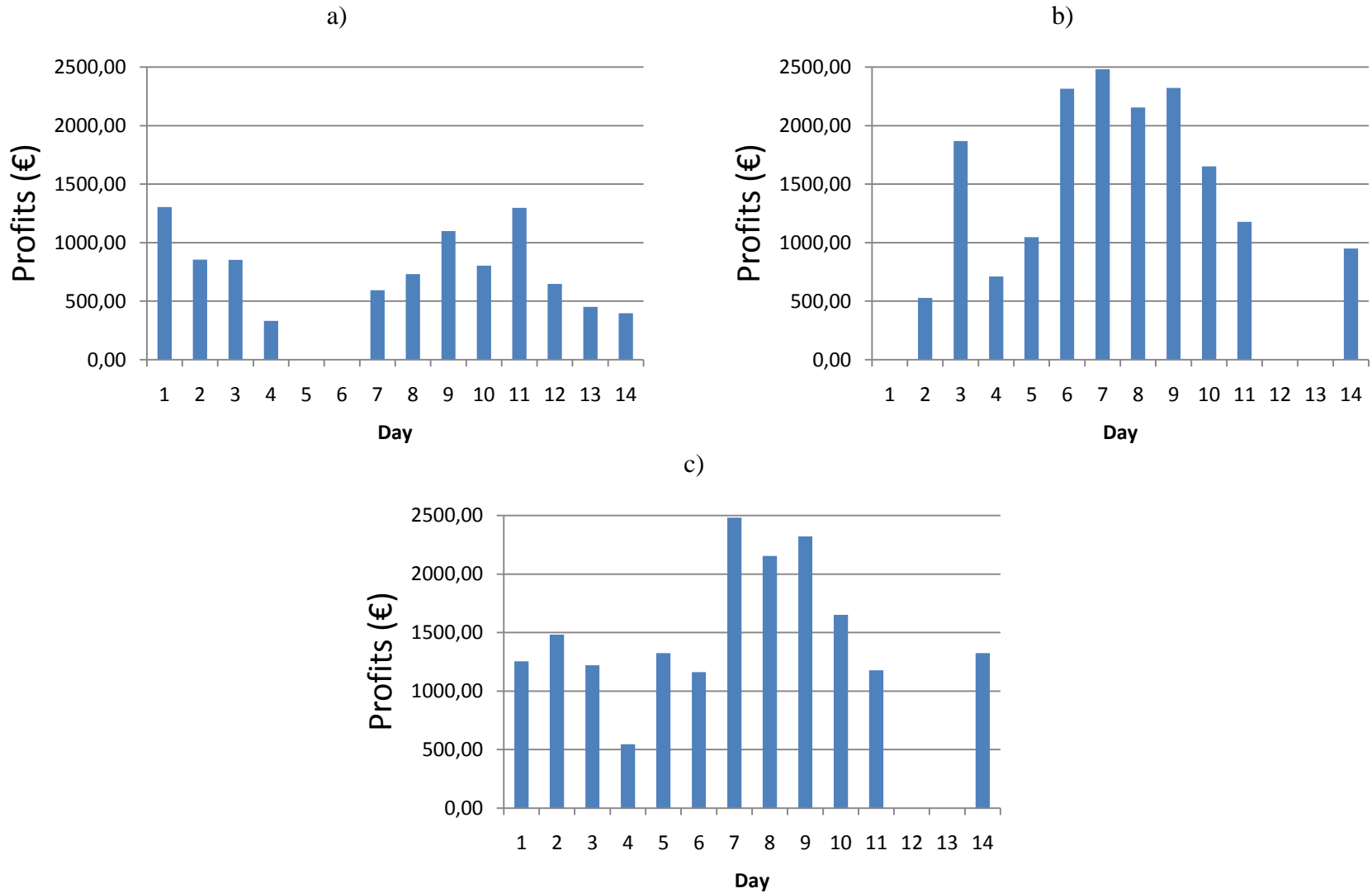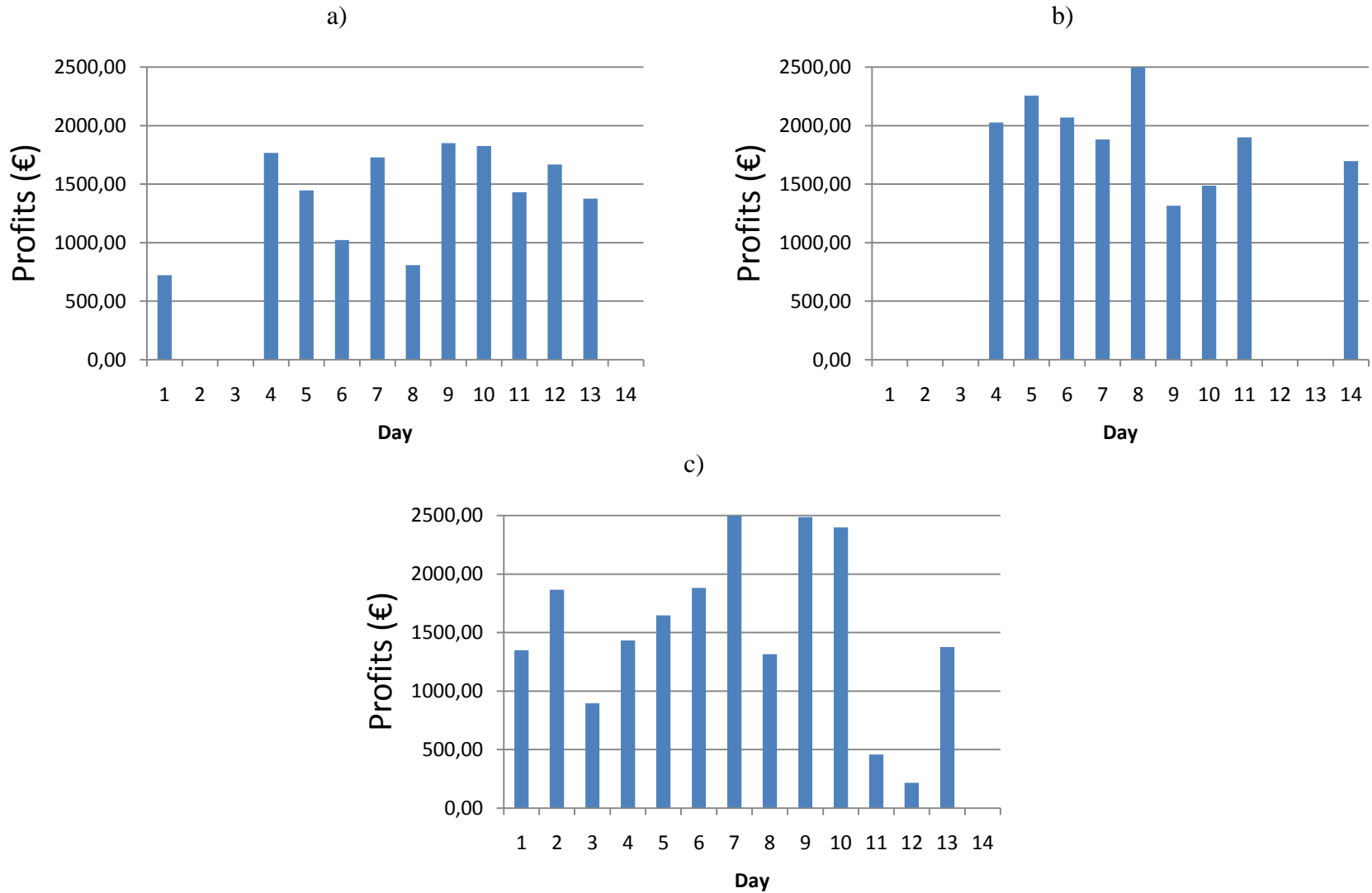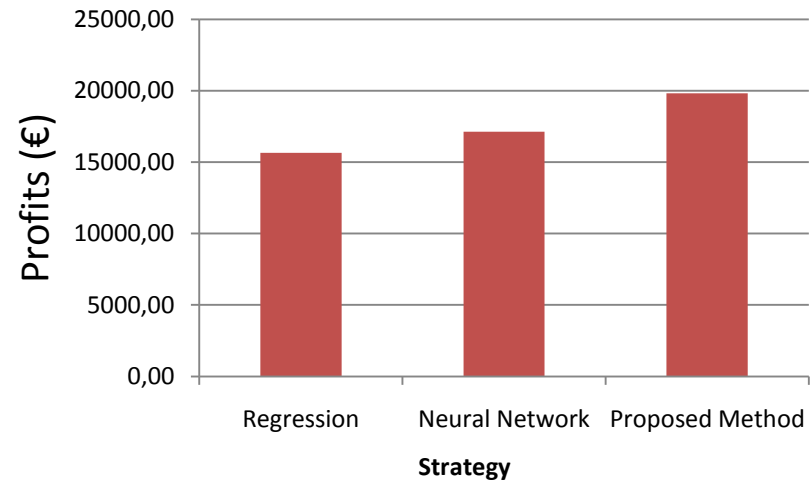
**Figure 6** – Comparison of the total profits obtained by Seller 2 in the third period of the considered 14 days
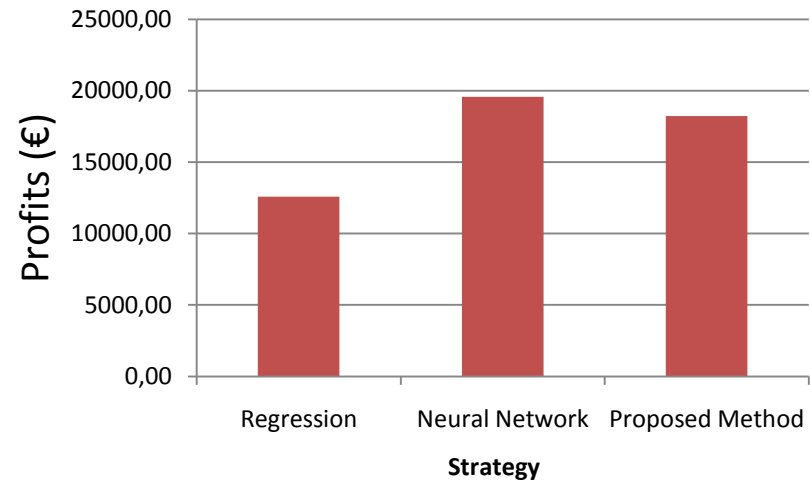
*Period 4*

**Figure 7** – Profits obtained by Seller 2 in the fourth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
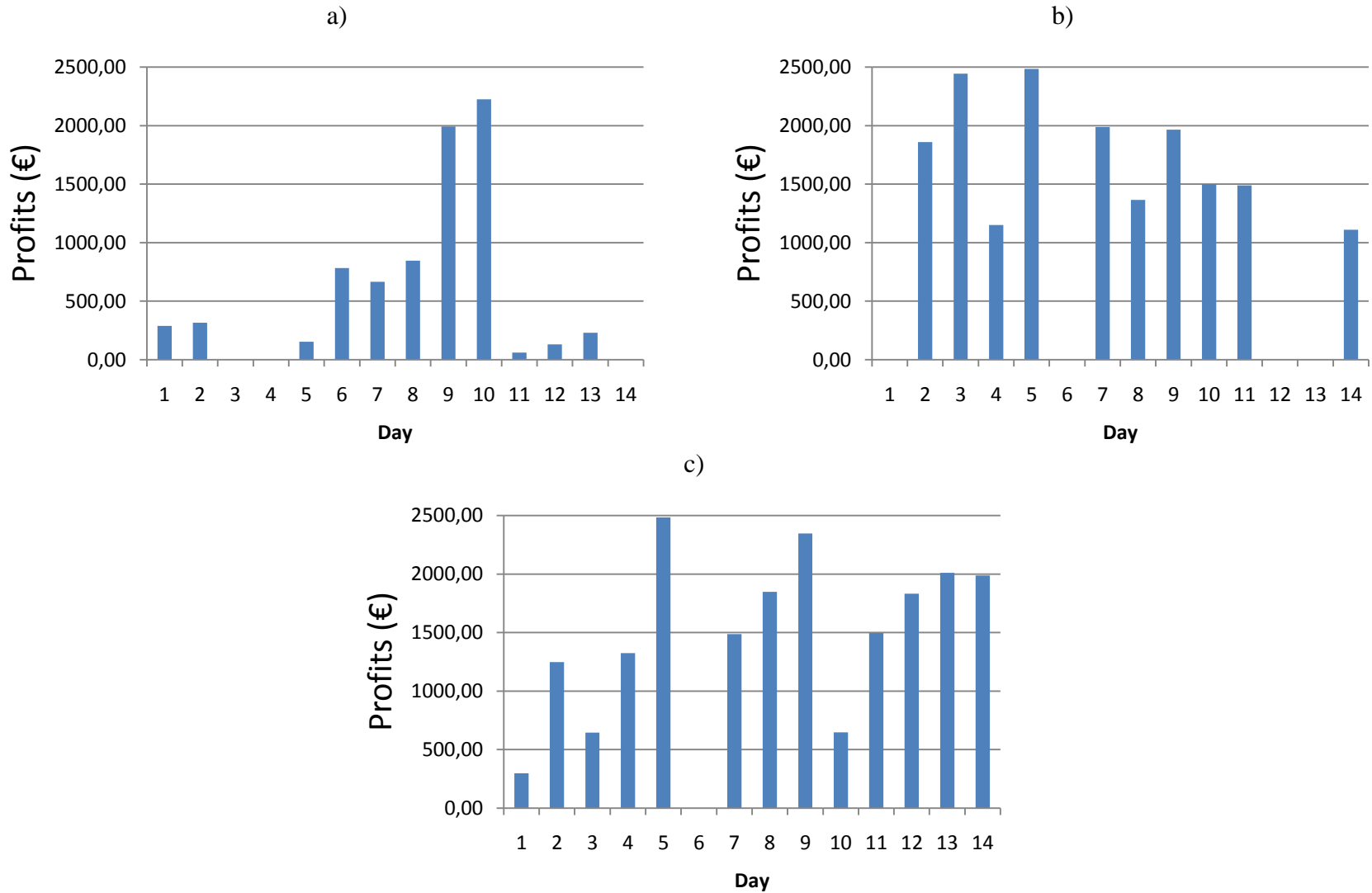
a)

b)



c)

**Figure 8** – Comparison of the total profits obtained by Seller 2 in the fourth period of the considered 14 days

*Period 5*

**Figure 9** – Profits obtained by Seller 2 in the fifth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
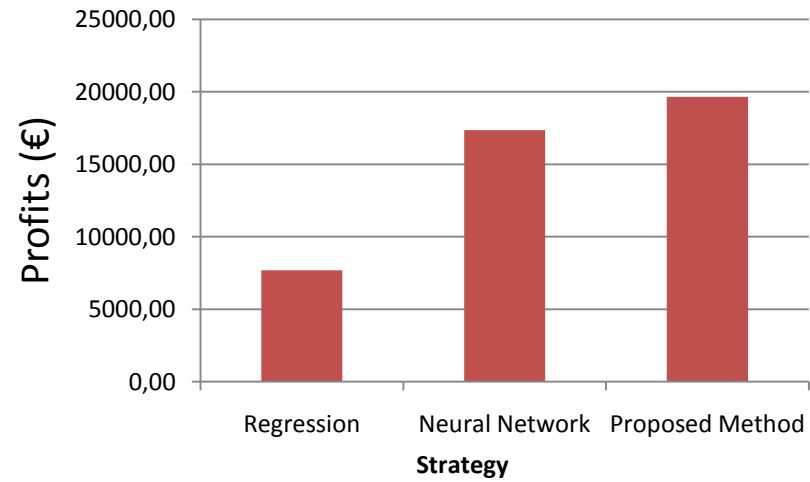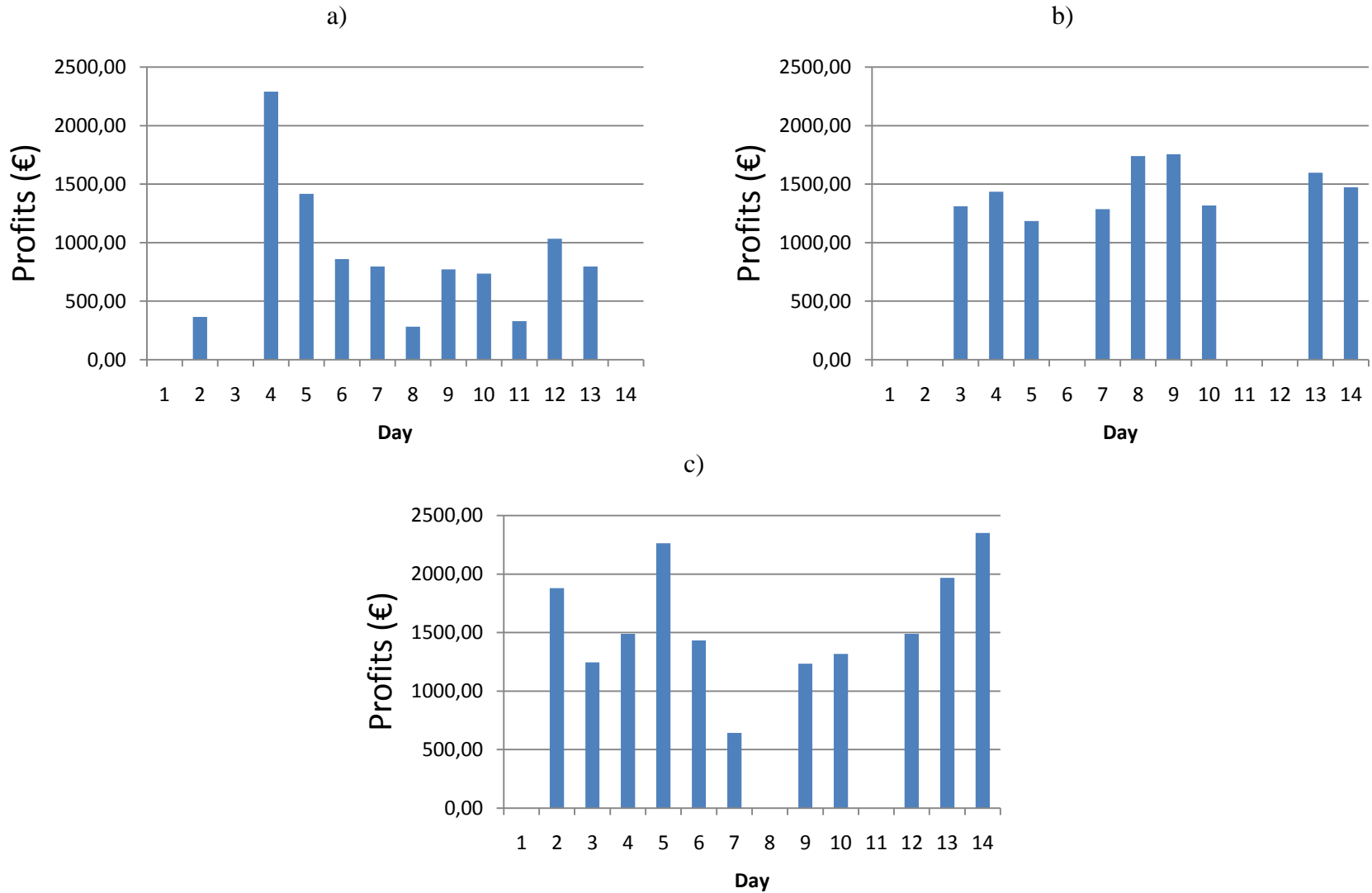
**Figure 10** – Comparison of the total profits obtained by Seller 2 in the fifth period of the considered 14 days

*Period 6*

**Figure 11** – Profits obtained by Seller 2 in the sixth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
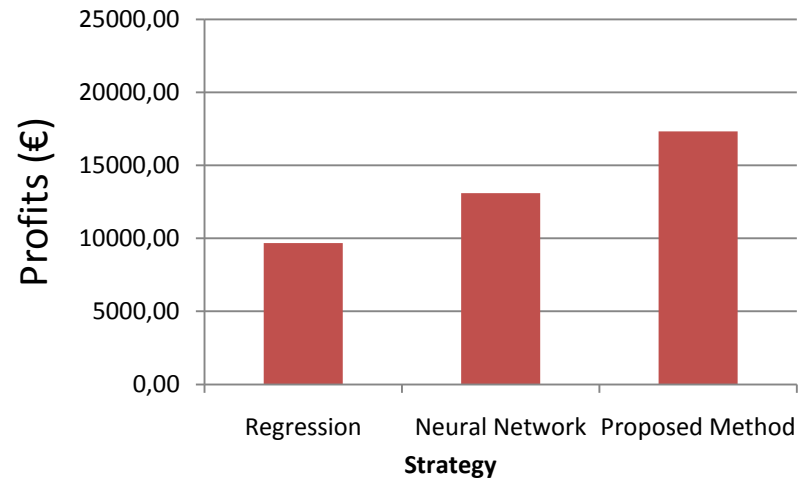
**Figure 12** – Comparison of the total profits obtained by Seller 2 in the sixth period of the considered 14 days

*Period 7*

**Figure 13** – Profits obtained by Seller 2 in the seventh period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
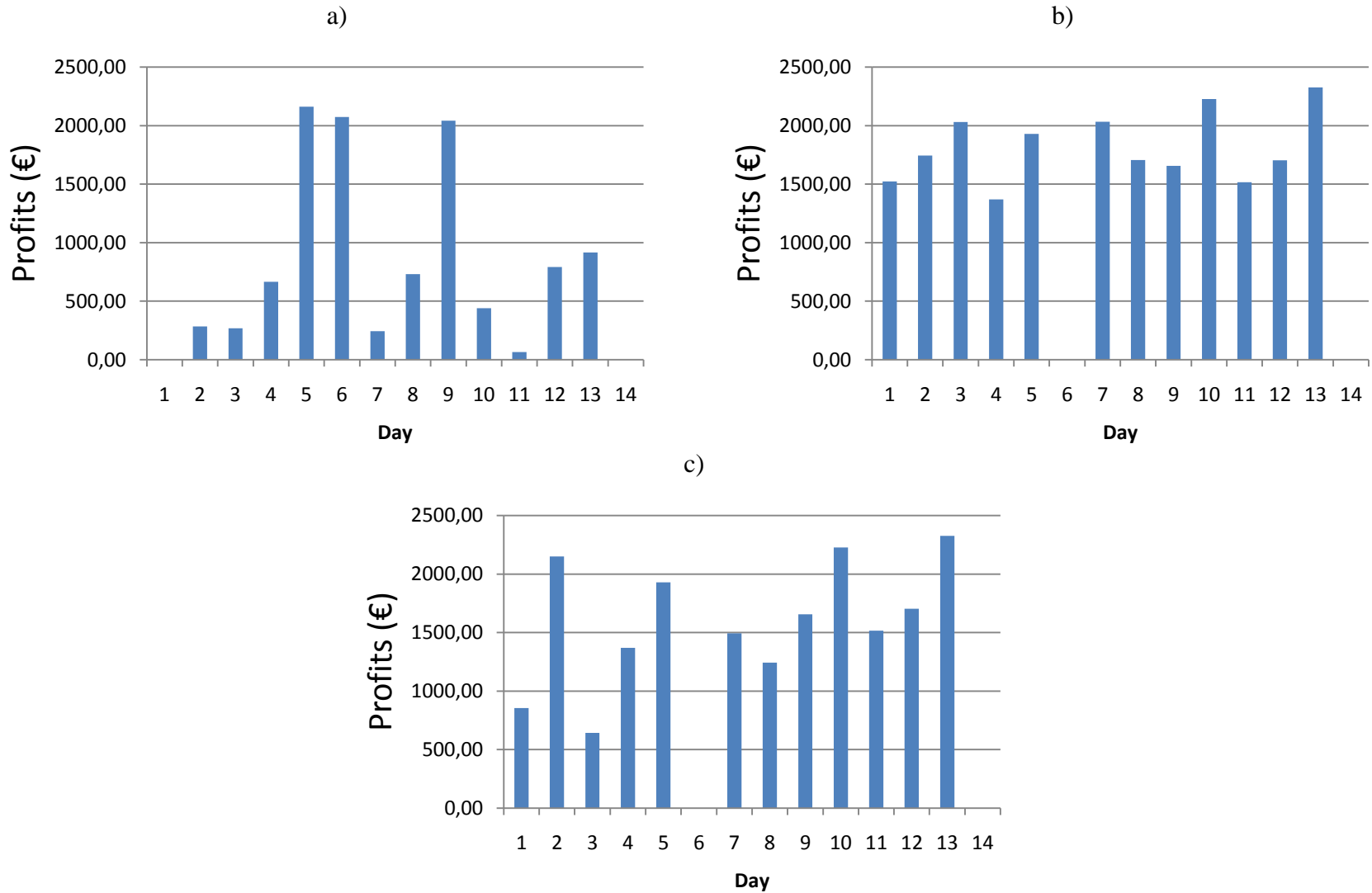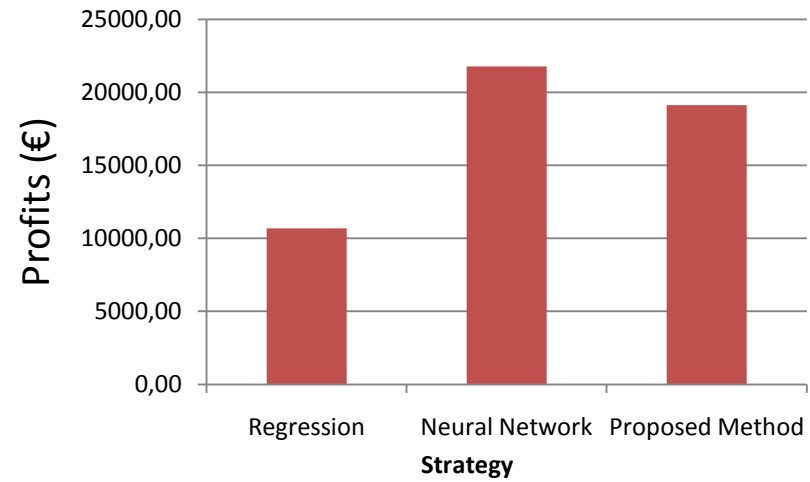
**Figure 14** – Comparison of the total profits obtained by Seller 2 in the seventh period of the considered 14 days

*Period 8*

**Figure 15** – Profits obtained by Seller 2 in the eighth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
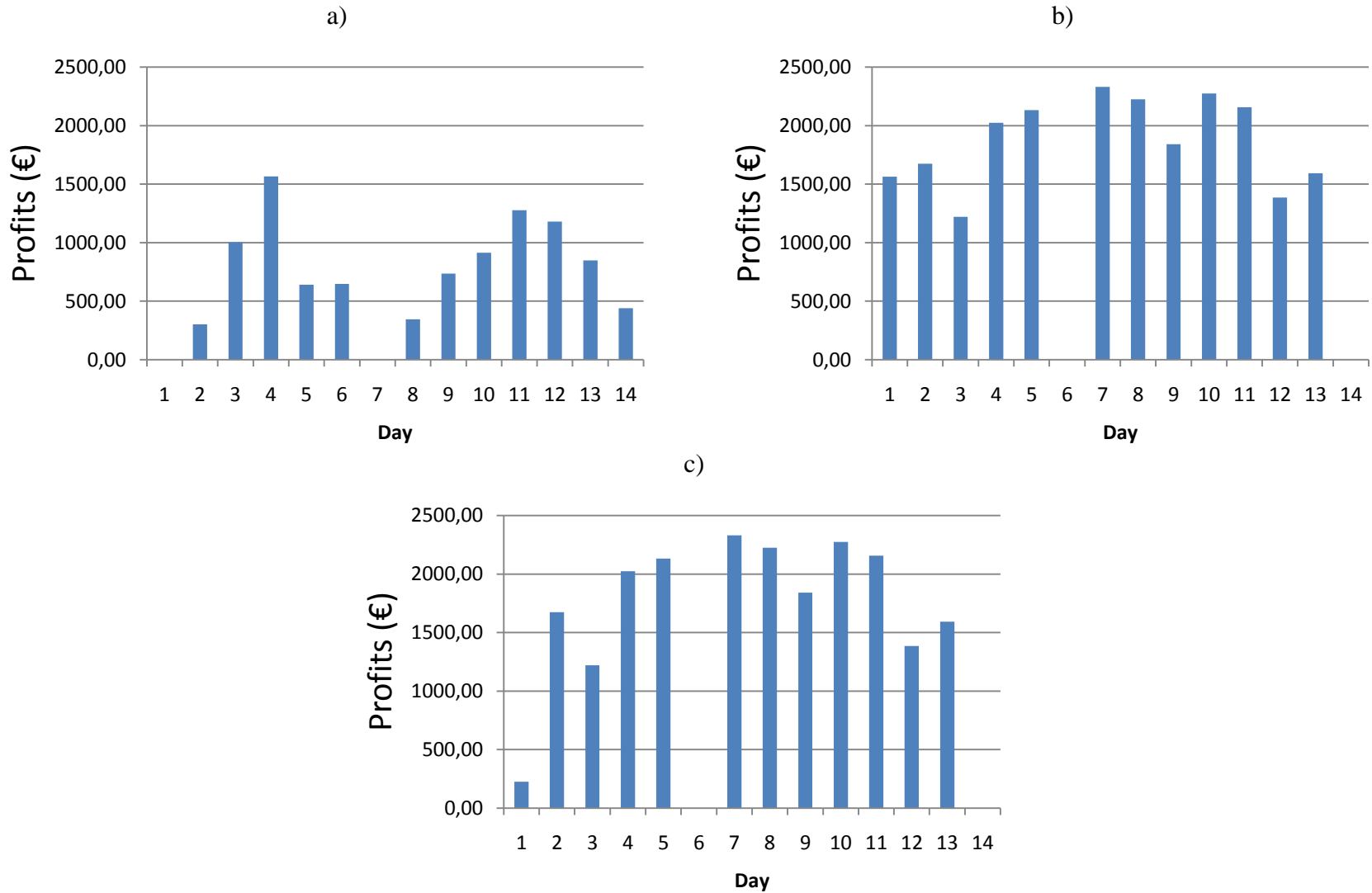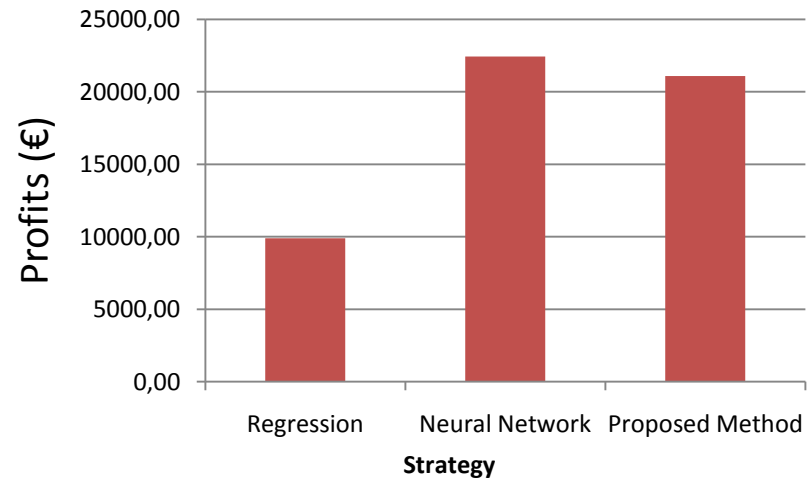
**Figure 16** – Comparison of the total profits obtained by Seller 2 in the eighth period of the considered 14 days

*Period 9*

**Figure 17** – Profits obtained by Seller 2 in the ninth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
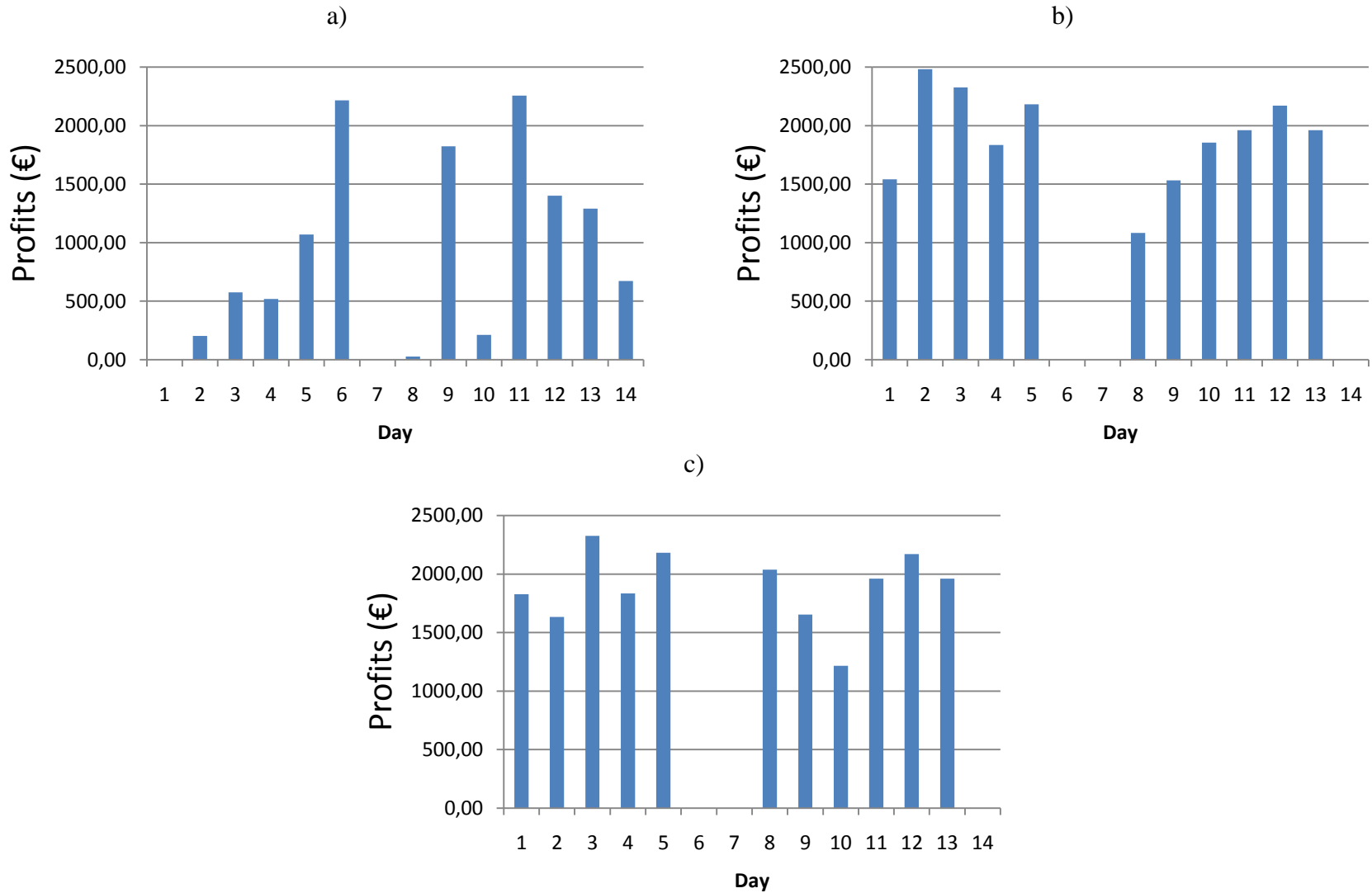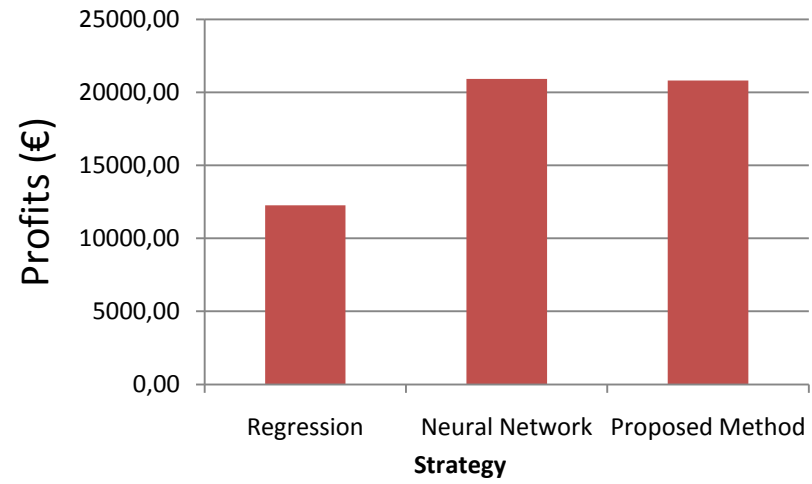
**Figure 18** – Comparison of the total profits obtained by Seller 2 in the ninth period of the considered 14 days

*Period 10*

**Figure 19** – Profits obtained by Seller 2 in the tenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
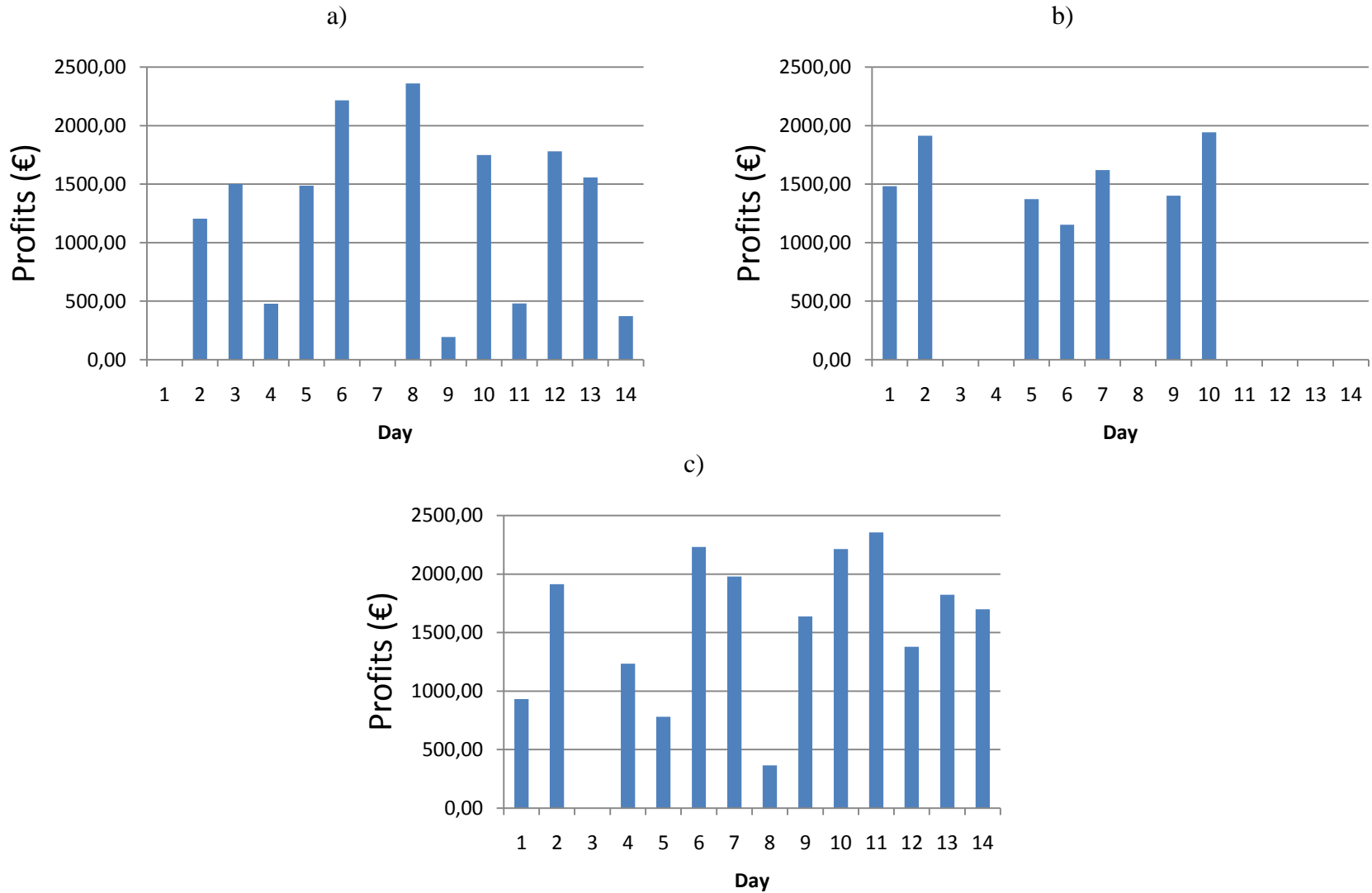
**Figure 20** – Comparison of the total profits obtained by Seller 2 in the tenth period of the considered 14 days

*Period 11*

**Figure 21** – Profits obtained by Seller 2 in the eleventh period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
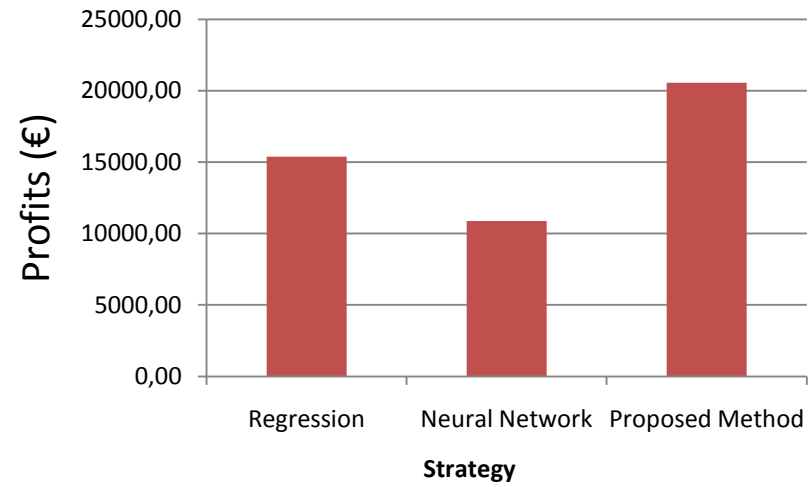
a)

b)

c)

**Figure 22** – Comparison of the total profits obtained by Seller 2 in the eleventh period of the considered 14 days

*Period 12*

**Figure 23** – Profits obtained by Seller 2 in the twelfth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
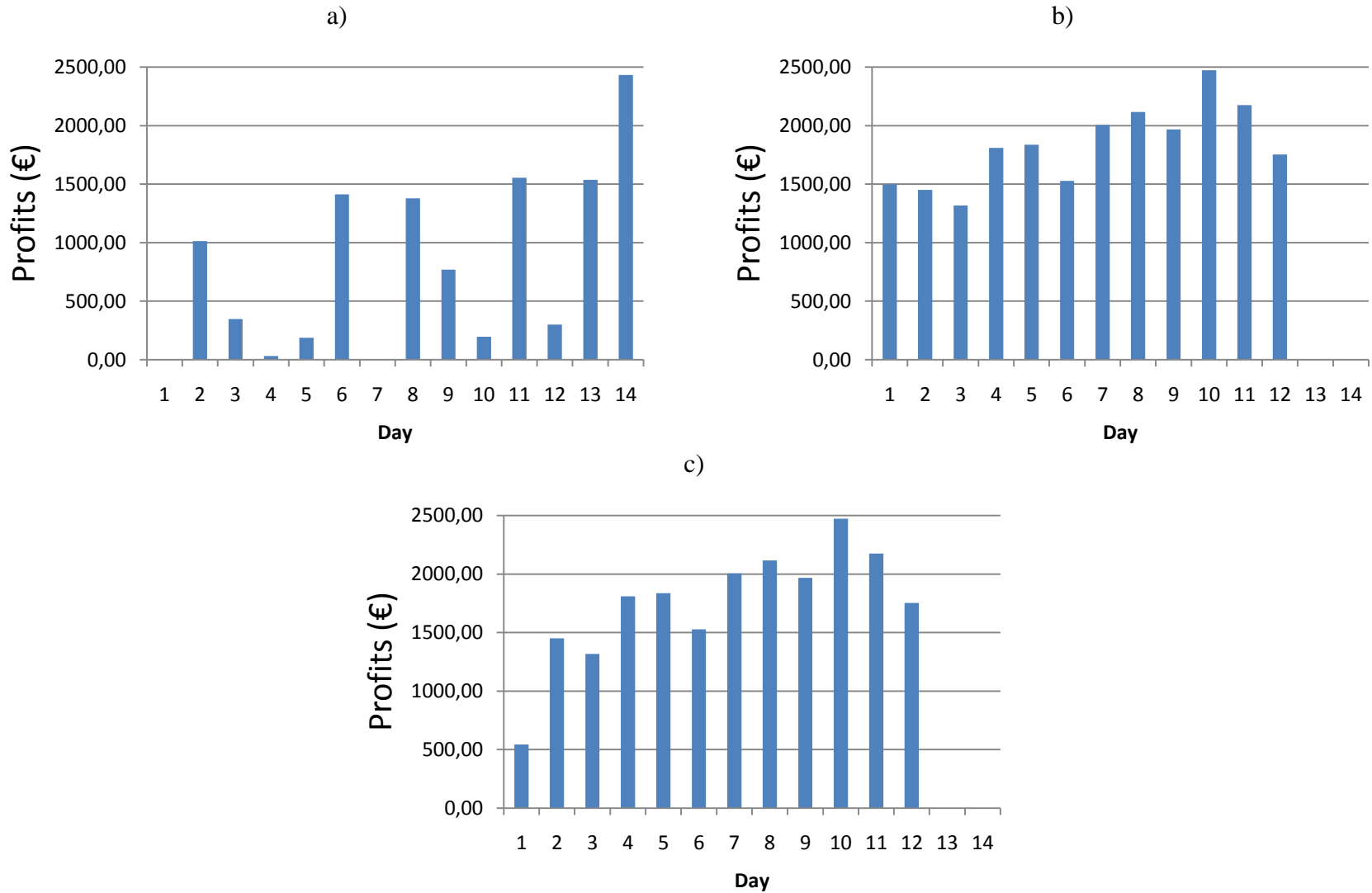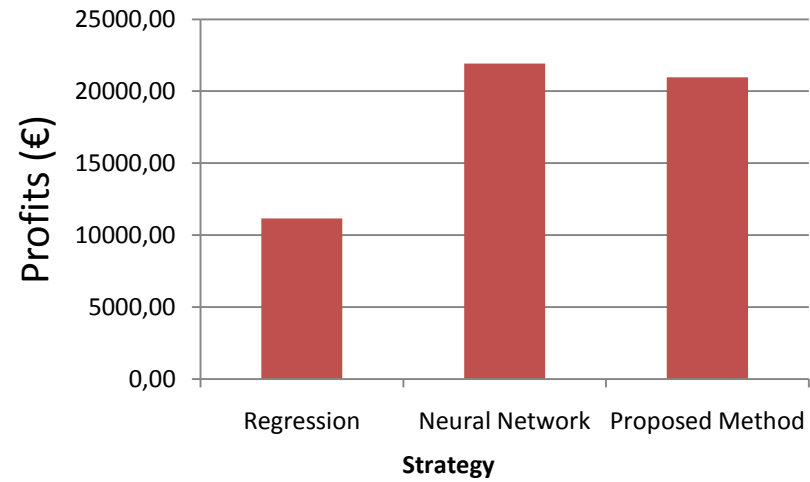
**Figure 24** – Comparison of the total profits obtained by Seller 2 in the twelfth period of the considered 14 days

*Period 13*

**Figure 25** – Profits obtained by Seller 2 in the thirteenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
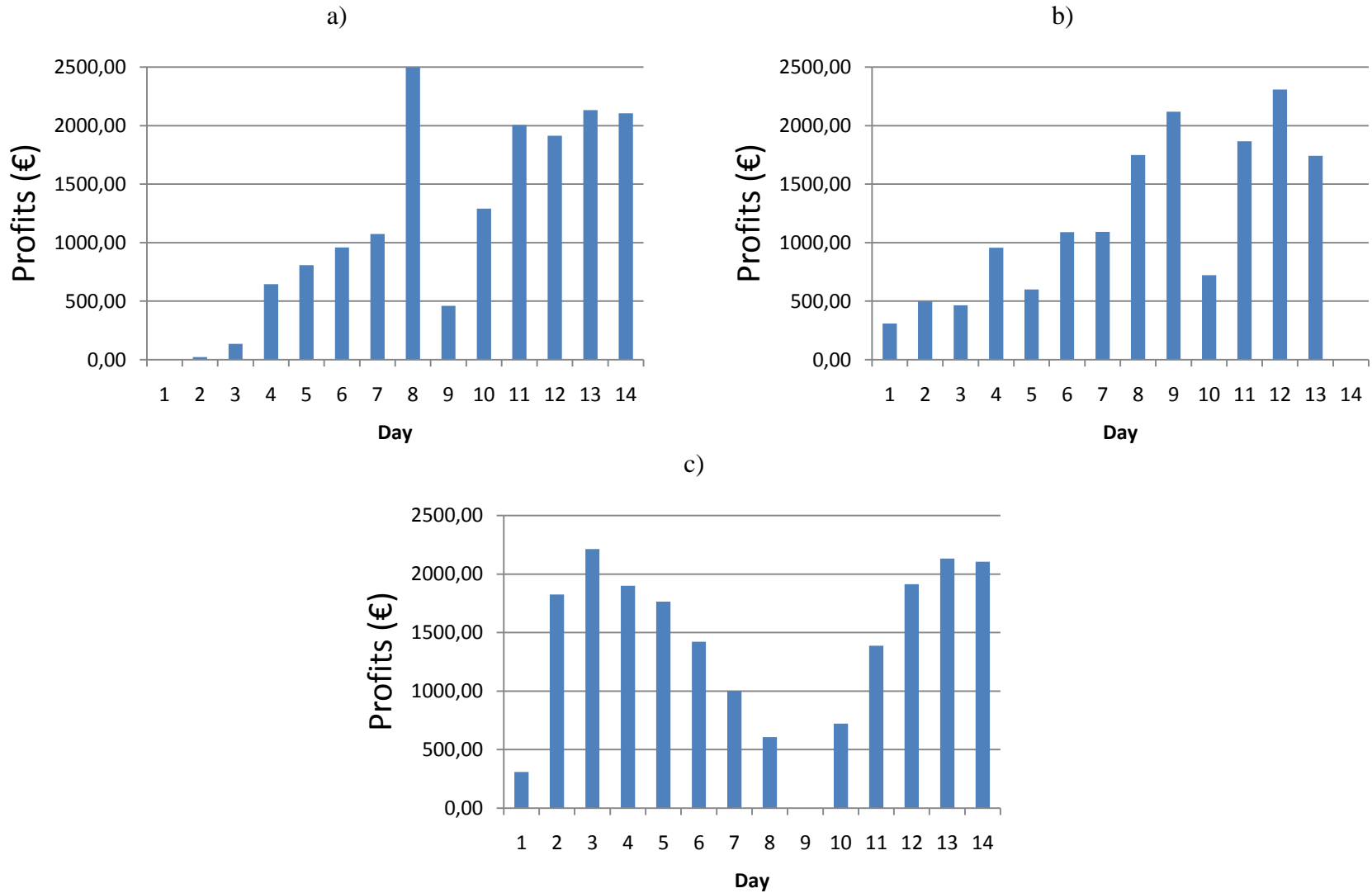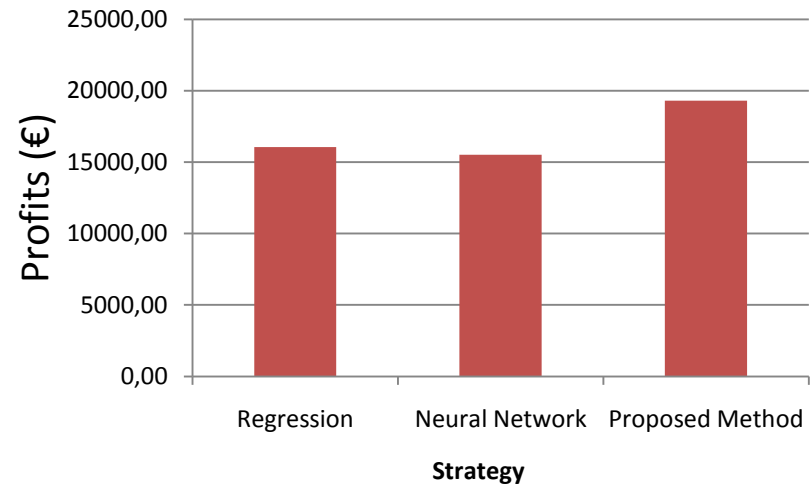
**Figure 26** – Comparison of the total profits obtained by Seller 2 in the thirteenth period of the considered 14 days

*Period 14*

**Figure 27** – Profits obtained by Seller 2 in the fourteenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
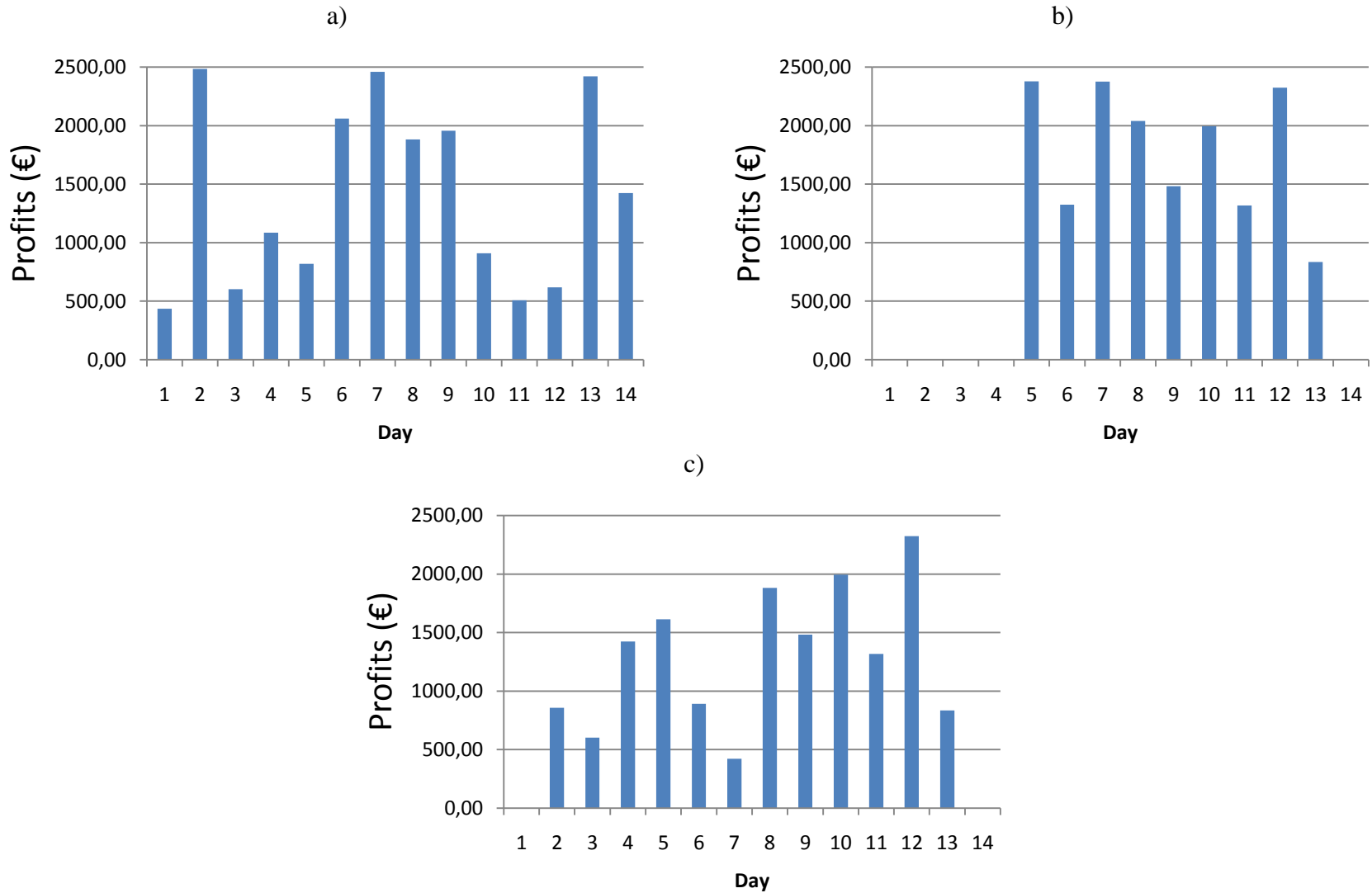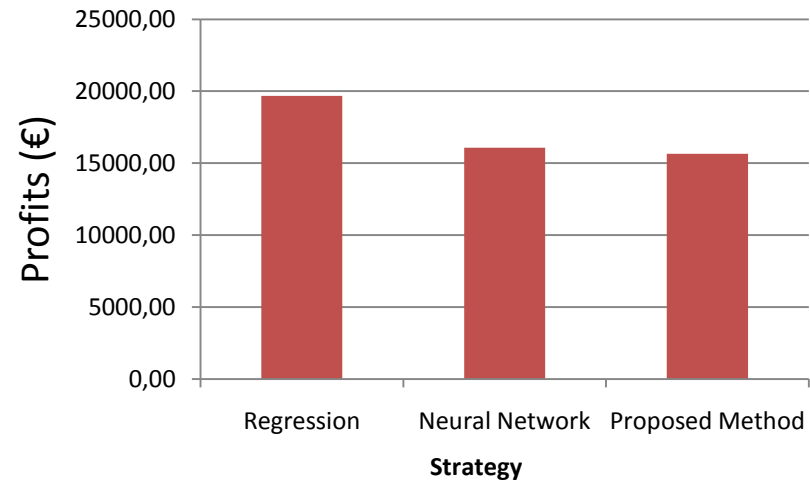
**Figure 28** – Comparison of the total profits obtained by Seller 2 in the fourteenth period of the considered 14 days

*Period 15*

**Figure 29** – Profits obtained by Seller 2 in the fifteenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
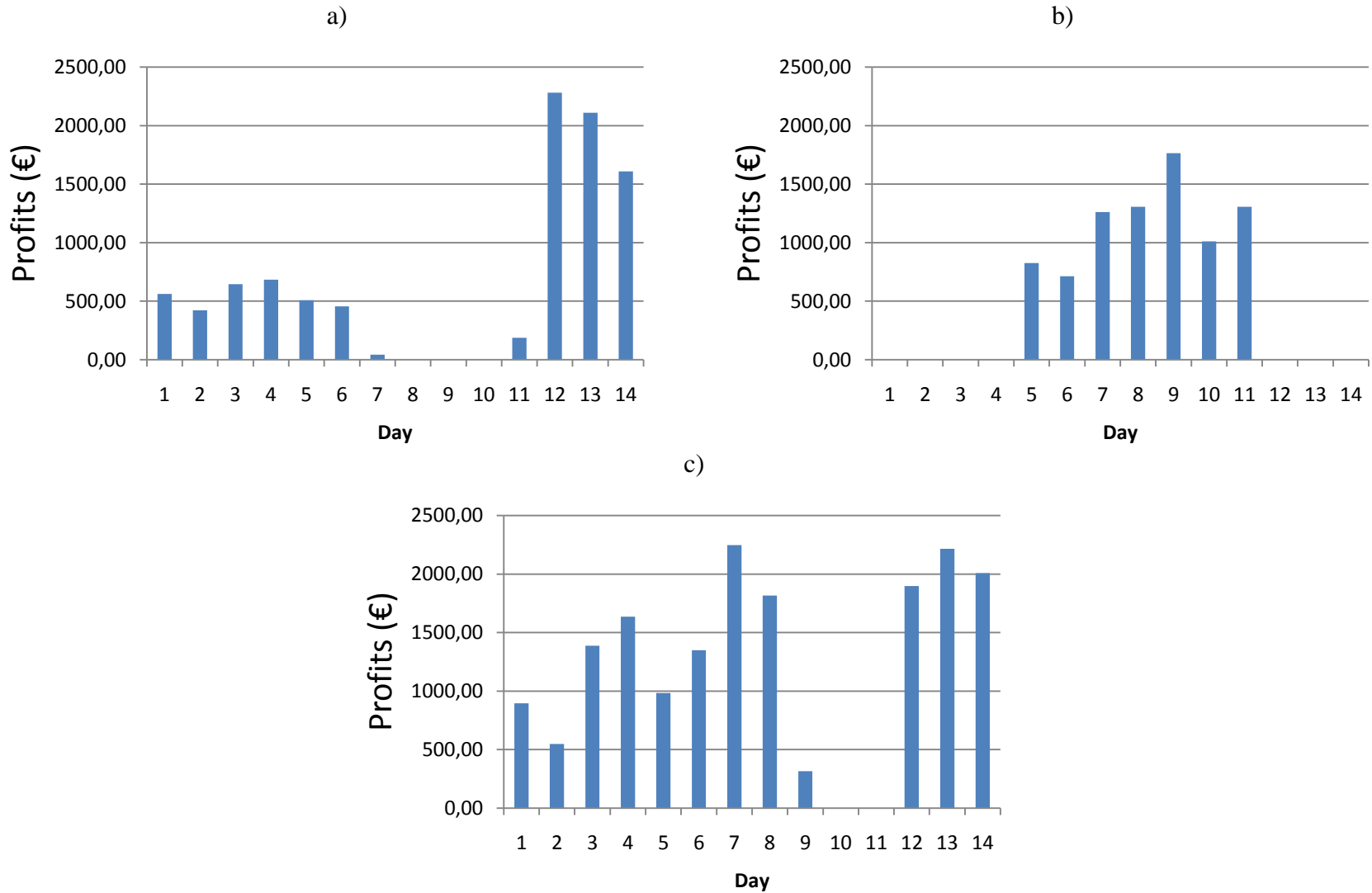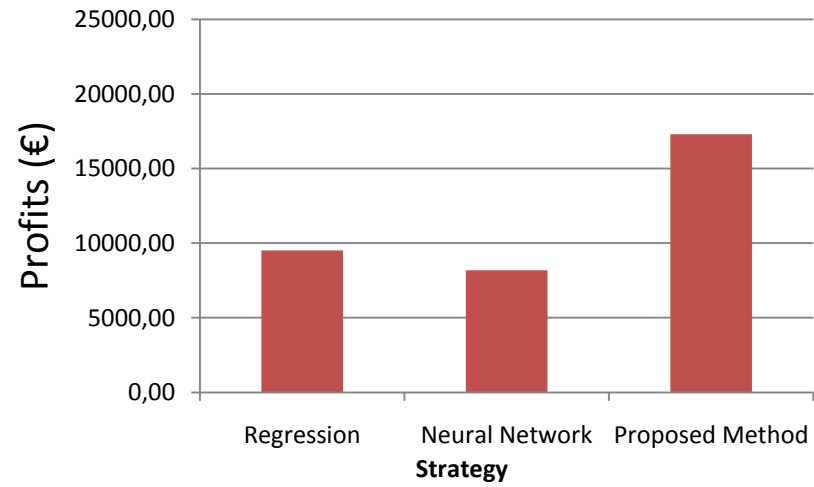
a)                                                                 b)

c)

**Figure 30** – Comparison of the total profits obtained by Seller 2 in the fifteenth period of the considered 14 days

*Period 16*

**Figure 31** – Profits obtained by Seller 2 in the sixteenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
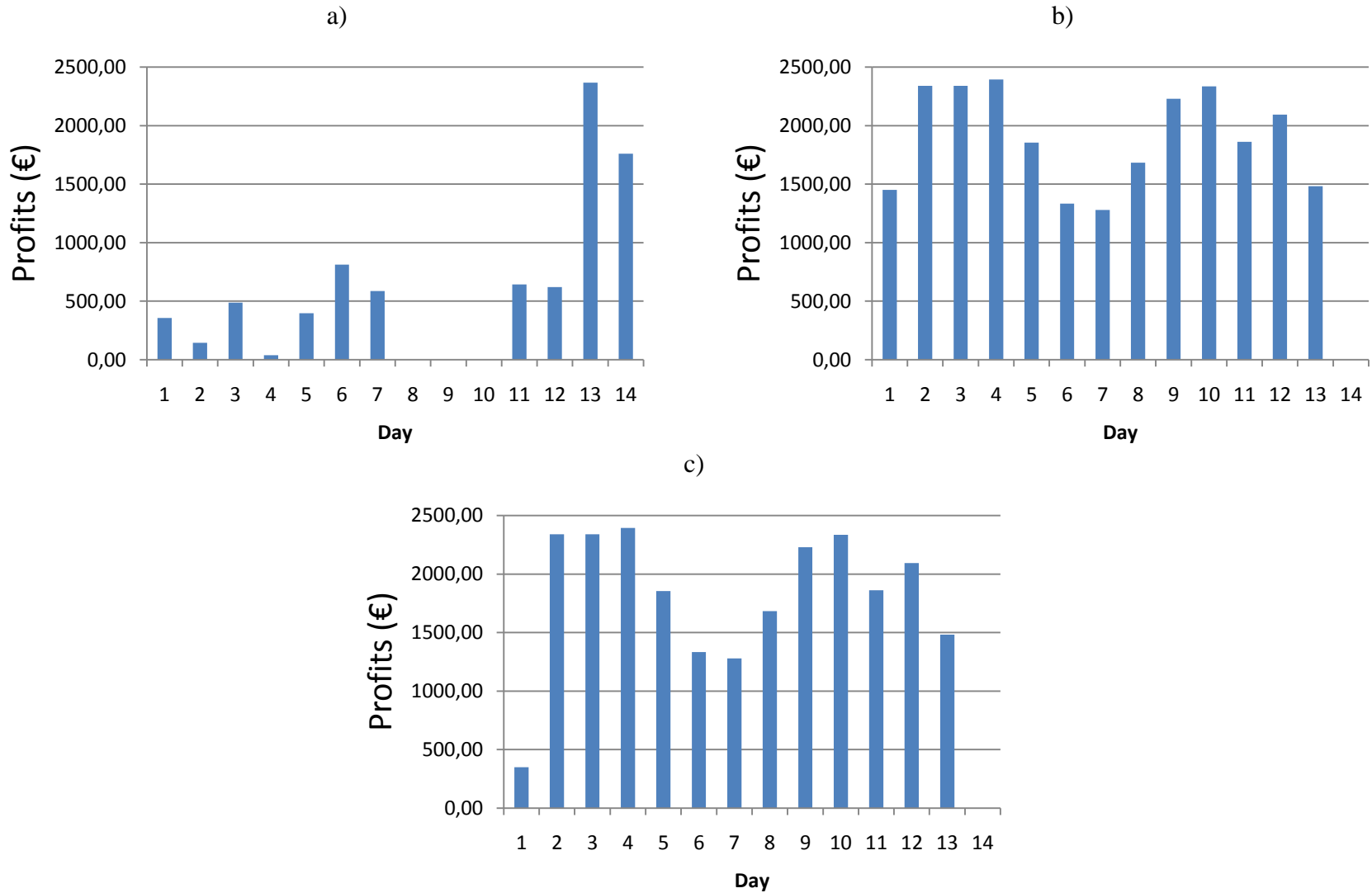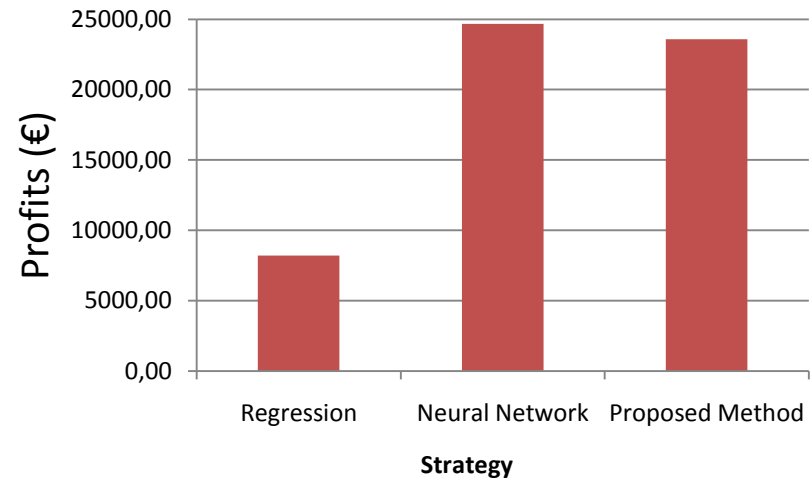
**Figure 32** – Comparison of the total profits obtained by Seller 2 in the sixteenth period of the considered 14 days

*Period 17*

**Figure 33** – Profits obtained by Seller 2 in the seventeenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
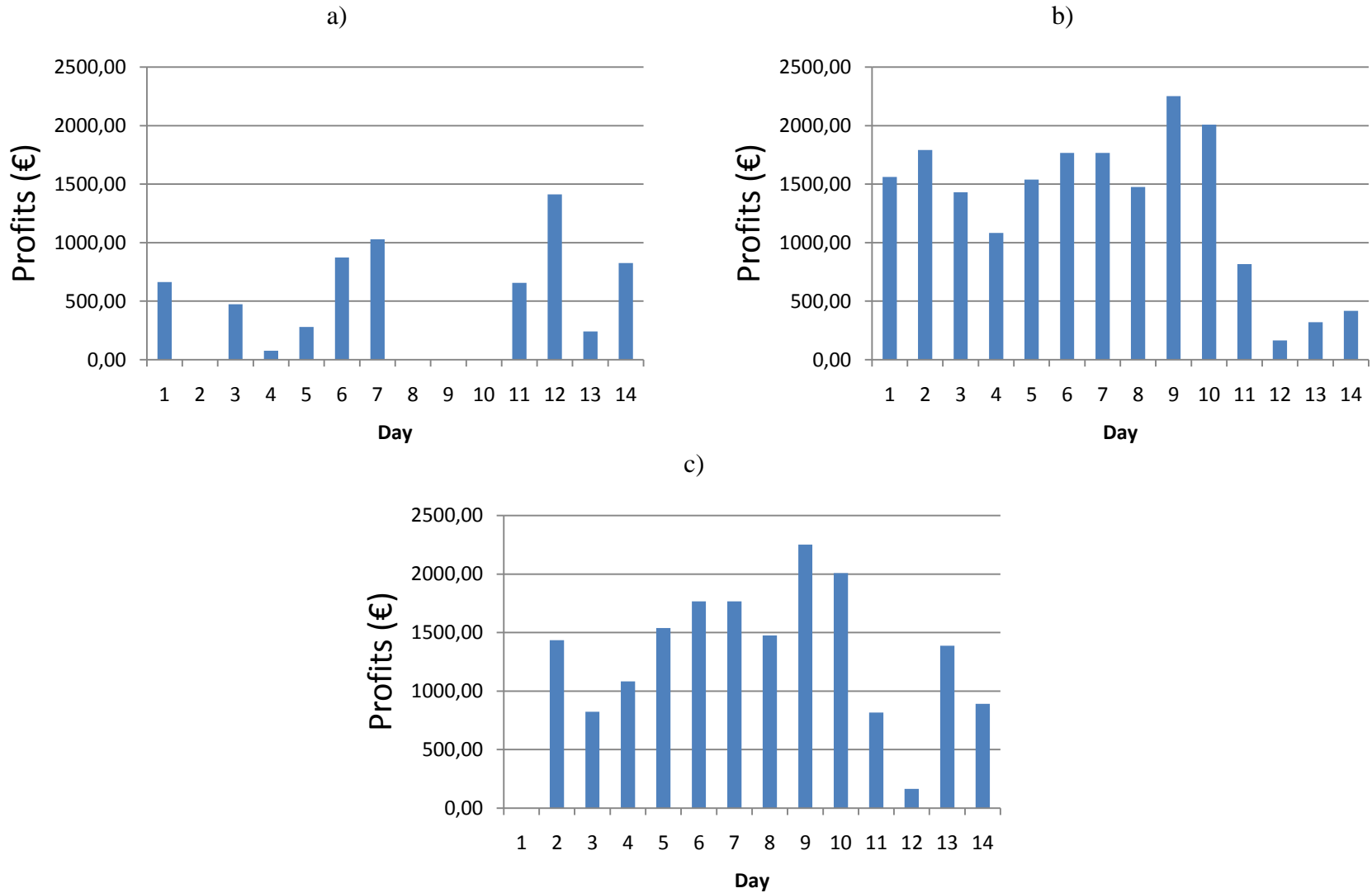
**Figure 34** – Comparison of the total profits obtained by Seller 2 in the seventeenth period of the considered 14 days

*Period 18*

**Figure 35** – Profits obtained by Seller 2 in the eighteenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
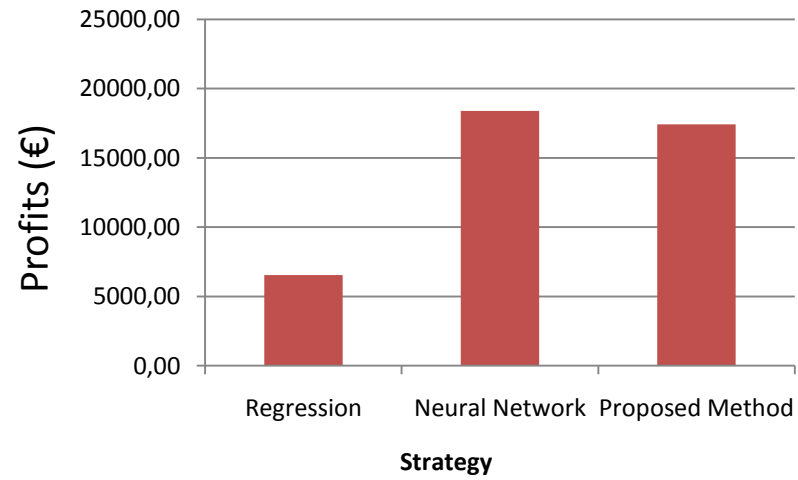
**Figure 36** – Comparison of the total profits obtained by Seller 2 in the eighteenth period of the considered 14 days

*Period 19*

**Figure 37** – Profits obtained by Seller 2 in the nineteenth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
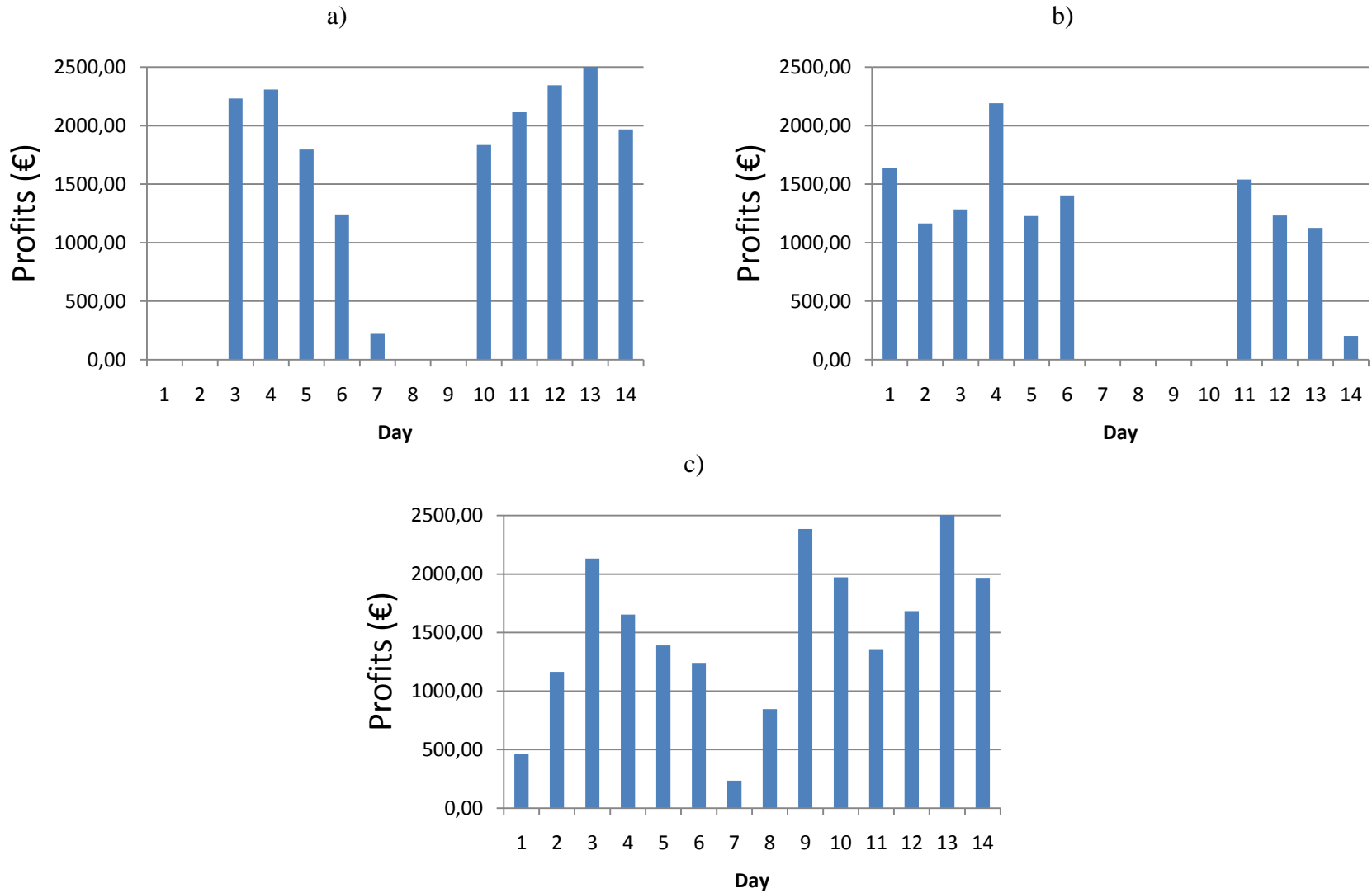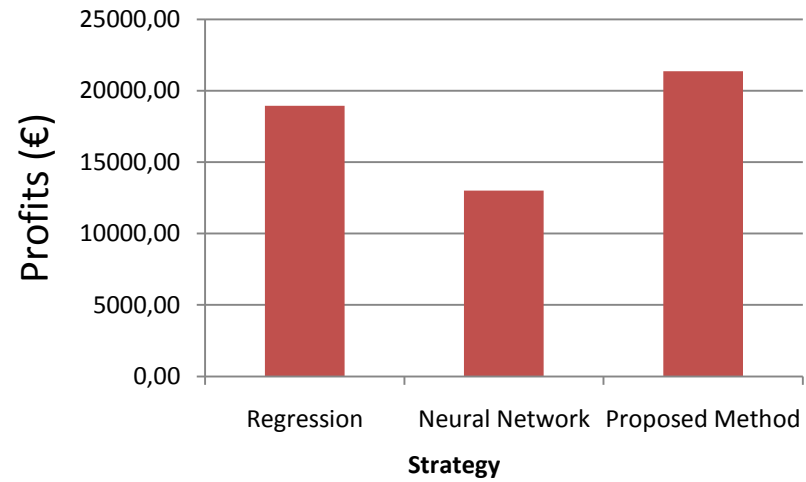
**Figure 38** – Comparison of the total profits obtained by Seller 2 in the nineteenth period of the considered 14 days

*Period 20*

**Figure 39** – Profits obtained by Seller 2 in the twentieth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
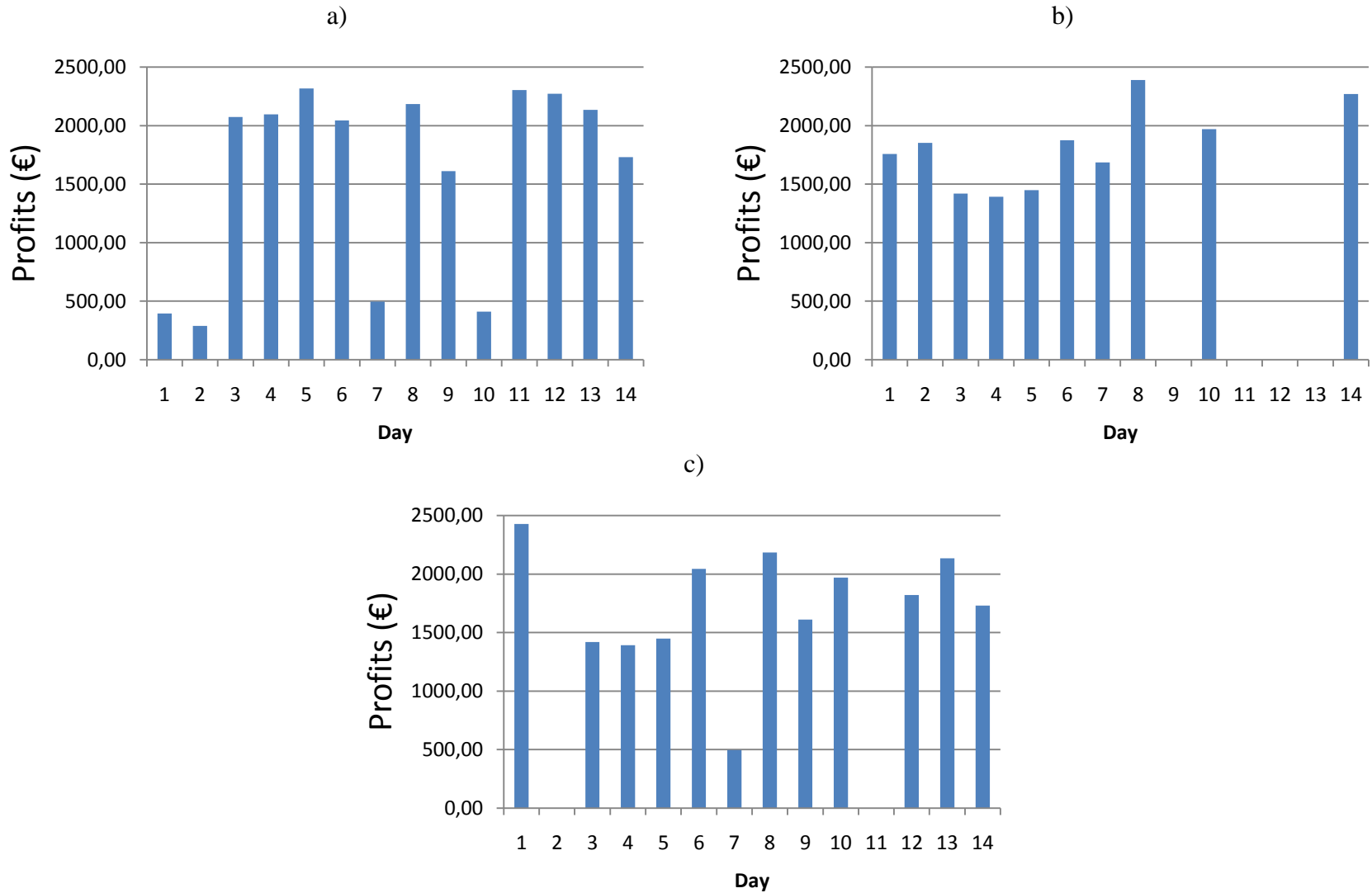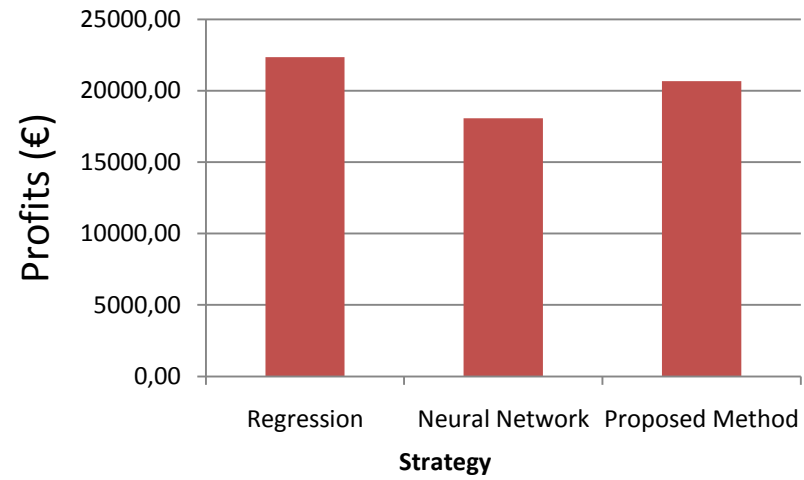
a)

b)

c)

**Figure 40** – Comparison of the total profits obtained by Seller 2 in the twentieth period of the considered 14 days

*Period 21*

**Figure 41** – Profits obtained by Seller 2 in the twenty-first period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
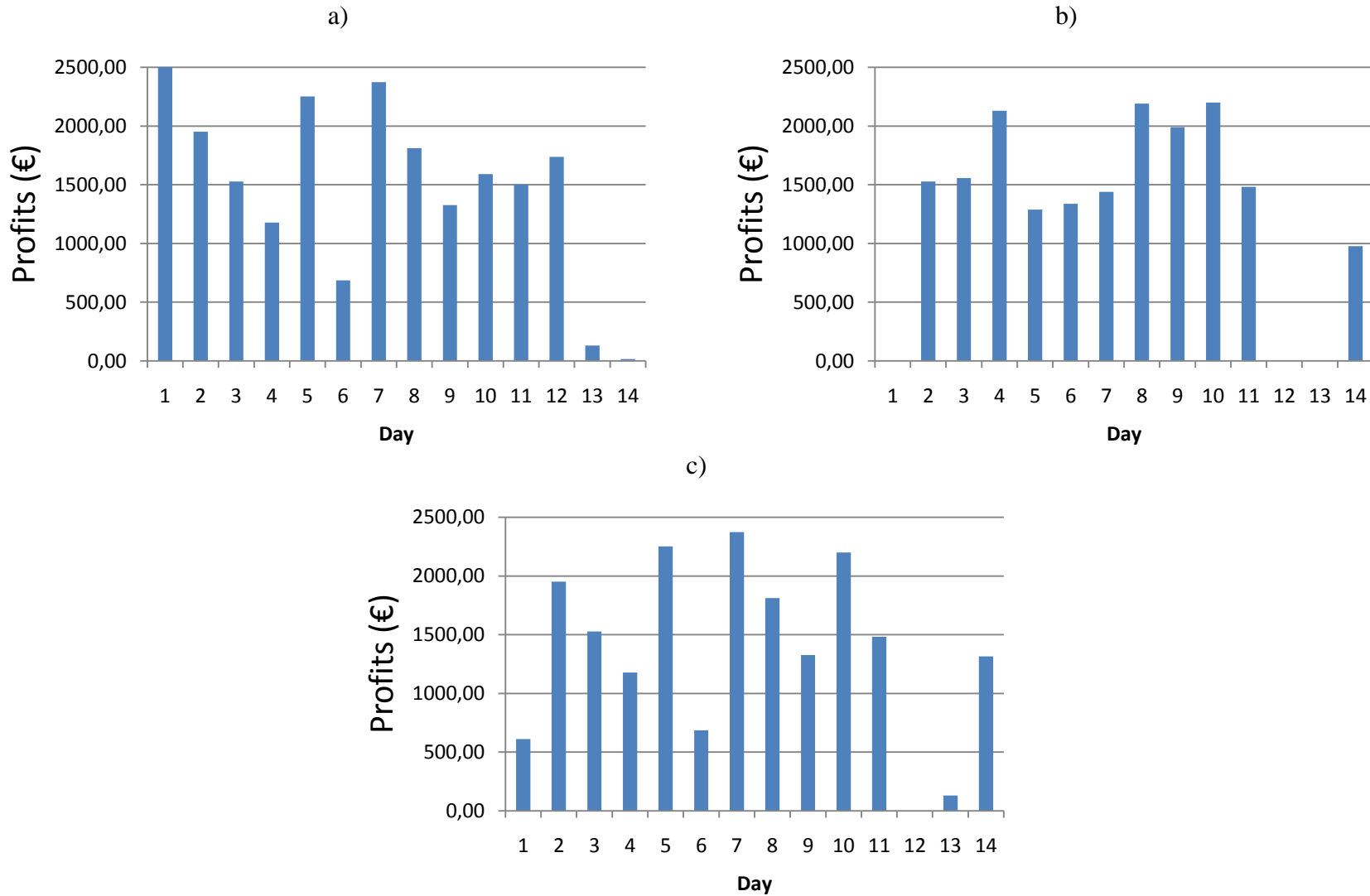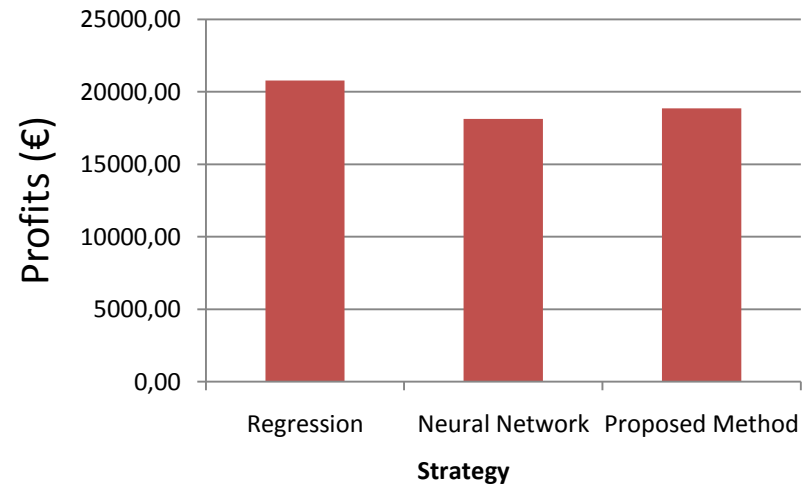
**Figure 42** – Comparison of the total profits obtained by Seller 2 in the twenty-first period of the considered 14 days

*Period 22*

**Figure 43** – Profits obtained by Seller 2 in the twenty-second period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
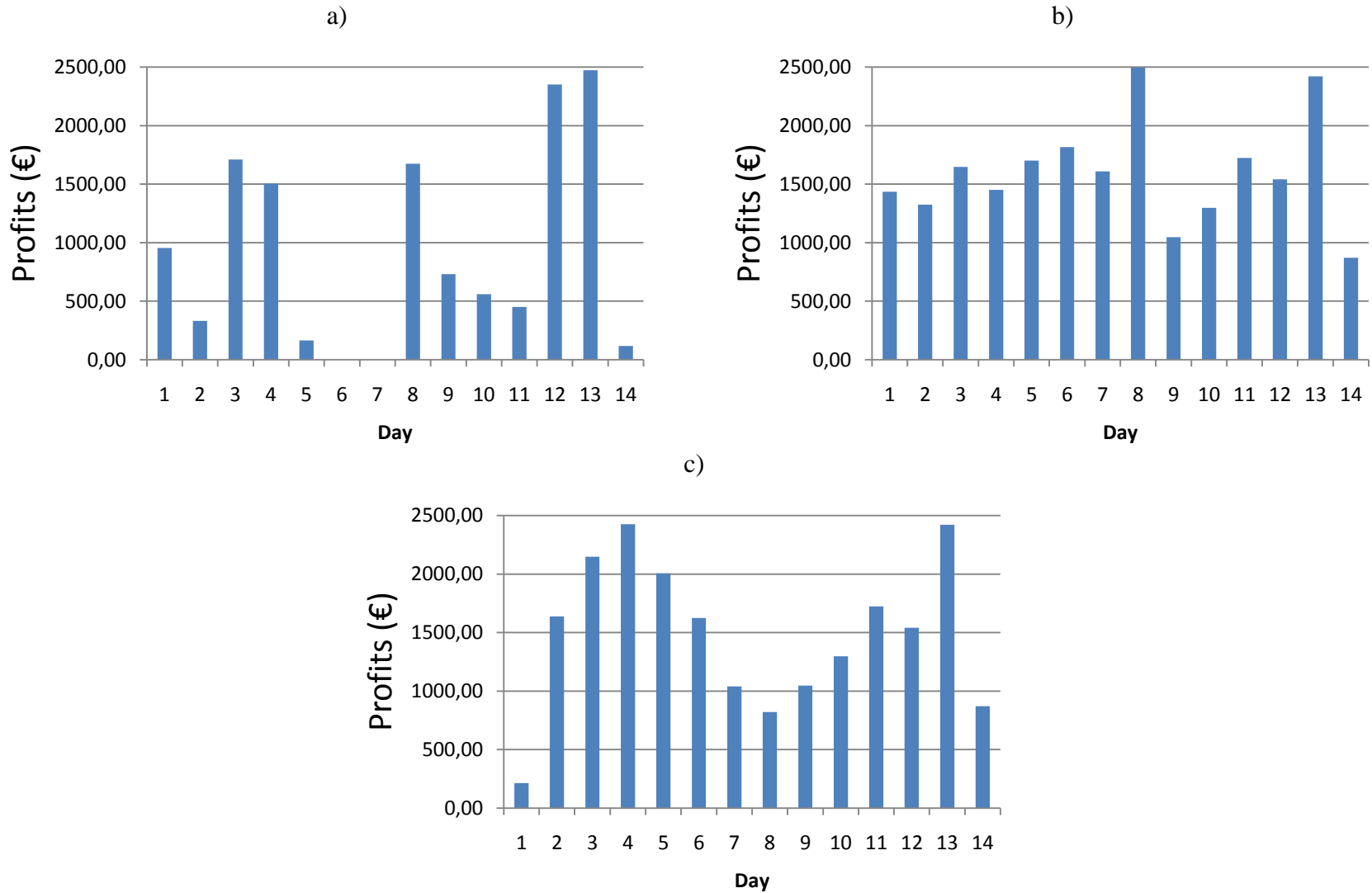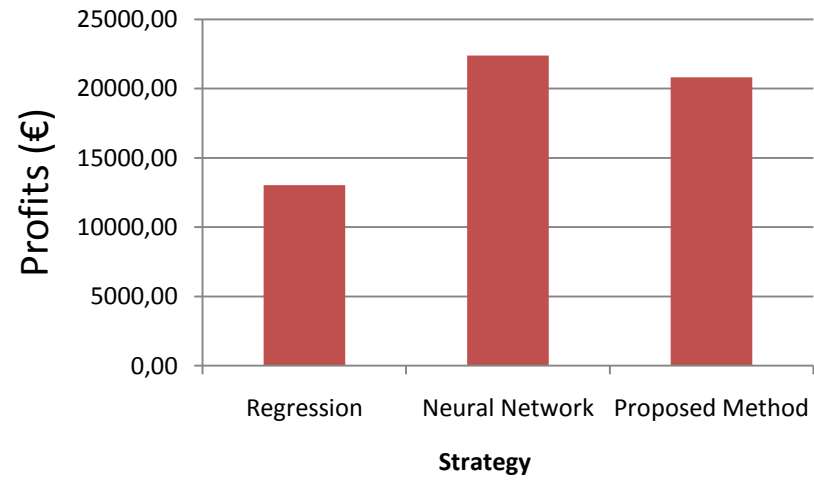
**Figure 44** – Comparison of the total profits obtained by Seller 2 in the twenty-second period of the considered 14 days

*Period 23*

**Figure 45** – Profits obtained by Seller 2 in the twenty-third period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
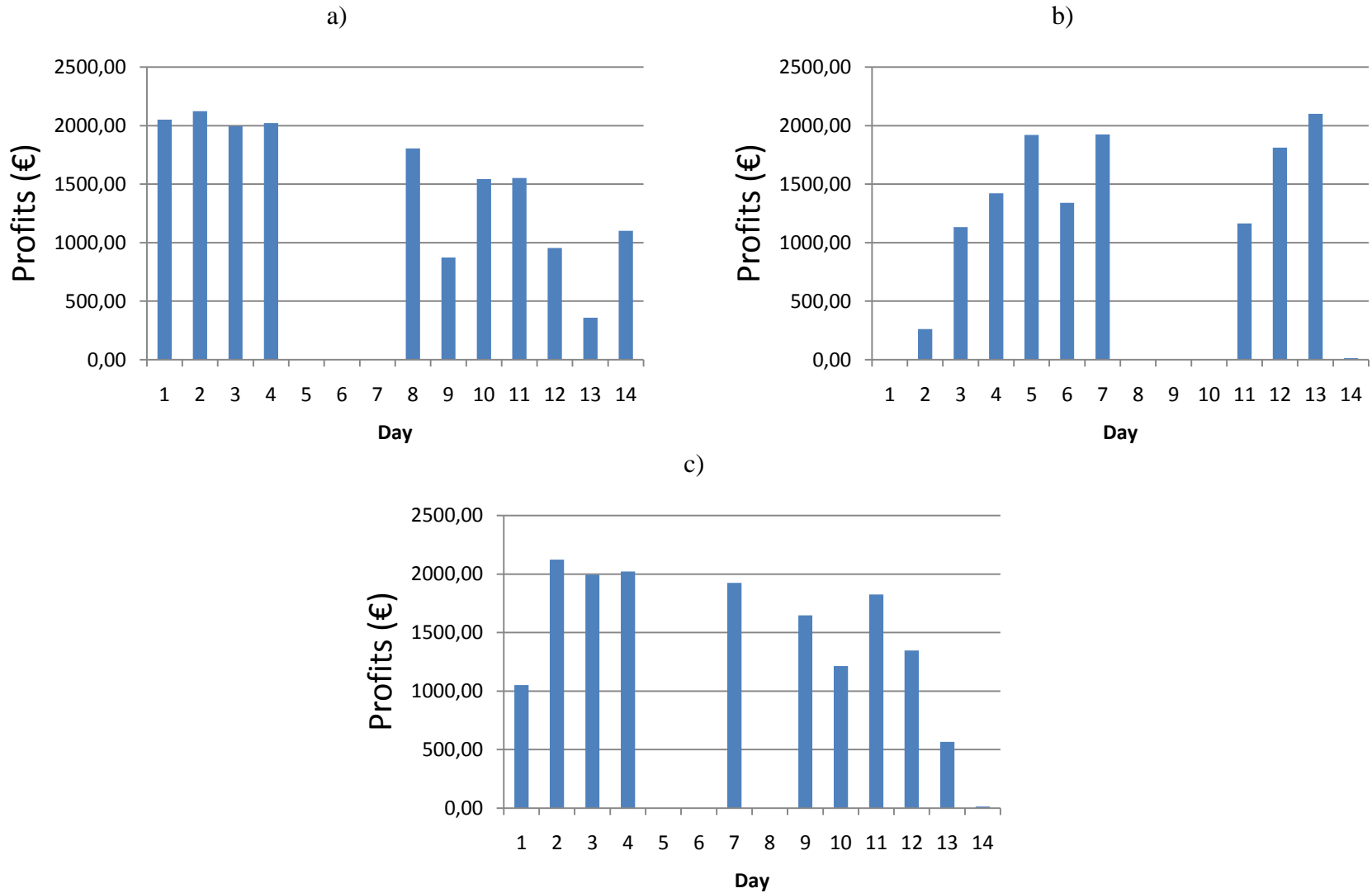
**Figure 46** – Comparison of the total profits obtained by Seller 2 in the twenty-third period of the considered 14 days

*Period 24*

**Figure 47** – Profits obtained by Seller 2 in the twenty- fourth period of the considered 14 days, using: a) the regression on the data of the last 5 business days, b) the Neural Network, c) the proposed strategy for bid definition
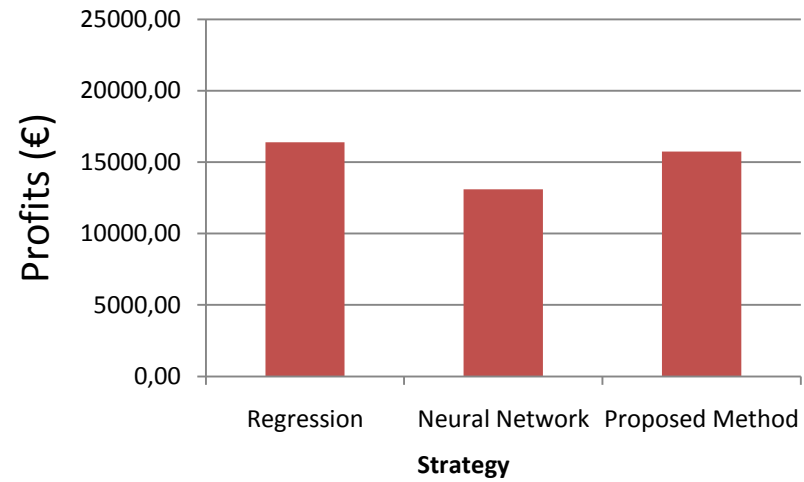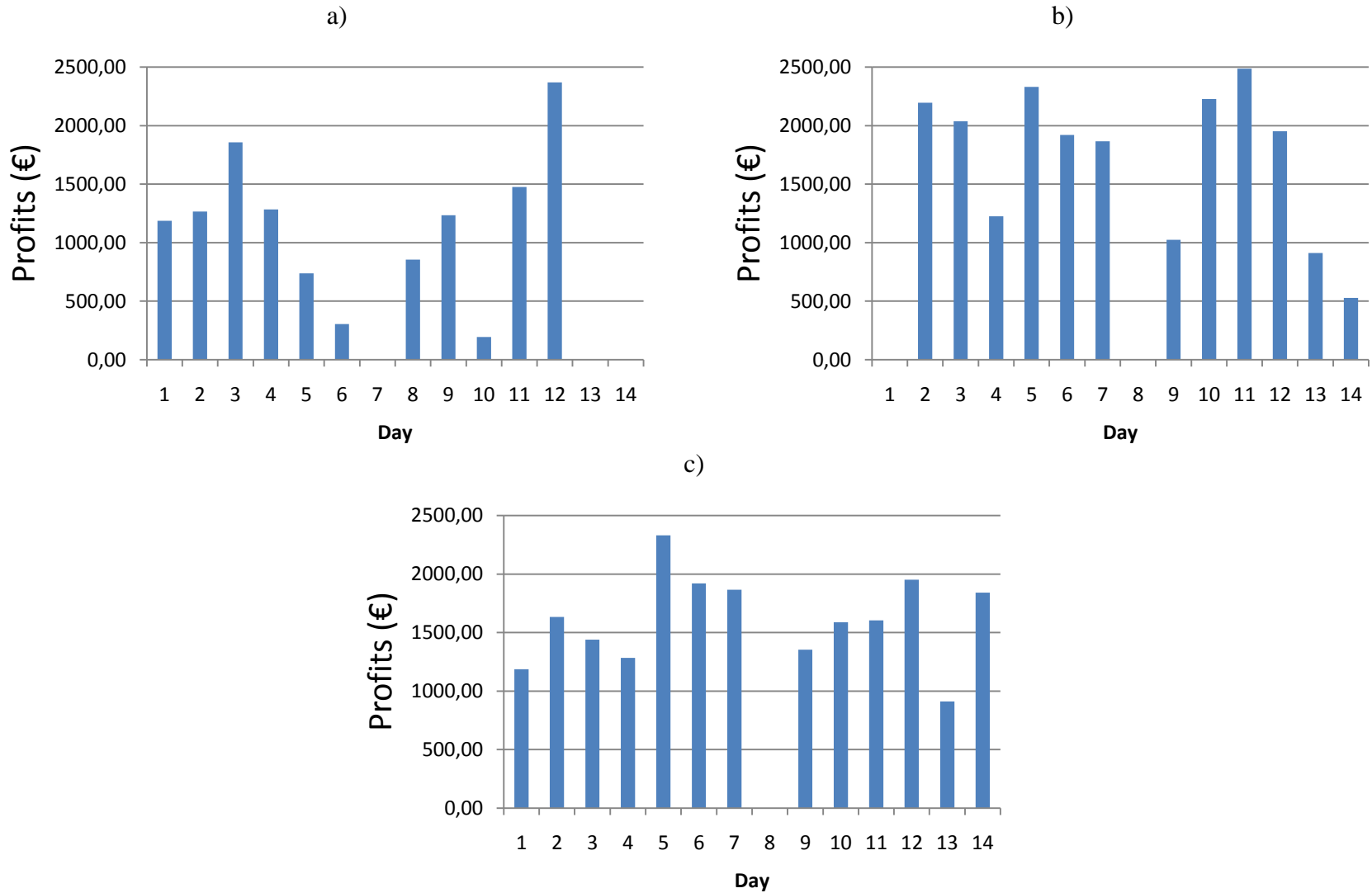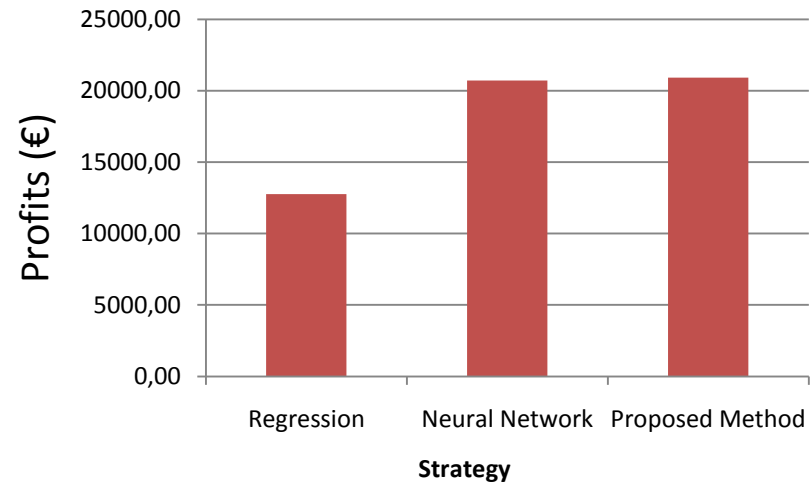
**Figure 44** – Comparison of the total profits obtained by Seller 2 in the twenty-fourth period of the considered 14 days

**Results Overview**

Analysing each period separately we can see that Seller 2 obtained higher profits using the proposed method over the other two considered strategies, in the majority of the periods. This can be shown by the comparison of the total profits obtained by this agent considering all the 24 periods of the 14 considered days, as presented in figure 45.

**Figure 45** – Comparison of the total profits obtained by Seller 2 in the end of the considered 14 days
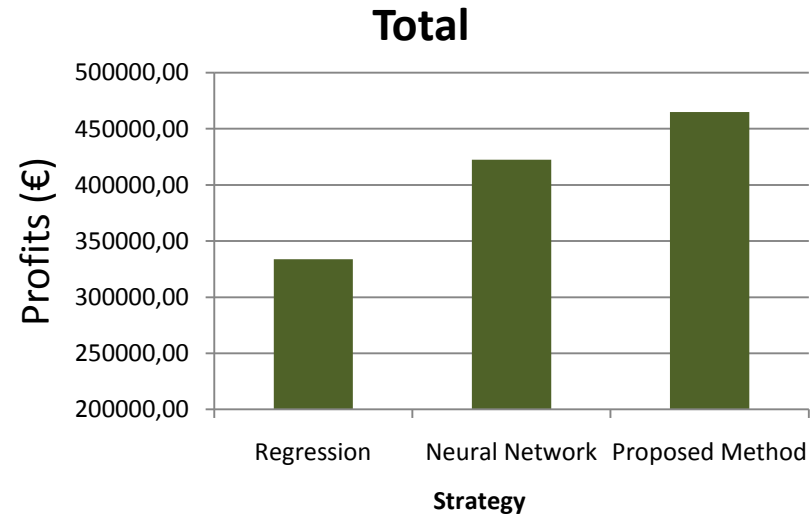


We can see in figure 45 that the proposed method obtained a higher total amount of profits when compared to the other two considered strategies. This shows the suitability of this method when applied to this problem.