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Abstract

We try to better understand the comparative advantages of structural and behavioral remedies of deregulation in electricity markets, an eminent policy issue for which the experimental evidence is scant and problematic. Specifically, we investigate theoretically and experimentally the effects on competition of introducing a forward market which the European Commission classifies as a behavioral remedy. We compare this scenario with its best alternative, the structural remedy of adding one more competitor by divestiture. Our study contributes to the literature by introducing more realistic cost configurations, by teasing apart competition effect and asset effect, and by investigating competitor numbers that reflect the market concentration in the European electricity industries. Our experimental data suggest that introducing a forward market has a positive effect on the aggregate supply in markets with two or three major competitors, configurations typical for the newly accessed and the old European Union member states, respectively. Introducing a forward market also increases efficiency.

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In contrast to previous findings, our data furthermore suggest that the effect of introducing a forward market is stronger than adding one more competitor. We thus provide evidence that behavioral remedies may be more effective than structural ones. Our data hence suggest that competition authorities are well advised, in line with EU law (European Commission, 2006a, p.11), to focus on introducing, and facilitating the proper functioning of, forward markets rather than on lowering market concentration by divestiture.

1. Introduction

Concentration in generator markets remains a major problem in the EU electricity markets. The European Commission (2007a, p.7), for example, concludes: "At the wholesale level, gas and electricity markets remain national in scope, and generally maintain the high level of concentration of the pre-liberalization period. This gives scope for exercising market power."

The European Commission suggests structural remedies[2] such as divestiture or asset swaps of power plants on a European scale (2007a, p.15), blocking mergers (2007a, p.12), auctioning large scale Virtual Power Plants (2007a, p.12), stimulating the entrance of new electricity generators (2007a, p.16), and increasing competition by enabling generators from abroad to sell electricity over cross-border transmission lines (2007a, p.8).

Several EU member states have experience with some of these structural remedies. For example, in the late nineties, the UK forced dominant electricity generators to divest plants; the two dominant electricity generators NationalPower and PowerGen together divested 6GW in 1996 and another 8GW in 1999, thus lowering concentration (Green, 2006). (However, beginning in 2000, several mergers reversed that trend.[3]) The UK also experienced a considerable degree of new entry.[4] Belgium, France, Italy, Denmark, and the Netherlands are

[2] The European Commission (2006b, p. 6) defines structural remedies as "changes to the structure of an undertaking. The most obvious one is the divestiture of an existing business. "

[3] In 2002 one of the largest generators, PowerGen, merged with TXU Europe, thus adding 3GW to its capacity (Green, 2006).

[4] The policy of allowing distributors to sign long-term contracts with independent power producers promoted entry of new electricity producers, mainly with new Combined-Cycle-Gas-Turbine (CCGT) generation technology (Newbery, 2002).

using, or used in the past, the auctioning of Virtual Power Plants[5] to lower market power (Willems, 2006)**.** Finally, several countries increased the capacity of cross-border transmission lines and harmonized their market regimes with neighboring countries to make it easier for generators to sell electricity over borders, thus increasing competition.

The encouragement of cross-border trading – while creating a larger, European, market – is likely to alleviate the concentration problem only marginally, as many electricity companies have merged across borders and become players in neighboring countries (Matthes, Grashof, and Gores, 2007). Increasing competition, while avoiding duplication of investment in generation assets,[6] is therefore done most efficiently by divestiture, i.e., by enforcing big incumbent power companies to sell parts of their plants, and thus to add to the capacity of competing new entrants. Of interest are also “softer” remedies, such as discouraging incumbents to replace old plants and encouraging new entrants to build generation assets, as this is effectively a form of divestiture (no duplication of investment in generation assets).

In addition to such structural remedies, policy makers and regulators have voiced interest in behavioral remedies[7] that, through the appropriate organization of electricity markets, prevent electricity generators to be able to use their market power. The wording of EU law suggests that behavioral remedies ought to be the default setting: “Structural remedies should only be imposed either where there is no equally effective behavioural remedy or where any equally effective behavioural remedy would be more burdensome for the undertaking

[5] When a generator sells a Virtual Power Plant, he sells part of his production capacity to other generators. This divestiture of generation capacity is called virtual as no production capacity changes hand, and the selling generator remains the owner of all its generation plants (Willems, 2006).

[6] Entry of new generators is generally not the most efficient solution to increase competition. When there is no need for new generation investment, entry, by adding excessive capacity, imposes deadweight losses on the market that can be larger than the gains of increased competition (Green, 1996). Divestiture is in such case the best alternative solution.

[7] The European Commission (2006b, p. 8) defines a behavioral remedy as “a measure that obliges the concerned undertaking(s) to act in a specific way.” Duso, Gugler, and Yurtoglu (2011, p. 980) characterize them as measures that “… effectively tackle the market power concerns potentially raised by mergers without destroying efficiency enhancing synergies.”

concerned than the structural remedy” (European Commission, 2006a, p.11). Recent evidence, however, suggests that, in general, behavioral remedies may be less effective than structural remedies (Duso et al., 2011).

Allaz and Vila (1993) make the theoretical case for the introduction of a forward market as a behavioral remedy that increases competitive pressure. Specifically, analyzing competition in a one-shot Cournot set-up, they show that a forward market lowers the amount of market power producers can exert. The contribution of Allaz and Vila (1993) is important since Lévêque (2006) argued that forward contracts are likely to decrease competition. Willems et al. (2009), drawing on Allaz and Vila (1993), provide intuition: In the spot market every producer maximizes his profit given by the profit function $\pi_i = p[q_i + q_{-i}](q_i - f_i) - c[q_i]$, where q_i stands for their own production, q_{-i} for the production of all other producers, and f_i for the number of units sold in the forward market. Taking the derivative with respect to q_i and setting it equal to zero yields $0 = d\pi_i/dq_i \Leftrightarrow -p'[Q](q_i - f_i) = p[Q] - c'[q_i]$. This equation can be rewritten[8] as $(s_i/E_p^Q) \cdot (1 - (f_i/q_i)) = (p[Q] - c'[q_i])/p[Q]$, where s_i stands for the market share and E_p^Q for the price elasticity of demand. We can see from the formula that the markup (the right-hand side of the equation) decreases in f_i, the number of units sold in the forward market. The more producers sell in the forward market, the closer the outcome in the spot market will be to the Walrasian, or efficient, outcome.

Welfare and consumer surplus thus increase in the number of units sold in the forward market. Do producers have incentives to sell units in the forward market? Allaz and Vila (1993) show that they do. Suppose that only one, privileged, firm could sell in the forward market. In that case this firm has a first mover’s advantage. It can, by selling the right number of units in the forward market, reach the Stackelberg equilibrium, which has a higher profit for the privileged firm. Thus, it cannot be a Nash-equilibrium for no firm to sell in the forward market. Consequently, when all firms are entitled to sell in the forward market, they all will, ending up worse off than

[8] Multiplying the left side by $1 = (p[Q] \cdot q_i \cdot Q/p[Q] \cdot q_i \cdot Q)$ gives $-p'[Q](q_i - f_i) \cdot (p[Q] \cdot q_i \cdot Q/p[Q] \cdot q_i \cdot Q) = p[Q] - c'[q_i]$. Rearranging this equation yields $-p'[Q] \cdot (Q/p[Q]) \cdot (q_i/Q) \cdot ((q_i - f_i)/q_i) = (p[Q] - c'[q_i])/p[Q]$.

when none of them had sold. This prisoner's-dilemma type result is standard textbook fare (e.g., Binmore 2007, chapter 10).

Allaz and Vila (1993) model the competition as a one-shot game. The Nash equilibrium of a one-shot game and that of a repeated game with predictable ending are theoretically (albeit not necessarily behaviorally; see Selten (1978, 1991) identical. This makes the Allaz and Vila model a fitting theoretical benchmark for an experiment with a fixed, or predictable, number of periods. Of course, in the real world the number of periods may not be fixed, or predictable, and the Nash equilibrium of the stage game is one of many equilibria, some of which may be collusive: see Liski and Montero (2006). Since all treatments have the same number of rounds, between-treatment results ought to be nonetheless informative.

We compare the results of introducing a forward market with those of the best alternative remedy: reducing market concentration by divestiture. We do so for competitor numbers that arguably reflect better the market concentration in the old European states than previous literature has done. We also use realistic cost configurations and tease apart competition and asset effect.

We show that, theoretically and behaviorally, the effects of introducing a forward market might be larger than adding one more competitor in markets both with two and three producers. Previously, Brandts, Pezanis-Christou, and Schram (2008) came to the opposite conclusion for the case of three initial competitors.

The question whether the theoretical predictions of Allaz and Vila (1993) will materialize in the reality of a dynamic setting such as the EU electricity market has clear policy implications. An affirmative answer would suggest that regulators formulate guidelines for, and promote, the design of effective forward markets.

In the following section we first discuss the experimental design (i.e., the basic parameterizations, treatments, underlying working hypotheses) and experimental procedures as well as related literature. In section 3 we report the results focusing on aggregate quantity, efficiency, and production efficiency. In section 4 we conclude. The appendices contain robustness tests and instructions.

2 Experimental design and procedures

2.0 A preliminary remark

We model the competition of generators in the spot and forward markets using the standard Cournot approach (see for example Borenstein & Bushnell, 1999; Le Coq& Orzen, 2006; Bushnell 2007; Newbery, 2009). The supply-function approach of Klemperer and Meyer (1989) has been argued to be a more accurate approach to model competition in electricity markets. The supply-function approach, however, is more complicated and predicts a continuum of equilibria which in turn brings about an equilibrium selection problem (see Devetag & Ortmann, 2007, for a recent review). Wolak & Patrick (2001) provide empirical evidence that dominant generators exert market power by declaring plants to be unavailable, thus shifting the supply curve and suggesting that the Cournot approach is an appropriate modeling choice. In addition, Willems et al. (2009) show that Cournot and supply-function approaches lead to comparable outcomes. In contrast, Green (2004) argues that that the Cournot approach does not accurately characterize producer behavior in England and Wales between 1985 and 2000.

Klemperer and Meyer (1989) show that the Cournot equilibrium outcome is the equilibrium with the maximal exertion of market power in the range of supply-function equilibria and hence, arguably, the natural benchmark. Brandt et al. (2008) show that this is also true for configurations with a forward market. The Cournot approach is thus relevant and interesting and a necessary first step for additional studies using the supply-function approach.

2.1 Treatments

We identify the effects of adding one more competitor through divestiture on the one hand and the effects of introducing a forward market on the other, and then compare the effects.

Table 1 summarizes our treatments and indicates how they compare with earlier studies, namely Le Coq and Orzen (2006) and Brandts et al. (2008), about which more below.

Table 1: Treatments

	2 producers	**3 producers**	**4 producers**
Without Forward Market	**M2**[#]	M3*	**M4**[†]
With Forward Market	**M2F**[#]	M3F*	–

\# The treatment is different from the one tested in Le Coq and Orzen (2006) in that our producers face quadratic marginal costs.
† The treatment is different from the one tested in Brandts et al. (2008) in that the market has been created from the market with 3 producers by divestiture, not by entry; producers thus have the same set of assets as those in the market with 3 producers.
* The treatment is identical to the one tested in Brandts et al. (2008).

A key characteristic is the number of producers in the electricity market. While there is some variance, assuming two producers for markets in the New EU Member States[9] and three producers for markets in the old EU Member States[10] seems a good approximation.[11]

For the NMS-12 we thus compare outcomes in markets with two producers and without a forward market (M2) with outcomes in such markets with a forward market (M2F). We also compare the difference in outcomes with the difference in outcomes of markets with two (M2) and three producers (M3), when for the latter we add one more producer by means of divestiture. In other words, we compare the differences of M2F – M2 and M3 – M2. In two other markets, calledM2zc and M2Fzc and not shown in Table 1, we replicated experimental treatments of Le Coq and Orzen (2006) by using their cost function (zero production costs). Our results are in

[9]The New EU Member States are the states that acceded to the EU in or after 2004. With the exception of Cyprus and Malta they are all post-communistic countries: Bulgaria (BG), Cyprus (CY), the Czech Republic (CZ), Estonia (EST), Hungary (H), Lithuania (LT), Latvia (LV), Malta (M), Poland (PL), Romania (RO), Slovakia (SK), and Slovenia (SLO).

[10] The old EU Member States are the states that joined the EU before 2004. These are: Austria (A), Belgium (B), England (UK), Germany (D), Denmark (DK), Spain (E), France (F), Finland (FIN), Greece (GR), Italy (I), Ireland (IRL), Luxembourg (L), the Netherlands (NL), Portugal (P), Sweden (S).

[11] The average Hirsch-Herfindahl Index (HHI) for the old (West-European) EU members in 2006 was equal to 3786, which is close to the case where three symmetrical firms compete (HHI = 3333). The new (Central- and East European) EU members had in 2006 a HHI equal to 5558, which is closer to the case where two symmetrical firms compete (HHI = 5000) (Van Koten and Ortmann, 2008). We are aware that extrapolating numbers in the lab to numbers in non-laboratory markets can be fraught with problems (e. g., Selten 1973; see also Huck et al. 2004) but are not aware of evidence that would invalidate our mapping here, so much more so since we are interested in relative (between-treatment) rather than absolute effects.

line with those of Le Coq and Orzen (2006); since these treatments were robustness tests, they are reported in Appendix A2.2.

For the EU-15 we compare outcomes in markets with three producers and without a forward market (M3) with outcomes in such markets with a forward market (M3F). We also compare the difference in outcomes with the difference in outcomes of markets with three (M3) and four producers (M4), when for the latter we add one more producer by means of divestiture. In other words, we compare the differences of M3F – M3 and M4 – M3.

2.2 Earlier experiments

Le Coq and Orzen (2006) conducted experiments in markets with two producers with and without a forward market and compared the outcomes with those in a market with four producers (with and without a forward market); importantly, their producers faced zero production costs. In line with earlier experiments, such as Huck et al. (2004), Le Coq and Orzen (2006) found that producers competed less (more) than predicted with two (four) producers. A forward market had a positive effect, but weaker than expected. Adding two more producers increased output significantly more than introducing a forward market.

Le Coq and Orzen (2006) consider the effects of a forward market in a market with two (and four) producers. While speaking possibly to the reality of electricity markets in the NMS-12 countries, the number of relevant competitors tends to be threeforEU-15countries. Moreover, the assumption that producers have zero marginal costs is unrealistic for all their scenarios. In our experiment, producers therefore face, more realistically (e.g., Newbery, 2002) and in line with Brandts et al. (2008), quadratic marginal costs.

Brandts et al. (2008) conducted experiments in markets with three producers with, and without, a forward market and compared the outcomes with those in a market with four producers (without a forward market). Producers had quadratic marginal costs. Brandts et al. (2008) find that a forward market significantly increases the quantity supplied, but that entry of a new generator increases the quantity supplied significantly stronger than the addition of a forward market.

Brandts et al. (2008) confound, however, two effects in their study: a competition effect[12] and an asset effect. The competition effect is brought about by an additional market participant; this makes the market more competitive and results in lower prices and a larger total number of units supplied. The asset effect is brought about by the additional production assets that are built and paid by a new entrant. Because Brandts et al. (2008) consider the entrance of a new generator, their treatment combines the competition and the asset effect: entrance increases competition, but also the aggregate size of production assets in the market, which reduces the aggregate cost and thus gives an extra incentive to increase production. Thus, assuming efficient production, any given level of aggregate production (the production of all producers together) is produced cheaper in the market with four producers than in the market with three producers. We conjectured that the asset-effect confound led to an overestimation of the effects of adding one more competitor in their study. Moreover, the welfare effects Brandts et al. (2008) report are not conclusive, as they do not take into account properly the very high costs of the increase in the asset base (the cost of building extra production plants).[13]

We therefore focus on the effect of divestiture as a benchmark for the effects of introducing a forward market, thus eliminating the asset effect confound and insulating the competition effect. To allow for comparisons, we drew (to the extent possible) on Brandts et al. (2008) and on Le Coq and Orzen (2006) to parameterize our experiment.[14]

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[12] Brandts et al. (2008) call this effect the “number effect”.

[13] Building electricity generation is very costly: When competition is lacking but there is no shortage of electricity production capacity, entrance leads to wasteful duplication of assets (Green, 1996).

[14] Another paper addressing forward markets is Ferreira, Kujal and Rassenti (2009). Ferreira et al. (2009) find that forward markets have a positive effect on the aggregate production with inexperienced subjects, but no - or a negative - effect with experienced subjects. Producers in their experiment face linear rather than quadratic marginal costs. Also, subjects had a mere 30 seconds to make a decision and no extra time to review the results, whereas the subjects in our study had 60 seconds to make a decision and another 60 seconds to review the result of that decision. Moreover, in the experiment of Ferreira et al. (2009) the treatments with experienced subjects were different from the treatments with inexperienced subjects in important details. For example, the experienced subjects did not have production costs and the demand function

2.3 Demand and supply

As in Brandts et al. (2008), the demand schedule is $p[Q] = Max[0, 2000 - 27Q]$, $Q \geq 0$. Also as in Brandts et al. (2008), we chose to program the demand side rather than have it enacted by experimental participants. This might reduce demand uncertainty which in turn is likely to influence (the speed of) convergence in our market. We believe it to be unlikely for this choice to interact with treatment effects in a differential and significant manner.

For our main treatments we model generators as incurring quadratic marginal costs. Marginal costs of producing electricity usually have a hockey-stick shape, i.e., they are flat with a sharp increase when capacity constraints become binding (Newbery, 2002). We consider quadratic marginal costs to be a reasonable approximation to the real marginal costs of electricity generators.

To be able to compare our results with those of Brandts et al. (2008), we also use the same specification of the costs for markets with three producers, abbreviated by M3for the market without forward market and by M3F for the market with forward market. Brandts et al. (2008) set the marginal cost of producing the i^{th} unit for a producer equal to $mc_3[q] = 2q^2$, cumulative costs can thus be calculated as $c_3[q] = \sum_{x=1}^{q} 2x^2 = 2/3\, q^3 + q^2 + 1/3\, q$.

The market with four producers, M4, is created from the market with three producers, M3, by divestiture; each of the three producers divests ¼th of their assets, and these three sets of assets are used to create a fourth,

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they faced was different. In addition, due to random matching, the experiment draws on very few independent data points (1 or 2).

We found their result that experience seemed to decrease the competitive effect of a forward market nonetheless interesting and, as a robustness test, ran additional sessions with experienced subjects for some of our treatments. Our subjects were experienced in the sense that they had participated in the experiment earlier. As a matter of fact, our experienced subjects were assigned to exactly the same treatment as the one in which they had participated earlier (with the exception for experienced subjects in treatment M2, where some subjects had participated previously in M3 or M4). We do not find that experienced subjects have a lower aggregate production than inexperienced subjects. On the contrary, our experienced subjects supply a slightly higher production which is in line with the experimental literature on the effect of experience on public good provision (Ledyard, 1995). We report the detailed results as a robustness test in Appendix A4.

identical producer. The markets with two producers, M2 and M2F, are created from the market with three producers, M3, by reversing the divestiture process (merger): one of the producers is split in halves and their assets are merged to the two remaining producers to create two larger, identical, producers. With the cost function of a producer in M3 given, the cost functions of producers in M2 and M4 can be calculated: $c_2[q] = 2/27\, q^3 + 2/3\, q^2 + 1/3\, q$, and $c_4[q] = 22/27\, q^3 + 4/3\, q^2 + 1/2\, q$.[15]

Note that the electricity generation asset base is the same for all three markets (M2, M3, and M4). Therefore, when generators make identical choices and the aggregate production is equal over different markets, the aggregate costs must also be equal.

[15] If all the assets in M3 would be merged into one single firm (M1), then this single firm would minimize its costs by dividing production equally over the three plants. The total costs of the firm in M1 would thus be $c_1[q] = 3 \cdot c_3\left[\frac{q}{3}\right]$. Likewise, if we started with M2 and merged the assets of the two firms into one single firm, then the cost function of the single firm in M1 would be given by $c_1[q] = 2 \cdot c_2\left[\frac{q}{2}\right]$. Now we can derive the cost function for a firm in M2: from $2 \cdot c_2[q/2] = c_1[q] = 3 \cdot c_3[q/3]$ follows that $c_2[q] = 3/2\, c_3[2/3\, q] = 8/27\, q^3 + 2/3\, q^2 + 1/3\, q$. In the same manner we can derive the cost function for a firm in M4: $c_4[q] = 3/4\, c_3[4/3\, q] = 32/27\, q^3 + 4/3\, q^2 + 1/3\, q$. Notice that for marginal costs the following equality holds: $c_2{}'[3/2\, q] = c_3{}'[q] = c_4{}'[3/4\, q]$. In line with intuition, the marginal costs of a firm in M3 thus increase faster (slower) than in M2 (M4).

Table 2summarizes the production costs for each generator in the market with two (M2), three (M3) and four (M4) generators, and identifies aggregate production in one market being equal to that in another market by bold numbers and colored cells. For example, the aggregate production in M2 (M4) is equal to that in M3 when the total number of units can be divided both by two (four) and three.

Table 2:[16] Overview of aggregate costs of producing

Market with two producers (after merger)					**Market with three producers (original market)**					**Market with four producers (after divestment)**				
Each Producer			Aggregate		Each Producer			Aggregate		Each Producer			Aggregate	
Units produced by each producer	Marginal Costs	Total Costs	Total Production	**Total Costs**	Units produced by each producer	Marginal Costs	Total Costs	Total Production	**Total Costs**	Units produced by each producer	Marginal Costs	Total Costs	Total Production	**Total Costs**
N	MC	TC	2*N	**2* TC**	N	MC	TC	3*N	**3*TC**	N	MC	TC	4* N	**4*TC**
0	0	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**
1	1	1	2	2	1	2	2	3	6					
2	5	6	4	**11**						1	3	3	4	**11**
3	9	15	6	**30**	2	8	10	6	**30**					
4	16	31	8	**62**						2	12	15	8	**62**
5	24	55	10	111	3	18	28	9	84					
6	35	90	12	**180**	4	32	60	12	**180**	3	30	45	12	**180**
7	47	137	14	273	5	50	110	15	330					
8	60	197	16	**394**						4	54	99	16	**394**
9	76	273	18	**546**	6	72	182	18	**546**					
10	93	366	20	**733**						5	84	183	20	**733**
11	113	479	22	957	7	98	280	21	840					
12	133	612	24	**1224**	8	128	408	24	**1224**	6	123	306	24	**1224**
13	156	768	26	1536	9	162	570	27	1710					
14	180	948	28	**1897**						7	168	474	28	**1897**
15	207	1155	30	**2310**	10	200	770	30	**2310**					
16	235	1390	32	**2779**						8	221	695	32	**2779**
17	264	1654	34	3308	11	242	1012	33	3036					
18	296	1950	36	**3900**	12	288	1300	36	**3900**	9	280	975	36	**3900**
19	329	2279	38	4559	13	338	1638	39	4914					
20	365	2644	40	**5287**						10	347	1322	40	**5287**
21	401	3045	42	**6090**	14	392	2030	42	**6090**					
22	440	3485	44	**6970**						11	420	1742	44	**6970**
23	480	3965	46	7931	15	450	2480	45	7440					
24	523	4488	48	**8976**	16	512	2992	48	**8976**	12	502	2244	48	**8976**
25	567	5055	50	10109	17	578	3570	51	10710					
26	612	5667	52	**11334**						13	590	2834	52	**11334**
27	660	6327	54	**12654**	18	648	4218	54	**12654**					
28	709	7036	56	**14073**						14	684	3518	56	**14073**
29	761	7797	58	15593	19	722	4940	57	14820					
30	813	8610	60	**17220**	20	800	5740	60	**17220**	15	787	4305	60	**17220**
31	868	9478	62	18956	21	882	6622	63	19866					
32	924	10402	64	**20805**						16	896	5201	64	**20805**
33	983	11385	66	**22770**	22	968	7590	66	**22770**					
34	1043	12428	68	**24855**						17	1013	6214	68	**24855**
35	1104	13532	70	27064	23	1058	8648	69	25944					
36	1168	14700	72	**29400**	24	1152	9800	72	**29400**	18	1136	7350	72	**29400**
37	1233	15933	74	31867	25	1250	11050	75	33150					

[16] Numbers have been rounded to the nearest whole number.

38	1301	17234	76	**34467**						19	1267	8617	76	**34467**
39	1369	18603	78	**37206**	26	1352	12402	78	**37206**					
40	1440	20043	80	**40086**						20	1405	10022	80	**40086**
41	1512	21555	82	43111	27	1458	13860	81	41580					
42	1587	23142	84	**46284**	28	1568	15428	84	**46284**	21	1549	11571	84	**46284**
43	1663	24805	86	49609	29	1682	17110	87	51330					
44	1740	26545	88	**53090**						22	1702	13273	88	**53090**
45	1820	28365	90	**56730**	30	1800	18910	90	**56730**					
46	1901	30266	92	**60533**						23	1860	15133	92	**60532**
47	1985	32251	94	**64501**	31	1922	20832	93	**62496**					
48	2069	34320	96	**68640**	32	2048	22880	96	**68640**	24	2027	17160	96	**68640**

The blue areas in a row show that the aggregate costs (in bold) are equal for markets of different sizes when the aggregate production is the same (assume efficient production).

To not unduly add to our subjects' cognitive load, we presented costs that were rounded according to the following rounding rules:

- All numbers smaller than 100 were rounded to the nearest integer: Thus, for example, 21.2 were rounded to 21 and 46.6 to 47.
- When a number was larger than 100, it was rounded to the nearest integer divisible by 5: Thus, for example, 121 was rounded to 120 and 147 to 150.
- When a number was larger than 1000, it was rounded to the nearest integer divisible by 10: Thus, for example, 1021 was rounded to 1020 and 1047 to 1050.
- When a number was larger than 10000, it was rounded to the nearest integer divisible by 50: Thus, for example, 10021 was rounded to 10000 and 10043 to 10050.

As a result these rounding rules, some of the aggregate total costs in Table 2 are different. The discrepancy is negligible, however; on average the absolute discrepancy is 0.12%. For the "rounded numbers" version of Table 2, see Table A1 in the Appendix.

The numbers we obtained after this rounding procedure were also the numbers we used to calculate the theoretical predictions.[17]

[17] Using the exact numbers gives virtually identical theoretical predictions.

2.4 Theoretical Predictions and Hypotheses

With demand given and the cost function defined, the profit function is given by $\pi_{i,MS} = p[q_i + q_{-i}](q_i - f_i) - c_{MS}[q_i]$ for market size $MS \in \{2,3,4\}$, where the cost functions are defined as above by $c_2[q] = 8/27\, q^3 + 2/3\, q^2 + 1/3\, q, c_3[q] = \sum_{x=1}^{q} 2x^2 = 2/3\, q^3 + q^2 + 1/3\, q$, and $c_4[q] = 32/27\, q^3 + 4/3\, q^2 + 1/3\, q$. We can now determine the Nash-equilibria for each of the treatments, keeping in mind that the subjects can choose only integer values for production.

Table 3: Theoretical predictions electricity markets

	NE M2	**NE M2F (two Nash-equilibria)**		NE M3	**NE M3F**	NE M4	Walras (M2, M2F)	Walras (M3, M3F)	Walras (M4)	JPM (M2, M2F)	JPM (M3)	JPM (M4)
q_{ti}^f	–	2	11	–	5	–	–	–	–	–	–	–
q_{ti}	20	20	22	14/15[18]	15	11	25/26[19]	17	13	16	11	8
q_t	40	40	44	43	45	44	51	51	52	32	33	32
p_t	920	920	812	839	785	812	623	623	596	1136	1109	1136
Prod.S.	31520	31520	28768	29537	27885	28768	21053	21063	19672	33572	33567	33572
Cons.S.	21060	21060	25542	24381	26730	25542	34425	34425	35802	13392	14256	13392
Total S.	52580	52580	54310	53918	54615	54310	55478	55488	55474	46964	47823	46964
Eff.(%)	94.8	94.8	97.9	97.2	98.4	97.9	100	100	100	84.7	86.2	84.7

Explanation of row terms: NE stands for the Nash-equilibrium, Walras for the Walrasian (welfare optimizing) equilibrium, and JPM for joint profit maximization (collusion).

Table 3 shows the theoretical predictions for our main treatments M2, M2F, M3, M3F, and M4.[20] The prefix NE stands for Nash equilibrium, Walras for the efficient solution (the outcome that maximizes the total surplus), [21] and JPM for Joint Profit Maximization (the monopoly solution).[22]

[18] One generator produces 15 units, the other two 14 units.

[19] One generator produces 26 units, the other two 25 units.

[20] The Nash equilibria have been numerically determined with *MATHEMATICA*. The set of programs can be downloaded as RAR file named "Nash-Equilibria with Forward Markets. rar", at https: //sites. google. com/site/slvstrnl/ElectricityMarketsExperiment. The predictions are based on the cost functions with numbers rounded according to the rounding procedure described in the body of the text. Predictions based on the continuous cost functions

Explanation of column terms: q_{ti}^f stands for the forward production of each producer, q_{ti} for the total production of forward (if it is present) and spot market for each producer, q_t for the total *aggregate* production of forward (if it is present) and spot market for all producers together, p_t for the price, *Prod.S* for producer surplus, *Cons.S* for consumer surplus, *Total.S* for total surplus, *Eff.(%)* for efficiency in percentage.

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are, except for the M2F condition, mostly identical: the chosen quantities are identical, and the difference in total surplus is less than 0. 02% and hence negligible. In the M2F condition the chosen quantities in the low Nash-equilibrium are lower when using the continuous functions – 40 instead of 42, hence the difference in total surplus is1. 8%.

[21] We define efficiency, following Brandts et al. (2008), as the joint consumer and producer surplus realized in the experiment divided by the maximum joint consumer and producer surplus (the Walrasian level of joint surplus).

[22] The market outcomes for JPM (M3, M3F) , JPM (M4), NE (M3), NE (M3F), Walras (M3, M3F), and Walras (M4) in this experiment are identically to those in Brandts et al. (2008), and our predictions are almost identical to the ones reported in their paper. Key differences are: Using the functions without a rounding procedure, we find that for the Nash-equilibrium with three producers NE (M3) the price is equal to 839 (rather than 866). For the welfare maximizing outcome with four generators, Walras (M4), we find that all three generators produce 14 units and one of them 15 units, instead of all of the generators producing 14 units. Total welfare is therefore 60799 and not 60788. For the monopoly case with four generators, JPM (M4), two generators produce 9 units and two 8 units, instead of all of them 8 units. As a result the producer surplus is higher, 34832 instead of 34728, the consumer surplus is lower, 15147 instead of 17010, and efficiency is lower, 82. 2% instead of 85. 1%. Also, when calculating the Nash-equilibrium with four producers with the cost function Brandts et al. (2008) used, we find that the price is equal to 677 rather than 704. Also, the producer surplus of M4 in this case is equal to 27635 rather than 27638.

For the Nash-equilibrium with three producers and a forward market (M3F), we find a unique symmetrical Nash-equilibrium in pure strategies where each producer sells 5 units in the forward market, and 10 additional units in the spot market. This is different from Brandts et al. (2008) who consider for their forward market (M3F) treatment partially mixed strategies (for the choice of additional units) and find an equilibrium where each producer sells 6 units in the forward market, and an additional 9 with probability . 944 and 10 with probability 0. 056. As we find a unique symmetric Nash-equilibrium in pure strategies, we do not follow Brandts et al. (2008) in broadening the equilibrium concept for this treatment (mixed strategies are also not considered for the other treatments). We note that the total (expected) production by all three producers is the same according to our computations and those reported by Brandts et al. (2008) – 45 units.

The theoretical predictions give us, for the particular parameterizations chosen, an indication of the effect on aggregate production and efficiency of either introducing a forward market or of adding one more competitor. We use these indications to formulate the hypotheses in Table 4.

Table 4: Hypotheses

Hq.1 (Quantity)	**HΩ.1 (Efficiency)**	**HΦ.1 (Production Efficiency)**
- q(M3F) > q(M4) > q(M3)	- Ω(M3F) > Ω(M4) > Ω(M3)	- Φ(M3F) = Φ(M3)
		- Φ(M4) < Φ(M3)

Hq.2 (Quantity)	**HΩ.2 (Efficiency)**	**HΦ.2 (Production Efficiency)**
- q(M3) > q(M2F) > q(M2)	- Ω(M3) > Ω(M2F) > Ω(M2)	- Φ(M2F) = Φ(M2)
		- Φ(M3) < Φ(M2)

Hq.3 (Quantity)	**HΩ.3 (Efficiency)**	
- q(M4) > q(M2F)	- Ω (M4) > q (M2F)	

Hypothesis 1 makes comparisons between markets with three and four producers. Both introducing a forward market and adding one more competitor to a market with three producers increases aggregate production, but introducing a forward market increases aggregate production more. Using q(x) to denote aggregate production in market structure x,[23] we thus conjecture that the remedies can be ranked as follows: q(M3F) > q(M4) > q(M3). Likewise, both remedies also increase efficiency, but introducing a forward market again is predicted to increase efficiency the most. Using Ω (x) to denote efficiency in market structure x, we thus conjecture that the remedies can be similarly ranked: Ω (M3F) > Ω (M4) > Ω (M3). We also test for effects on production efficiency. We define production efficiency, following Brandts et al. (2008), as the actual producer surplus divided by the producer surplus had production taken place in the most efficient manner. As marginal costs are quadratic, production is fully efficient only if the aggregate production is evenly distributed over the producers. Like Brandts et al. (2008) we assume that more producers in a market should make it more difficult to achieve an even distribution, but that introducing a forward market should not have an effect. We thus conjecture Φ(M4) < Φ(M3), and Φ(M3F) = Φ(M3).

[23] To facilitate comparisons with related literature, we use the same notation as Brandts et al. (2008). Also parts of our presentation have been inspired by Brandts et al. (2008).

Hypothesis 2 makes comparisons between markets with two and three producers. Adding one more competitor to a market with two producers increases aggregate production. Introducing a forward market in a market with two producers results in two welfare-rankable Nash-equilibria: one with quantity 40 ("low")and one with quantity 44 ("high"). We have no prior and we thus conjure that each Nash-equilibrium has an equal probability to be played. We therefore conjecture that the remedies can be ranked as follows: q(M3) > q(M2F) > q(M2).[24] Both remedies also increase efficiency. We conjecture that: Ω(M3) > Ω (M2F) > Ω(M2). For productive efficiency we assume again that more producers in a market should make it more difficult to achieve an even distribution, while introducing a forward market should not have an effect. We thus conjecture Φ(M3) < Φ(M2) and Φ(M2F) = Φ(M2).

Hypothesis 3 makes comparisons between markets with two and four producers. The theoretical results suggest that the effect of introducing a forward market is not as large as that of adding two more competitors; we thus conjecture q(M4) > q(M2F) and Ω(4) > Ω(M2F).

2.5 Experimental procedures

The experimental sessions were conducted in October 2009, December 2009, and April 2010 in Prague at CERGE-EI.[25] Our subjects were students at the Charles University or at the University of Economics, both

[24] The ranking depends on whether the high or the low Nash-equilibrium is mostly played. When only the lower is played, the ranking is: Q(M2F) = Q(M2), Q(M3) > Q(M2), AND Q(M2F) < Q(M3). When only the higher is played, the ranking is: Q(M2F) > Q(M2), Q(M3) > Q(M2), AND Q(M2F) > Q(M3). Assuming that both Nash-equilibria will be played with equal probability results in the predictions that Q(M2F) > Q(M2) and Q(M2F) < Q(M3).

[25] We obtained in October 2009 four data points for each treatment, in December 2009 four data points for M2zc, M2Fzc, M2F, M2, , M3, and three data points for treatments M3F and M4, and in April 2010 three data points for M2zc, M2Fzc, M2F, M2, M3, and four data points for the treatments M3F and M4. The original game plan was to obtain additional four data points for all treatments in December 2009. Unusual numbers of no-shows for treatments M3F and M4 derailed that plan. Several pilot sessions were run during the summer of 2009. None of the subjects in the pilot (mostly CERGE-EI students) participated in the regular sessions. We also ran an experimental session in October 2010 as a robustness test for the effect of subject experience. The October 2010 data are only used in the robustness test reported in Appendix A4.

located in Prague. A total of 198 students participated. The sessions with a forward market lasted about 2 hours, the sessions without forward market lasted about 90 minutes. The subjects earned on average 382 Czech Koruna per hour including a show-up fee of 100 Korunas. Subjects thus earned on average 640 Korunas[26], with the minimum earning being 330 and the maximum earning being 1080 Korunas, indicating that our experiment was well incentivized on the margin. The same experimenter read the (English language) instructions to the subjects for all sessions.

The market simulation was programmed in Z-Tree (Fischbacher, 2007). As mentioned, the demand schedule was pre-programmed. Experimental participants enacted the roles of producers and sellers. They were not shown the demand schedule but were given on screen, and as printout, an earnings-table. During the experiment subjects were shown, after they had submitted their choice for the (forward) spot market, the following outcomes: the aggregate quantity sold, the resulting price per unit on the (forward) spot market, their own profit, and their own marginal and cumulative costs. Subjects were not shown their competitors' profits, costs, or individual contributions to the aggregate quantity sold. In the treatment with two subjects, M2 and M2F, subject could, however, calculate the competitor's individual contribution.

In the treatments with a forward market every round had two periods, the first period for the forward market and the second period for the spot market. In the first period, producers decided how many units to produce and to sell in the forward market. Producers sold units to traders. The units that producers sold were promises to produce and to deliver units to traders in the second period (in the spot market). The units that were sold in the forward market were thus produced later, in the second period.

In the forward market two pre-programmed traders competed in prices for the total number of units that were offered.[27] Traders were programmed to act rationally, with their actions defining a demand schedule, which we

[26] This amount equaled about €26 (and about €36at official purchasing power parity, and even more on student-specific purchasing power parity). In other words, the earnings were salient and certainly in line with standard remuneration practices in experimental economics.

[27] In our experiment traders are, as in Le Coq & Orzen (2006), pre-programmed. The manner in which traders are represented in the experiment should not significantly affect outcomes, as traders are middlemen (between producers in the forward market and end demand in the spot market). Earlier experimental evidence indicates that the presence of

presented to our producers.[28] The trader that offered the highest price per unit won all units. When they offered the same price – which they do in equilibrium – a winner was drawn at random. As the pre-programmed traders were rational and competed in prices, they could predict the Nash-equilibrium spot price and offer this price for the units offered in the forward market. The pre-programmed traders didn't observe the number of units offered by each producer, only the total number of units. They assumed that producers offered an equal number of units in the forward market.[29] Using this assumption, the traders were programmed to predict, conditional on the total number of units offered in the forward market, q^f, the Nash-equilibrium total production in the spot market: $q^{NE}[q^f]$.[30] By substituting the predicted total production in the spot market in the demand schedule, the traders predicted the Nash-equilibrium price in the spot market: $p[q^{NE}[q^f]]$. As traders offered the Nash-equilibrium price for all units, $p[q^{NE}[q^f]]$ defines the demand schedule in the forward market. Producers were shown this forward-market demand schedule in the first period of each round; they could thus use this information when deciding on the number of units to offer in the forward market. At the end of the period, all producers were paid the number of units they produced in the forward market times the price per unit minus the production cost. Appendix A3 shows the predicted aggregate production and price in the spot market, conditional on the total production in the forward market (stage A).

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strategically acting middlemen generally does not alter allocations and that the profit of middlemen converges to zero quickly (Plott & Uhl, 1981). Brandts et al. (2008) use experimental subjects as traders and find indeed that traders earn only a small fraction (about 8%) of the profits that a producer earns.

[28] The full consolidated instructions can be downloaded at https: //sites. google. com/site/slvstrnl/electricitymarketsexperiment.

(**For ease of access, and refereeing purposes, the consolidated instructions are submitted in the accompanying file**).

[29] When the total of units sold forward is not divisible by the number of producers in the market, the trader assumes that the numbers of units sold forward by each producer are as close as possible. For example, when the total number of units sold forward is 14 in M3, the trader assumes that two producers sold 5 units and one producer 4 units. Violation of this assumption affects the prediction only minimally.

[30] This procedure is virtually identical to the one used in Le Coq and Orzen (2006).

In the second period of each round, producers decided the number of units to produce and sell in the spot market. The pre-programmed traders sold all the units they bought. The price per unit was determined by substituting the number of units sold by all producers in the forward and spot market together for Q in the demand schedule $p[Q] = Max[0, 2000 - 27Q]$. All producers were paid the number of units they produced in the spot market times the price per unit minus the production cost.

3. Results

Being conservative, we treat each set of sellers ("a group") in a particular treatment as one data point only. We thus have 11 statistically independent data points for all treatments; since each participant took part in one experimental session only, data points are also independent across treatments. None of the participants went bankrupt.

Each treatment consisted of 24 rounds. For our statistical tests, we use only the last 12 rounds of the data, as the experiment is complicated and, we know – for example, from relatively easy auction experiments – that subjects need several rounds of trading to become familiar with the laboratory environment before they react to the embedded incentives (Hertwig and Ortmann, 2001).[31]

Following Le Coq and Orzen (2006), we test for disparity with the Nash-equilibrium predictions using two-sided Wilcoxon one-sample signed-rank tests (two-sided signed-rank tests), unless indicated otherwise. For comparison between the averages of the treatment in our experiment, we use, following Brandts et al. (2008), F-tests based on an OLS regression of the dependent variable on the 5 treatment dummies, M2, M2F, M3, M3F, and M4, without a constant (F-tests). The error terms are adjusted for clustering at the group level by using the robust Huber/White/sandwich estimator (Froot, 1989). In addition, we ran robustness tests using, as did Le Coq and Orzen (2006), Wilcoxon rank-sum tests (rank-sum tests). These tests confirmed most of the results presented here.[32] The results of these tests can be found in Appendix A2.1.

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[31] Including all 24 rounds does not change our results qualitatively and most results remain strongly significant.

[32] We also ran Jonckheere tests for all our hypotheses. As these tests confirm the results of our F-tests and rank-sum tests, we do not report them.

3.1. Aggregate Quantity

Figure 1shows the evolution of total (aggregate) quantities sold per period, averaged over treatment groups. Treatments with two producers are represented by circles, with three producers by triangles, and with four producers by squares. The treatments without forward markets are represented by open circles, triangles or squares, the treatments with forward markets by filled circles or triangles.

The trade volume in all treatments starts out rather low[33] but then moves quickly into the direction of the Nash-equilibrium. Production stabilizes between rounds 8 and 12.

Figure 1: Aggregate production

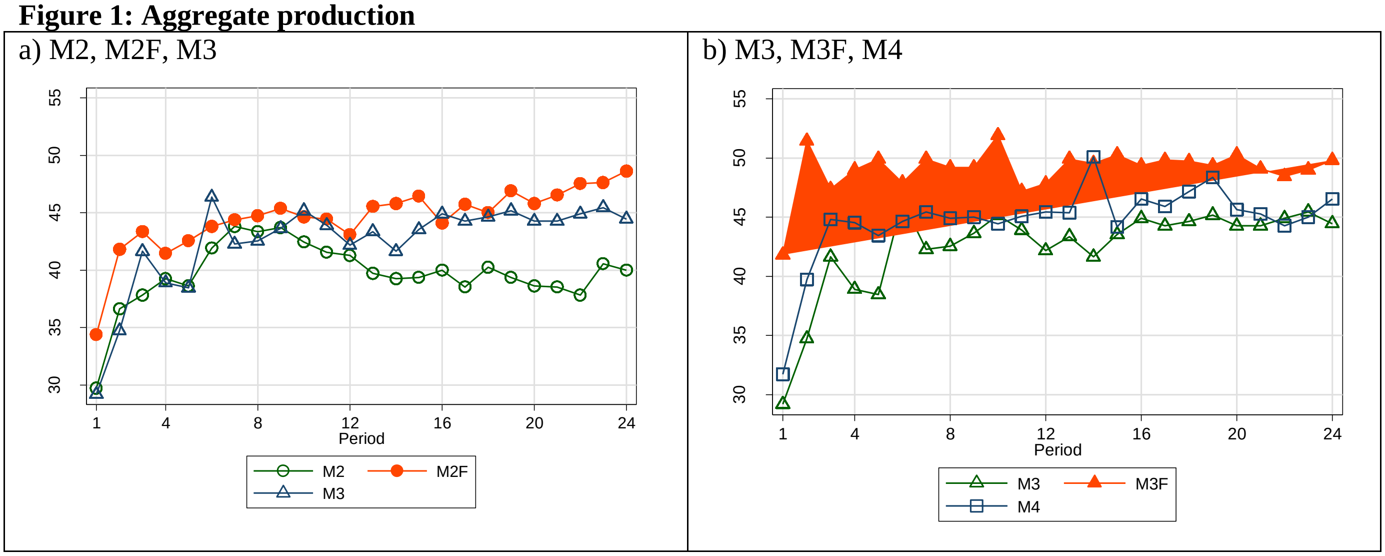

Table 5 shows the overall average aggregate production per treatment group, with the standard error in parenthesis.[34] The row below gives the size of the observed aggregated quantity relative to the Nash-equilibrium prediction in percentages.

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[33] It is likely that these trajectories are anchored by the examples in the instructions in which we used low numbers to facilitate understanding of the basic relationships. Loss averse behavior in the light of initially considerable uncertainty could be another explanation.

[34] The standard error is computed based on the averages for each of the 11 independent groups over the last 12 rounds.

Table 5 Production averages in the last 12 rounds

	M2	M2F	M3	M3F	M4
Average production	39.3 (1.52)	46.3 (2.06)	44.2 (1.22)	49.6 (0.61)	46.2 (0.98)
% of NE prediction	*98.7%*	*116 %/ 105%*[35]	*102.9%*	*110.1%*	*105.0%*
Number of observations	N = 11	N = 11	N = 11	N = 11	N = 11
% of NE prediction - earlier studies[36]	*93. 2%, Le Coq and Orzen(2006) 92.7%, Huck et al. (2004)*	*93.8%, Le Coq and Orzen (2006)*	*102.7%, Huck et al. (2004) 98.9%, Brandts et al. (2008)*	*103.6%, Brandts et al. (2008)*	*113.7%, Le Coq and Orzen (2006) 102.8%, Brandts et al. (2008) 102.9%, Huck et al. (2004)*

In the M2 and M2F conditions the standard error is relatively high. Of the treatments without forward markets, M2 and M3 are not significantly different from the Nash-equilibrium predictions (two-sided signed rank test, both p-values > 0.32), while M4 is significantly larger (p-value = 0.068). Of the treatments with a forward market, the production in M3F is significantly higher than the Nash-equilibrium (p-value = 0.004) and

[35] The first number gives the percentage of output relative to the low production Nash-equilibrium, the second number relative to the high production Nash-equilibrium.

[36] The averages by Huck et al. (2004) reported here are based on their meta-analysis of 19 experiments with Cournot competition. A Wilcoxon signed-rank test indicates that our results are not significantly different from their results (p-values for M2, M3 and M4 are 0. 155, 0. 657 and 0. 534 respectively). Compared with Brandts et al. (2008), the production is significantly higher in condition M3F (p < 0. 006) and not significantly different in the conditions M3 (p-value = 0. 213) and M4 (p-value = 0. 534). Compared with Le Coq and Orzen (2006), production is significantly higher in conditions M2F (p-value = 0. 010 for the low and p-value = 0. 033 for the high Nash-equilibrium) and M4 (p-value = 0. 010) and not significantly different in condition M2 (p-value = 0. 182). For comparison, we also ran treatments with zero production costs, M2zc and M2Fzc. In these treatments the average production is 83% of the Nash-equilibrium prediction which is significantly lower than Le Coq and Orzen (2006) found (both p-values < 0. 041). The results of these tests may be found in Appendix A2.

production in M2F is significantly higher than the low Nash-equilibrium (p-value = 0.021) but not significantly different from the high Nash-equilibrium (p-value = 0.248).

Without a forward market, when the number of competitors is equal to two (three or four), production tends to be smaller (larger) than the Nash-equilibrium, which is in line with earlier findings (Le Coq and Orzen, 2006; Huck, Normann, and Oechssler, 2004). We see no evidence for stable collusion; indeed the data suggest the opposite. A regression of aggregate production on the period of the experiment shows a significant upwards slope, suggesting that over time, as subjects become more experienced with the task, they become less likely to collude.

Table 6: Effects of one more competitor and forward market on quantities, Hq.1, Hq.2, and Hq.3

	OLS regression, with correction for clustering on group level, followed by an one-sided F-test on equality of the coefficients (Clustering on group)		
Hq.1 - Markets with 3 producers	**q(M3F) > q(M3)*** (p < 0.001)**	q(M4) > q(M3) (p = 0.105)	**q(M3F) > q(M4)*** (p = 0.002)**
Number of observations (independent groups)	N = 792 (11)	N = 924 (11)	N = 924 (11)

Hq.2 - Markets with 2 producers	**q(M2F) > q(M2)*** (p = 0.003)**	**q(M3) > q(M2)** (p = 0.006)**	q(M3) > q(M2F) (p = 0.813)
Number of observations (independent groups)	N = 528 (11)	N = 660 (11)	N = 660 (11)

Hq.3	q(M4) > q(M2F) (p = 0.521)
Number of observations (independent groups)	N = 792 (11)

Table 6 presents the results of the F-tests based on OLS regressions.[37]

[37] As a robustness test we also compared the averages for the groups using a two-sample Wilcoxon rank-sum (Mann-Whitney) test. The hypotheses accepted (rejected) are the same, except for Hypothesis 2. b (which becomes insignificant) and Hypothesis 3. c (which becomes significant). See the Appendix for a detailed analysis.

Results testing Hypothesis q.1: In markets with 3 competitors, introducing a forward market increases production, and the effect is stronger than adding one more competitor, q(M3F) > q(M3), and q(M3F) > q(M4).

We find partial support for Hypothesis q.1:

- q(M3F) ≤ q(M3) is REJECTED in favor of q(M3F) > q(M3), p-value < 0.001.
- q(M4) ≤ q(M3) is NOT rejected in favor of q(M4) > q(M3) , p-value = 0.105.
- q(M3F) ≤ q(M4) is REJECTED in favor of q(M3F) > q(M4) , p-value = 0.002.

Introducing a forward market increases aggregate production 12% in markets with three competitors (q(M3F) > q(M3), p-value < 0.001). This confirms earlier findings such as in Brandts et al. (2008). Adding one more competitor in markets with three competitors increases aggregate production 4%, and this effect is barely significant, p-value = 0.105). We find that introducing a forward market increases the aggregate production by 7% more than increasing competition by adding one more competitor, and this difference is strongly significant (q(M3F) > q(M4), p-value = 0.002).

Results testing Hypothesis q.2: In markets with 2 competitors, both introducing a forward market and adding one more competitor increases production, and the latter effect is not stronger than the first(M2F) > q(M2), q(M3) > q(M2), and NOT q(M3) > q(M2F).

We find partial support for Hypothesis q.2:

- q(M2F) ≤ q(M2) is REJECTED in favor of q(M2F) > q(M2), p-value = 0.003.
- q(M3) ≤ q(M2) is REJECTED in favor of q(M3) > q(M2) , p-value = 0.006.
- q(M3) ≤ q(M2F) is NOT rejected in favor of q(M3) > q(M2F) , p-value = 0.813.

In line with the theoretical predictions, introducing a forward market increases aggregate production by18% in markets with two competitors. This increase is strongly significant (q(M2F) > q(M2), p-value = 0.003). Adding one more competitor in markets with two competitors increases aggregate production by 12%. This increase is significant (q(M3) > q(M2), p-value = 0.006). Adding one more competitor does not increase aggregate production significantly more than introducing a forward market (p-value = 0.813). We thus cannot reject q(M2F) ≥ q(M3). Our data in fact suggest the ranking q(M2F) > q(M3), as q(M2F) is 5%higher than q(M3).

Results testing Hypothesis q.3: Adding two more competitors does not increase production more than adding a forward market, q(M4) ≤ q(M2F).

We find no support for Hypothesis q.3:

- q(M4) ≤ q(M2F) is NOT rejected in favor of q(M4) > q(M2F), p-value = 0.521.

Doubling the number of competitors does not increase production significantly more than introducing a forward market. This is in contrast with the theoretical predictions. Our data indicate the opposite ordering instead; q(M2F) is 4% higher than q(M4). This is surprising as Le Coq and Orzen (2006) found that the production of two competitors *with* forward market is strictly lower than that of four competitors *without* a forward market. Recall that in our treatments producers have steeply increasing production costs, while in their treatments producers have zero costs. Our result thus suggests that production costs make it harder for producers to collude. Indeed, in our treatments with two producers with production costs, M2 and M2F, subjects produced more than the Nash equilibrium, while in our treatment with two producers and zero costs, M2zc and M2Fzc, subjects produced fewer units than the Nash equilibrium. See the Appendix 2.2 for a detailed discussion of our results for M2zc and M2Fzc.

3.2. Efficiency

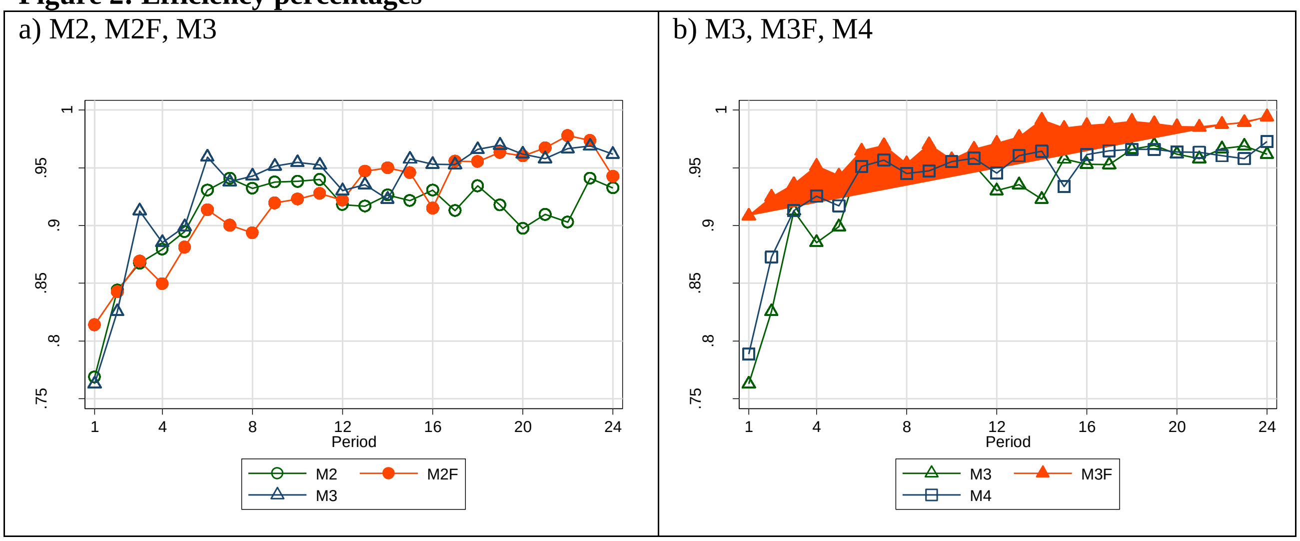
As mentioned above, we define efficiency, following Brandts et al. (2008), as the joint consumer and producer surplus realized in the experiment divided by the maximum joint consumer and producer surplus (the Walrasian level of joint surplus). For the markets with a forward market, these measures are based on the outcomes in the forward and spot market together.

Table 7 shows the observed average efficiency level in the last 12 rounds, with the standard error in parenthesis. The row below gives the level of the observed average efficiency level relative to the Nash-equilibrium prediction in percentages. The efficiency levels are close to the Nash-equilibrium prediction; efficiency is significantly lower in M2 (p-value < 0.068) and higher in M2F (p-value = 0.083 in the low and 0.790 in the high Nash-equilibrium). This is mostly in line with earlier findings such as those in Brandts et al. (2008).

Figure 2 show the evolution of efficiency per period, averaged over groups. Efficiency quickly converges and after period 8 its level is equal or higher than 90% for all treatments except M2. The highest efficiency levels in the last twelve periods are realized by treatments with forward markets, M2F and M3F.[38]

Table **7** shows the observed average efficiency level in the last 12 rounds, with the standard error in parenthesis. The row below gives the level of the observed average efficiency level relative to the Nash-equilibrium prediction in percentages. The efficiency levels are close to the Nash-equilibrium prediction; efficiency is significantly lower in M2 (p-value < 0.068) and higher in M2F (p-value = 0.083 in the low and 0.790 in the high Nash-equilibrium). This is mostly in line with earlier findings such as those in Brandts et al. (2008).

Figure 2: Efficiency percentages



[38] See the Appendix for graphs of efficiency levels per period for the individual treatment together with the Nash-equilibrium prediction.

Table 7: Efficiency averages in the last 12 rounds

	M2	M2F	M3	M3F	M4
Average efficiency as % of Walras	92.0 (1.71)	95.5 (1.73)	95.6 (0.77)	98.7 (0.32)	96.1 (0.57)
% of NE prediction	97.2%	97.5%/100.7%[39]	98.3%	100.5%	98.6%
Number of observations	N = 11	N = 11	N = 11	N = 11	N = 11
% of NE prediction - earlier studies[40]	92.5%, Le Coq and Orzen (2006)	93, 6%, Le Coq and Orzen (2006)	94.2%, Brandts et al. (2008)	96.7%, Brandts et al. (2008)	95.4%, Brandts et al. (2008) 109.3%, Le Coq and Orzen (2006)

Error! Not a valid bookmark self-reference. presents the results of the F-tests.[41] Aggregate production in the market is the most important determinant of efficiency, as production inefficiency has minor influence only. The results of the tests of hypotheses regarding efficiency thus closely follow those regarding aggregate production.

Table 8: Effects of one more competitor and forward market on efficiency, HΩ.1, HΩ.2 and HΩ.3

	OLS regression, with correction for clustering on group level, followed by an one-sided F-test on equality of the coefficients (Clustering on group)		
HΩ.1 - Markets with 3 producers	**Ω(M3F) > Ω(M3)*** (p < 0.001)**	Ω(M4) > Ω(M3) (p = 0.293)	**Ω(M3F) > Ω(M4)*** (p < 0.001)**
Number of observations (independent groups)	**N = 792 (11)**	N = 924 (11)	**N = 924 (11)**

HΩ.2 - Markets with 2 producers	**Ω(M2F) > Ω(M2)* (p = 0.075)**	**Ω(M3) > Ω(M2)****	Ω(M3) > Ω(M2F) (p = 0.708)

[39] The first number gives the percentage of efficiency relative to the high production Nash-equilibrium, the second number relative to the low production Nash-equilibrium.

[40] Using a Wilcoxon signed-rank test to compare with the results reported by Brandts et al. (2008) shows that in our results efficiency is significantly higher (p-values = 0. 003 for M3, M3F and M4). Compared with Le Coq and Orzen (2006, efficiency is significantly higher in condition M2F (p-value = 0. 062 for the low Nash-equilibrium and p-value = 0. 050 for the high Nash-equilibrium), significantly lower in condition M4 (p-value = 0. 003) and not significantly different in M2 (p-value = 0. 131).

[41] The robustness tests, one-sided Wilcoxon rank-sum tests, confirmed our results at the same significance levels.

		(p = 0.026)	
Number of observations (independent groups)	**N = 528** **(11)**	**N = 660** **(11)**	N = 660 **(11)**

HΩ.3	Ω(M4) > Ω(M2F) (p = 0.351)
Number of observations	N = 792

Results testing Hypothesis Ω.1: In markets with 3 competitors, introducing a forward market increases efficiency, and the effect is stronger than adding one more competitor, Ω (M3F) > Ω (M4), and Ω (M3F) > Ω (M3).

We find partial support for Hypothesis Ω.1:

- Ω(M3F) ≤ Ω(M3) is REJECTED in favor of Ω(M3F) > Ω(M3), p-value < 0.001.
- Ω(M4) ≤ Ω(M3) is NOT rejected in favor of Ω(M4) > Ω(M3) , p-value = 0.293.
- Ω(M3F) ≤ Ω(M4) is REJECTED in favor of Ω(M3F) > Ω(M4) , p-value < 0.001.

Introducing a forward market in a market with three producers increases efficiency with 3.1% and this is strongly significant Ω (M3F) > Ω (M3), p-value < 0.001). Adding one more competitor increases efficiency with a mere 0.5%, and this is not significant (NOT Ω (M4) > Ω (M3), p-value = 0.293). The increase in efficiency from introducing a forward market is larger than that from adding one more competitor, and that effect is strongly significant (Ω (M3F) > Ω (M4), p-value < 0.001).

Results testing Hypothesis Ω.2: In markets with 2 competitors, both introducing a forward market and adding one more competitor increases efficiency, and the strength of the effects are of the same order, Ω (M2F) > Ω (M2), Ω (M2F) > Ω (M2), and NOT Ω (M3) > Ω (M2F).

We find partial support for Hypothesis Ω.2:

- Ω(M2F) ≤ Ω(M2) is REJECTED in favor of Ω(M2F) > Ω(M2), p-value = 0.075.
- Ω(M3) ≤ Ω(M2) is REJECTED in favor of Ω(M3) > Ω(M2) , p-value = 0.026.
- Ω(M3) ≤ Ω(M2F) is NOT rejected in favor of Ω(M3) > Ω(M2F) , p-value = 0.708.

Introducing a forward market increases efficiency with 3.5% and this is significant (Ω (M2F) > Ω(M3), p-value = 0.075). Adding one more competitor increases efficiency with 1.1% and this is also significant (Ω (M3) > Ω(M2), p-value = 0.026). The increase in efficiency due to adding one more competitor is not significantly larger than that due to the introduction of a forward market (NOT (Ω(M3) > Ω(M2F), p-value = 0.708).

Results testing Hypothesis Ω.3: Adding two more competitors does not increase efficiency more than introducing a forward market, Ω (M2F) ≤ Ω(M4).

We find no support for Hypothesis Ω.3:

- Ω (M4) ≤ Ω(M2F) is NOT rejected in favor of Ω (M4) > Ω(M2F), p-value = 0.351.

The effect of introducing a forward market with two competitors does not increase efficiently significantly less than doubling the number of competitors.

3.3 Production Efficiency

As mentioned above, following Brandts et al. (2008) we define production efficiency as the actual producer surplus divided by the producer surplus had production taken place in the most efficient manner.[42] We find that the effect of productive inefficiency is small and inconsequential. We therefore present here only the main results and give a more extensive treatment in Appendix A3:

- Results testing Hypothesis Φ.1: In markets with 3 competitors, introducing a forward market does not decrease productive efficiency, while adding one more competitor does (p-value = 0.093), Φ(M4) < Φ(M3) and Φ(M3F) ≥ Φ(M3).
- Results testing Hypothesis Φ.2: In markets with 2 competitors, introducing a forward market (p-value = 0.046) and adding one more competitor (p-value = 0.019) decrease productive efficiency, Φ(2F) < Φ(M2), and Φ(3F) < Φ(M3)

[42] Given the quadratic marginal cost function this implies an as even as possible division of units over the producers.

3.4 Rationality in forward markets

Using the assumption of rational behavior, Allaz and Vila (1993) argue that the forward price will be equal to the spot price, which implies that traders make zero profits. We indeed see this in our data for the treatments with a forward market: M2F and M3F. We estimated the relative markup of the spot market over the forward market price, defined by the difference between the two, divided by the average price: $P_{S-F} = (P_S - P_F)/\left(\left(\frac{1}{2}\right)(P_S + P_F)\right)$. The average (standard error) of P_{S-F} over the last 12 rounds is 0.001 (0.01), which is not significantly different than zero ($p < 0.93$). This indicates that traders are making an insignificantly small profit. Regressing P_{S-F} on the period shows a negative (albeit not significant) trend, thus indicating, in accordance with Plott and Uhl (1981) that the profit of traders diminishes with time. The total number of units producers offer on the forward market thus accurately predicts the total number of units they sell on the spot market, which indicates rational behavior.

3.5 Summary of results and comparison to earlier experiments

Table 9 summarizes our theoretical and experimental results for the aggregate production, together with the key results of earlier experiments. We do not summarize the data on efficiency and productive inefficiency because the data on efficiency closely follow the patterns of the data on aggregate production, while the effect of productive inefficiency is small and inconsequential (see section 3.3).

Table 9 Comparison of our results with those of earlier studies

		Theoretical predictions in our study	Results of earlier studies	Empirical results of our study
Market with 2 competitors	One more competitor (OMC)	+ 7.5%	-	+ 12.1% **
	Forward Market (FM)	+ 5%#	+ 20.9% *** (Le Coq & Orzen, 2006)	+ 17.8% ***
	Largest increase by	**OMC is** 2.4% higher than FM#	-	**FM is** 4.7% higher than OMC (not significant)

Market with 3 competitors	One more competitor (OMC)	+ 2.3%	+ 19.6%*** (Brandts et al., 2008)	+ 4.4% (not significant)
	Forward Market (FM)	+ 4.7%	+ 9.5%** (Brandts et al., 2008)	+ 12.0% ***
	Largest increase by	**FM is** 2.3% higher than One more competitor	**OMC is** 9.2% higher than FM** (Brandts et al., 2008)	**FM is** 7.3% higher than OMC***

▬ ▬ : Results contrast with earlier results

▬▬ : Results contradict earlier results

: Assuming that in M2F high and low Nash-equilibrium are played with the same probability.

Our results show that in markets with three competitors, in line with our theoretical prediction and earlier experimental results (Brandts et al., 2008), introducing a forward market significantly increases aggregate production. Introducing a forward market increases aggregate production significantly more than adding one more competitor, which is in line with our theoretical prediction, but contradicts the findings of Brandts et al.(2008) (the contradictory findings are indicated by the dark background in Table 9). In line with our theoretical prediction, adding one more competitor increases aggregate production. The increase is, however, not significant, which is in contrast with the findings of Brandts et al. (2008). While the lack of significance is likely caused by the relatively small number of independent observations, we note that Brandts et al. (2008) had even less. In markets with two competitors, in line with earlier experimental results (Le Coq and Orzen, 2006), introducing a forward market significantly increases aggregate production. We could not replicate the finding of Brandts et al. (2008) that this increase would be smaller than that of adding one more competitor. Our data suggest the opposite relationship.

Our present study contributes to our understanding of the effects of forward markets and competition in electricity market settings. The following questions for future work suggest themselves: Is the effect of a forward market the same in a experiments with an indefinite time horizon? Demand uncertainty also introduces an insurance motive on the side of producers. Does the strategic effect of forward markets stay the same under demand uncertainty?

4. Conclusion

We have tried to better understand the comparative advantages of behavioral and structural remedies meant to promote competitiveness in electricity markets. We investigate theoretically and experimentally the effects of the introduction of a forward market on competition in electricity markets. We compared this scenario with the best alternative, reducing concentration by adding one more competitor by divestiture. Our work contributes to the literature by introducing more realistic cost configurations of steeply increasing marginal costs, teasing apart competition effect and asset effect, and studying numbers of competitors that reflect better the market concentration in the European states.

Our experimental results suggest that the behavioral remedy of introducing a forward market in concentrated markets with two or three competitors is an effective remedy for increasing the aggregate supply. This is in line with the empirical studies of Wolak (2001) and Van Eijkel and Moraga-Gonzalez (2010), who found empirical evidence that forward trading increased the aggregate supply in the Australian electricity market and in the Dutch gas market, respectively. Our experimental results also suggest that the effect of the behavioral remedy of introducing a forward market is larger than that of the structural remedy of adding one more competitor by divestiture. This is a new result: earlier evidence suggests that behavioral remedies in general are less effective than structural remedies (Duso et al., 2011).

This is a policy relevant finding: competition authorities should, in line with the EU law rather focus on the behavioral remedy of introducing a forward market than on the structural remedy of lowering market concentration by divestiture.

At present, the EU has no single policy towards the design of forward markets for electricity. Such a policy might improve on the effectiveness of forward markets in the EU, as design is an important factor for the thickness of forward markets in EU countries (European Commission, 2007a, p.127). In Spain, for example, forward trading is de facto forbidden by design (European Commission, 2007a, p.127). In Greece forward trading has been made virtually impossible by design, as it has made trading in the pool mandatory (European Commission, 2007b, p.50). In contrast, in France the PowerNext exchange market allows for the trading of forward and future contracts of months, quarters, and years ahead. Our study indicates that the design, or evolution, of such public forward exchanges as in France (and many other developed markets) should indeed be encouraged. Moreover, the public observability of forward positions is essential for the competition-increasing effect of Allaz and Vila (1993) to arise (Hughes and Kao, 1997; Van Eijkel and Moraga-Gonzalez, 2010). Observability of forward positions may not be optimal in markets with large volumes of Over-The-Counter trading. The EU could thus implement methods to increase the observability of the forward positions, by having for example the regulator publish aggregated and anonymized totals of forward positions.

Our results contradict the findings of Brandts et al. (2008) who found a stronger effect for the structural remedy of adding one more competitor than for the behavioral remedy of introducing a forward market. Their result stems most likely from their confounding of competition effect and asset effect. In Brandts et al. (2008) adding one more competitor not only increases competition, but also increases the aggregate asset base, which reduces the aggregate cost and thus gives an extra incentive to increase production. This asset effect is likely influential, as producers have steeply increasing costs. The welfare effects these authors report are not conclusive, however, as they do not incorporate the costs of the increase in the asset base (the cost of building extra production plants). In our study we control for the asset effect by adding one more competitor by divestiture. As a result the effect of the structural remedy of adding one more competitor is weaker and is now dominated by the effect of the behavioral remedy of introducing a forward market.

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Appendix A: Production costs

Table A1: Overview of aggregate cost of producing (rounded numbers)

Market with two producers (original market)					**Market with three producers (after first divestment)**					**Market with four producers (after second divestment)**				
Each Producer			Aggregate		Each Producer			Aggregate		Each Producer			Aggregate	
Units produced by each producer	Marginal Costs	Total Costs	Total Production	**Total Costs**	Units produced by each producer	Marginal Costs	Total Costs	Total Production	**Total Costs**	Units produced by each producer	Marginal Costs	Total Costs	Total Production	**Total Costs**
N	MC	TC	2*N	**2* TC**	N	MC	TC	3*N	**3*TC**	N	MC	TC	4* N	**4*TC**
0	0	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**
1	1	1	2	2	1	2	2	3	6					
2	5	6	4	**12**						1	3	3	4	**12**
3	9	15	6	**30**	2	8	10	6	**30**					
4	16	31	8	**62**						2	12	15	8	**60**
5	24	55	10	110	3	18	28	9	84					
6	35	90	12	**180**	4	32	60	12	**180**	3	30	45	12	**180**
7	45	135	14	270	5	50	110	15	330					
8	60	195	16	**390**						4	55	100	16	**400**
9	80	275	18	**550**	6	70	180	18	**540**					
10	90	365	20	**730**						5	85	185	20	**740**
11	115	480	22	960	7	100	280	21	840					
12	130	610	24	**1220**	8	130	410	24	**1230**	6	120	305	24	**1220**
13	160	770	26	1540	9									
14	180	950	28	**1900**		160	570	27	1710	7	170	475	28	**1900**
15	210	1160	30	**2320**	10	200	770	30	**2310**					
16	230	1390	32	**2780**						8	220	695	32	**2780**
17	260	1650	34	3300	11	240	1010	33	3030					
18	300	1950	36	**3900**	12	290	1300	36	**3900**	9	280	975	36	**3900**
19	330	2280	38	4560	13	340	1640	39	4920					
20	360	2640	40	**5280**						10	345	1320	40	**5280**

21	410	3050	42	**6100**	14	390	2030	42	**6090**					
22	430	3480	44	**6960**						11	420	1740	44	**6960**
23	490	3970	46	7940	15	450	2480	45	7440					
24	520	4490	48	**8980**	16	510	2990	48	**8970**	12	500	2240	48	**8960**
25	560	5050	50	10100	17	580	3570	51	10710					
26	620	5670	52	**11340**						13	590	2830	52	**11320**
27	660	6330	54	**12660**	18	650	4220	54	**12660**					
28	710	7040	56	**14080**						14	690	3520	56	**14080**
29	760	7800	58	15600	19	720	4940	57	14820					
30	810	8610	60	**17220**	20	800	5740	60	**17220**	15	790	4310	60	**17240**
31	870	9480	62	18960	21	880	6620	63	19860					
32	920	10400	64	**20800**						16	890	5200	64	**20800**
33	1000	11400	66	**22800**	22	970	7590	66	**22770**					
34	1050	12450	68	**24900**						17	1010	6210	68	**24840**
35	1100	13550	70	27100	23	1060	8650	69	25950					
36	1150	14700	72	**29400**	24	1150	9800	72	**29400**	18	1140	7350	72	**29400**
37	1230	15930	74	31860	25	1250	11050	75	33150					
38	1320	17250	76	**34500**						19	1270	8620	76	**34480**
39	1350	18600	78	**37200**	26	1350	12400	78	**37200**					
40	1450	20050	80	**40100**						20	1380	10000	80	**40000**
41	1500	21550	82	43100	27	1450	13850	81	41550					
42	1600	23150	84	**46300**	28	1600	15450	84	**46350**	21	1550	11550	84	**46200**
43	1650	24800	86	49600	29	1650	17100	87	51300					
44	1750	26550	88	**53100**						22	1700	13250	88	**53000**
45	1800	28350	90	**56700**	30	1800	18900	90	**56700**					
46	1900	30250	92	**60500**						23	1900	15150	92	**60600**
47	2000	32250	94	**64500**	31	1950	20850	93	**62550**					
48	2050	34300	96	**68600**	32	2050	22900	96	**68700**	24	2000	17150	96	**68600**

Appendix B: Robustness tests

B.1 Alternate statistical tests

Taking a cue from Le Coq and Orzen (2006), we ran one-sided Wilcoxon rank-sum tests as robustness tests for our hypotheses on quantity, efficiency and productive efficiency. Table A2 shows the result of the robustness tests on quantity. Overall they confirm our findings in the main test with two exceptions. The relationship q(M4) > q(M3) is not significant anymore (p-value = 0.154) but barely so. The relationship q(M2F) > q(M3) has a lower p-value and thus is significant (p-value = 0.086).

Table A2: Test results quantity hypotheses

	One-sided two-sample Wilcoxon rank-sum (Mann-Whitney) test		
Hq.1 - Markets with 3 producers	**q(M3F) > q(M3)*** (p < 0.001)**	q(M4) > q(M3) (p = 0.154)	**q(M3F) > q(M4)*** (p = 0.010)**

	N = 22	N = 22	N = 22

Hq.2 - Markets with 2 producers	**q(M2F) > q(M2)** (p = 0.01275)**	**q(M3) > q(M2)** (p = 0.012)**	**q(M2F) > q(M3)* (p = 0.070)**
Number of observations	N = 22	N = 22	N = 22

Hq.3	q(M4) > q(M2F) (p = 0.794)
	N = 22

Table A3 shows the result of the robustness tests on efficiency. Overall they confirm our findings in the main test; all relationships have the same levels of significance (0.1, 0.05, or 0.01) as in the main test.

Table A3: Test results for HΩ.1, HΩ.2 and HΩ.3

	One-sided two-sample Wilcoxon rank-sum (Mann-Whitney) test		
HΩ.1 - Markets with 3 producers	**Ω(M3F) > Ω(M3)*** (p = 0.002)**	Ω(M4) > Ω(M3) (p = 0.311)	**Ω(M3F) > Ω(M4)*** (p < 0.001)**
Number of observations	N = 22	N = 22	N = 22

HΩ.2 - Markets with 2 producers	**Ω(M2F) > Ω(M2)* (p =** 0.079**)**	**Ω(M3) > Ω(M2)** (p = 0.039)**	Ω(M2F) > Ω(M3) (p = 0.7251)
Number of observations	N = 22	N = 22	N = 22

HΩ.3	Ω(M4) > Ω(M2F) (p = 0.603)
Number of observations	N = 22

Table A4 shows the result of the robustness tests on production efficiency. Overall they confirm our findings in the main test with one exception: The relationship Φ(M4) < Φ(M3)* has a slightly higher p-value and thus is no longer significant (p-value = 0.100) but barely so.

Table A4: Test results for HΦ.1 and HΦ.2

	One-sided two-sample Wilcoxon rank-sum (Mann-Whitney) test	
HΦ.1 – Markets with 3 producers	Φ(M4) < Φ(M3) (p = 0.100)	Φ(M3F) < Φ(M3) (p = 0.859)
Number of observations	N = 22	N = 22

HΦ.2– Markets with 2 producers	**Φ(M3) < Φ(M2)** (p = 0.041)**	**Φ(M2F) < Φ(M2)* (p = 0.079)**
Number of observations	N = 22	N = 22

Notably, the robustness tests confirm the results we found in the main tests, and suggest that introducing a forward market may have also a stronger effect on competition than adding one more competitor in markets with two competitors.

B.2 Comparability of data from sessions with two producers with(out) costs

We ran treatments for markets with two producers without costs to allow comparisons with an earlier experiment on the effect of forward markets by Le Coq and Orzen (2006). Table B1 shows the theoretical predictions for these cases.

Table B1: Theoretical predictions zero-cost markets

	NE M2-zc	NE **M2F-zc**	Walras-zc (n = 2)	JPM-zc (n = 2)
q_{ti}^{f}	–	16	–	–
q_{ti}	25	30	37	18/ 19[43]
q_t	50	60	74	37
p_t	650	380	2	1001
Prod.S.	32500	22800	148	37037
Cons.S.	33075	47790	72927	17982

[43] One generator produces 18 units, the other 19 units.

Total S.	65575	70590	73075	55019
Eff.(%)	89.74	96.60	100	75.29

Explanation of row terms: NE stands for the Nash-equilibrium, Walras for the Walrasian (welfare optimizing) equilibrium, and JPM for joint profit maximization (collusion).
Explanation of column terms: q_{ti}^f stands for the forward production of each producer, q_{ti} for the total production of forward (if it is present) and spot market for each producer, q_t for the total *aggregate* production of forward (if it is present) and spot market for all producers together, p_t for the price, *Prod.S* for producer surplus, *Cons.S* for consumer surplus, *Total.S* for total surplus, *Eff.(%)* for efficiency in percentage.

Figure B1: Average aggregate quantities sold per period

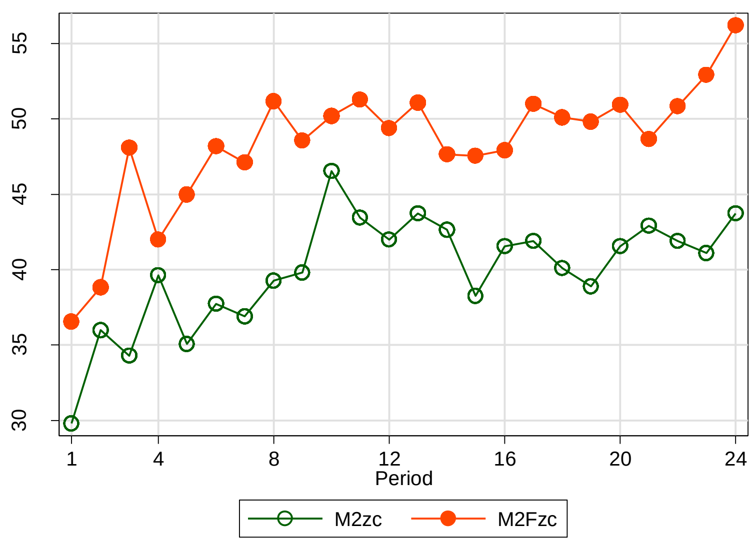


Figure B1 shows the evolution of total (aggregate) quantities sold per period, averaged over groups. The treatments without forward markets are represented by open circles, the treatments with forward markets by filled circles. As in all other treatments, the aggregate productions starts out rather low, 44 and then quickly jump up in the direction of the Nash-equilibrium. Between round 10 and 12 behavior has stabilized.

Averages by group

Table B2 shows that aggregate production tends to be significantly (p-value < 0.093) smaller than the Nash-equilibrium, confirming results of Le Coq and Orzen (2006).

[44] We believe this might be an anchoring effect induced by the instructions, which presented examples with low (and hence simple) numbers so as not to unduly complicate the understanding of the basic relationships.

Table B2: Production Averages and comparison

Averages		
	M2zc	M2Fzc
Average production	41.6 (1.91)	50.3 9 (2.51)
% of NE prediction	79.9%	83.8%
Number of observations	N = 11	N = 11
% of NE prediction Le Coq and Orzen (2006)	*93, 2%,*	*93, 8%,*

Table B3 shows that, using a one-sided Wilcoxon rank-sum test, the increase in aggregate production due to a forward market is significant (p-value = 0.014), confirming results of Le Coq and Orzen (2006).

Table B3: Tests of effect of forward market

Main tests		
one-sided Wilcoxon rank-sum test		**M2Fzc > M2zc** (p = 0.014)**
Number of observations		N = 11

Robustness tests		
OLS regression with correction for clustering on group level, followed by one-sided F test on equality of the coefficients		**M2Fzc > M2zc*** (p < 0.010)**
Number of observations (independent groups)		N = 572 (11)

Figure B2: Average efficiency per period

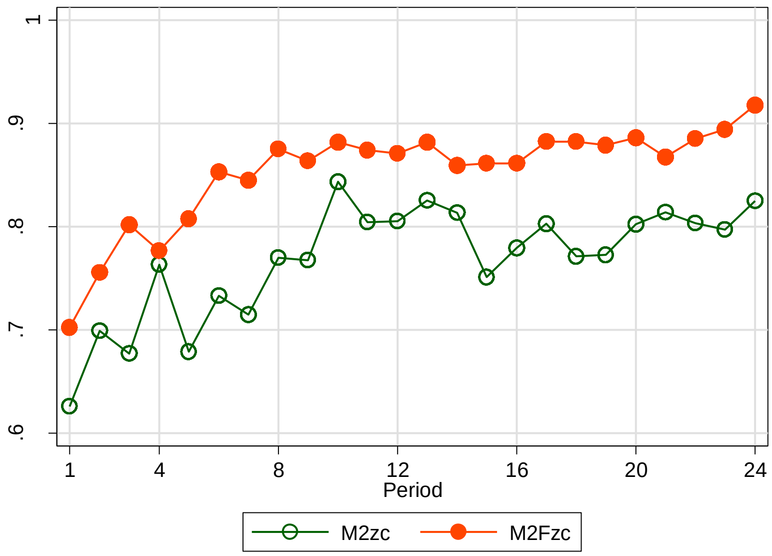


Figure B2 shows the evolution of efficiency per period, averaged over groups. The treatments without forward markets are represented by open circles, the treatments with forward markets by filled circles. As producers have no production costs, production efficiency as defined in the main text is always 100%. Efficiency is thus determined by the aggregate production and the average efficiency in Figure A2 thus closely follows the aggregate average production (Figure B1). Efficiency is lower than the Nash-equilibrium prediction. Table B4 shows, using a two-sided Wilcoxon one-sample signed-rank tests, that these differences are significant (both p-values < 0.017).

Table B4: Efficiency averages and comparison

	M2zc	M2Fzc
Average efficiency as % of Walras	79.7 (2.10)	88.3 (2.37)
% of NE prediction	89.8%	90.7%
Number of observations	N = 11	N = 11
one-sided Wilcoxon rank-sum test		**M2Fzc > M2zc*** (p < 0.010)**
Number of observations		N = 16
OLS regression with correction for clustering on group level, followed by one-sided F test on equality of the coefficients		**M2Fzc > M2zc** (p = 0.011)**
Number of observations		N = 572

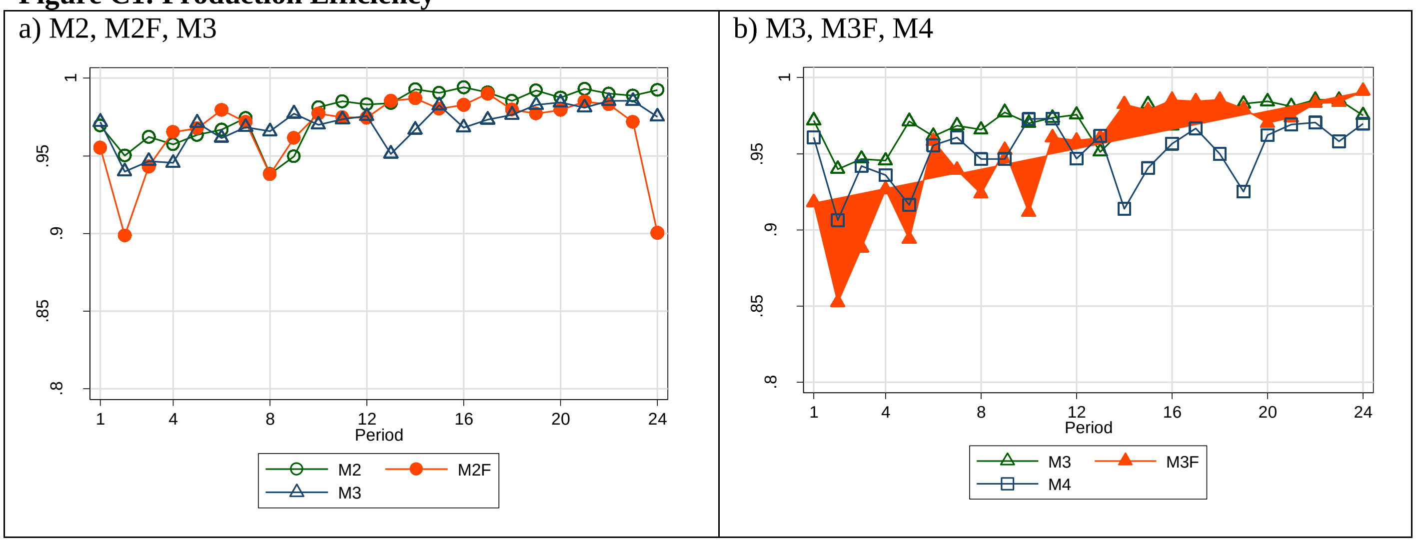
(independent groups)		(11)

Appendix C: Production Efficiency

As mentioned above, we define production efficiency, following Brandts et al. (2008), as the actual producer surplus divided by the producer surplus had production taken place in the most efficient manner.[45] Figure c1 shows the evolution of efficiency per period, averaged over groups. Efficiency quickly converges and after period 8 its level is mostly equal or higher than 90% for all treatments.

The treatments with two traders are represented by circles, with three traders by triangles, and with four traders by squares. The treatments without forward markets are represented by open rounds, triangles or squares, the treatments with forward markets by filled rounds or triangles. M3 is clearly lower than M2, and M2F is most of the time in the middle. M4 is clearly lower than M3 and M3F, while there is no visible difference between M3 and M3F.

Figure C1: Production Efficiency



[45] Given the quadratic marginal cost function this implies an as even as possible division of units over the producers.

Table C1 shows the overall average of production efficiency in the last 12 rounds, with the standard error in parenthesis. The row below gives the size of the observed aggregated quantity relative to the Nash-equilibrium prediction in percentages.

Table C1: Production efficiency averages in the last 12 rounds

	M2	M2F	M3	M3F	M4
Average Production Efficiency	99.0 (0.35)	97.5 (0.81)	97.6 (0.59)	98.0 (0.69)	95.4 (1.63)
Number of observations	N = 11	N = 11	N = 11	N = 11	N = 11

Table C2: Effects of one more competitor and forward market on productive efficiency, HΦ.1 and HΦ.2

	OLS regression, with correction for clustering on group level, followed by a one-sided F test (Clustering on group)	
HΦ.1 – Markets with 3 producers	**Φ(M4) < Φ(M3)* (p = 0.093)**	Φ(M3F) < Φ(M3) (p = 0.666)
Number of observations (independent groups)	N = 1001 **(11)**	N = 858 **(11)**

HΦ.2– Markets with 2 producers	**Φ(M3) < Φ(M2)** (p = 0.019)**	**Φ(M2F) < Φ(M2)** (p = 0.046)**
Number of observations (independent groups)	N = 715 **(11)**	N = 572 **(11)**

Table C2 presents the results of the F-tests based on OLS regressions.[46]

Results testing Hypothesis Φ.1: In markets with 3 competitors, introducing a forward market does not decrease productive efficiency, while adding one more competitor does, Φ(M4) < Φ(M3) and Φ(M3F) ≥ Φ(M3).

We find support for Hypothesis Φ.1:

- Φ(M4) ≥ Φ(M3) is REJECTED in favor of Φ(M4) < Φ(M3) , p-value = 0.093.
- Φ(M3F) ≥ Φ(M3) is NOT rejected in favor of Φ(M3F) < Φ(M3) , p-value = 0.666.

Adding one more competitor to M3 decreases the production efficiency with 2.4%, and this decrease is significant (Φ(M4) < Φ(M3), p-value = 0.093). Introducing a forward market does not lower production

[46]Robustness tests confirm our results, but show a weaker significance (p-value = 0. 100) for Φ(M4) < Φ(M3).

efficiency; the data rather suggest the opposite as efficiency is higher in the market with a forward market than in the market without one (though not significantly so).

Results testing Hypothesis Φ.2: In markets with 2 competitors, introducing a forward market and adding one more competitor decrease productive efficiency, Φ(2F) < Φ(M2), and Φ(3F) < Φ(M3)

We find support for Hypothesis Φ.2:

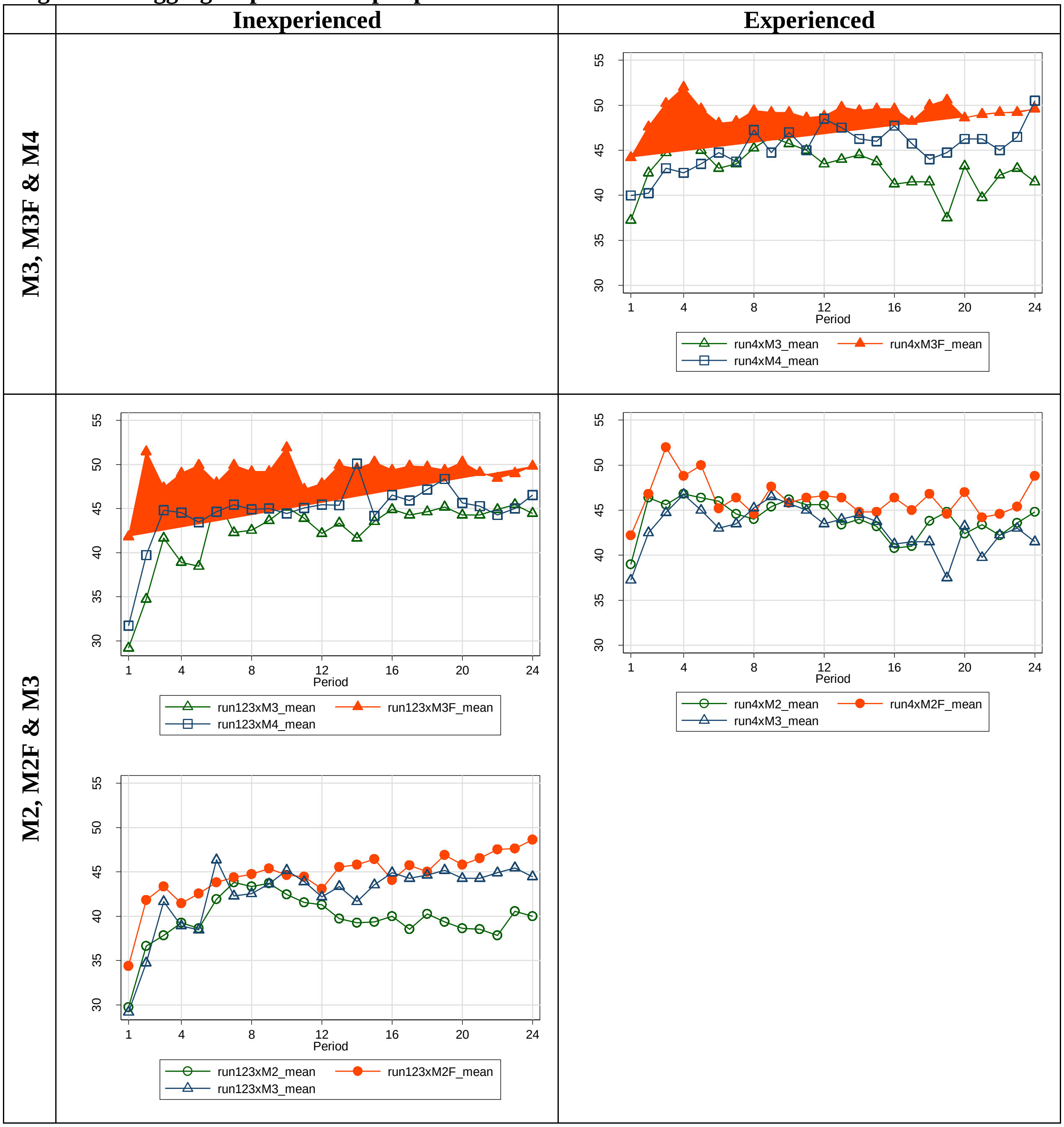
- $\Phi(M3) \geq \Phi(M2)$ is REJECTED in favor of $\Phi(M3) < \Phi(M2)$, p-value = 0.019.
- $\Phi(M2F) \geq \Phi(M2)$ is REJECTED in favor of $\Phi(M2F) < \Phi(M2)$, p-value = 0.046.

Adding one more competitor to M2 decreases production efficiency with 1.4%. Introducing a forward market to a market decreases production efficiency with 1.5%. Both decreases are significant.

Appendix D: Sessions with experienced subjects

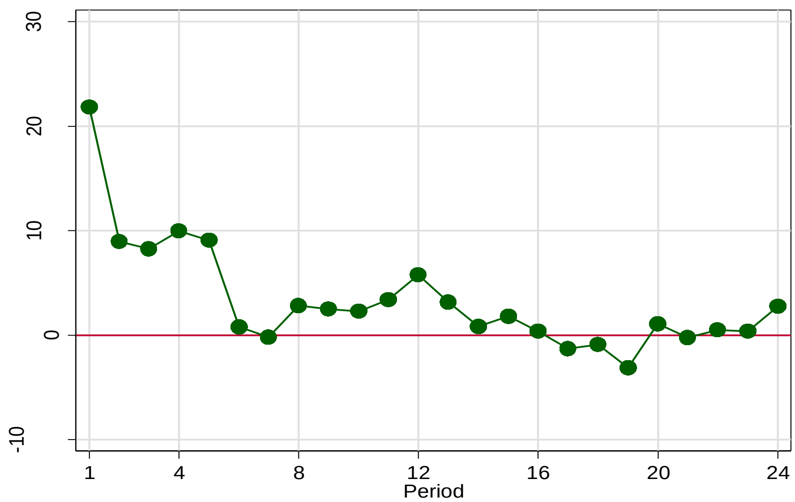
In October 2010 we ran sessions with subjects that had taken part in earlier sessions of the experiment. For each treatment we have 5 independent groups, except for M3F and M4, where we have 4 independent groups. For all treatments except M2 we assigned subjects to the exact same treatment they had participated in earlier. In the M2 treatments we had to rely on some subjects that had earlier participated in M3 or M4. Figure D1 shows the aggregate production for inexperienced subjects on the left and for experienced on the right. As can be seen, the basic pattern is the same. The eyeball test reveals that the largest differences are in the first periods – experienced subjects produce visibly more.

Figure D1: Aggregate production per period



We noted above that subjects start out producing rather low (below the average over all rounds) and that we believe that this is an instruction's effect. In the instructions we gave examples with low number to facilitate understanding. We believe this triggered our subjects to produce low amounts in the first few rounds. Experienced subjects seem less susceptible to this instructional framing effect. Figure D2 shows how much experienced subjects produced more than inexperienced ones on average over all treatments. Experienced subjects produce 20% more in the first round. After that the difference levels off to 10% and from round 6 on the difference hovers close to zero.

Figure D2: Percentage increase of aggregate production by experienced subjects



To test if the aggregate production of experienced subjects is different from that of inexperienced subjects, we run a regression of the aggregate production on the treatment dummies interacted with the experience dummy for the last 12 periods:

$$AggSupply = \left\{ \begin{array}{l} InExp \cdot \left(\beta_{IE,M2} \cdot M2 + \beta_{IE,M2F} \cdot M2F + \beta_{IE,M3} \cdot M3 + \beta_{IE,M3F} \cdot M3F + \beta_{IE,M4} \cdot M4 \right) + \\ \qquad Exp \cdot \left(\beta_{E,M2} \cdot M2 + \beta_{E,M2F} \cdot M2F + \beta_{E,M3} \cdot M3 + \beta_{E3F} \cdot M3F + \beta_{E,M4} \cdot M4 \right) \ + \varepsilon \end{array} \right\}$$

InExp (*Exp*)is the dummy for the inexperienced (experienced) subjects, and *M2*, *M2F*, *M3*, *M3F*, and *M4* are the dummies for the treatments. I then run 2-sided F-tests for the differences between $\beta_{IE,i}$ (inexperienced subjects) and $\beta_{E,i}$ (experienced subjects) for all treatments. Table D1 reports the results.

Table D1: Comparison of experienced and inexperienced subjects

	M2	**M2F**	**M3**	**M3F**	**M4**
InExperienced	39.34 (1.46)	46.31 (1.976)	44.24 (1.18)	49.55 (0.58)	46.20 (0.95)
Experienced	43.12 (1.53)	45.73 (2.40)	41.98 (1.57)	50.94 (0.16)	46.38 (0.93)
Difference	**+3.78**	-0.58	-2.26	**+1.39**	+0.18
Significance	**0.0781**	0.8533	0.2527	**0.025**	0.8937

Differences are significant for treatments M2 and M3F. In both these treatments experienced subjects produced *more* than inexperienced subjects. Another indication that experience leads to more productions comes from regressing the aggregate production on the treatment dummies and a time variable to records how many months it is ago that the subject participated in the experiment. We conjecture that the more recently a subject has participated, the more strongly their experience is still present, and thus the more strongly might be the effect of experience on the subject's decisions. The time variable is indeed negative and significant ($p < 0.035$): subjects that participated 6 months ago produce on average 2.2 units more than subjects that participated 12 months ago.

Experience increasing aggregate production is in line with the experimental evidence for public provision games. This evidence indicates that private contributions to a public good fall with experience (Ledyard, 1995). The private contribution that producers could make in Cournot competition is to exercise restraint in selling units on the forward and spot markets. Such a restraint softens competition in the spot market which results in a higher overall profit. Experienced producers thus make lower "public contributions" by not restraining themselves.

(NOT FOR PUBLICATION)

Appendix E: Predictions of the spot market price by our automated traders

M2F-zc: Total Production Stage A, Predicted Total Production and Resulting (Spot) Price

Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price
0	49.4	667
1	50.0	649
2	50.7	631
3	51.4	613
4	52.0	595
5	52.7	577
6	53.4	559
7	54.0	541
8	54.7	523
9	55.4	505
10	56.0	487
11	56.7	469
12	57.4	451
13	58.0	433
14	58.7	415
15	59.4	397
16	60.0	379
17	60.7	361
18	61.4	343
19	62.0	325
20	62.7	307
21	63.4	289
22	64.0	271
23	64.7	253
24	65.4	235
25	66.0	217
26	66.7	199
27	67.4	181
28	68.0	163
29	68.7	145
30	69.4	127
31	70.0	109
32	70.7	91

Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price
33	71.4	73
34	72.0	55
35	72.7	37
36	73.4	19
37	74.0	1
38	74.7	0
39	75.4	0
40	76.0	0
41	76.7	0
42	77.4	0
43	78.0	0
44	78.7	0
45	79.4	0
46	80.0	0
47	80.7	0
48	81.4	0
49	82.0	0
50	82.7	0
51	83.4	0
52	84.0	0
53	84.7	0
54	85.4	0
55	86.0	0
56	86.7	0
57	87.4	0
58	88.0	0
59	88.7	0
60	89.4	0
61	90.0	0
62	90.7	0
63	91.4	0
64	92.0	0
65	92.7	0

Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price
66	93.4	0
67	94.0	0
68	94.7	0
69	95.4	0
70	96.0	0
71	96.7	0
72	97.4	0
73	98.0	0
74	98.7	0
75	99.4	0
76	100.0	0
77	100.7	0
78	101.4	0
79	102.0	0
80	102.7	0
81	103.4	0
82	104.0	0
83	104.7	0
84	105.4	0
85	106.0	0
86	106.7	0
87	107.4	0
88	108.0	0
89	108.7	0
90	109.4	0
91	110.0	0
92	110.7	0
93	111.4	0
94	112.0	0
95	112.7	0
96	113.4	0

M2F: Total Production Stage A, Predicted Total Production and Resulting (Spot) Price

Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price
0	40.0	921
1	40.2	915
2	40.4	909
3	40.6	903
4	40.9	897
5	41.1	890
6	41.3	884
7	41.6	878
8	41.8	872
9	42.0	866
10	42.2	860
11	42.5	854
12	42.7	848
13	42.9	842
14	43.1	836
15	43.3	830
16	43.6	824
17	43.8	818
18	44.0	812
19	44.2	806
20	44.5	800
21	44.7	794
22	44.9	788
23	45.1	782
24	45.3	776
25	45.6	770
26	45.8	764
27	46.0	758
28	46.2	752
29	46.4	746
30	46.7	740
31	46.9	734
32	47.1	728
33	47.3	723
34	47.5	717
35	47.7	711
36	48.0	705
37	48.2	699
38	48.4	693
39	48.6	688
40	48.8	682
41	49.0	676
42	49.3	670
43	49.5	664
44	49.7	659
45	49.9	653
46	50.1	647
47	50.3	641
48	50.5	636
49	50.7	630
50	51.0	624
51	51.2	619
52	52.0	596
53	53.0	569
54	54.0	542
55	55.0	515
56	56.0	488
57	57.0	461
58	58.0	434
59	59.0	407
60	60.0	380
61	61.0	353
62	62.0	326
63	63.0	299
64	64.0	272
65	65.0	245
66	66.0	218
67	67.0	191
68	68.0	164
69	69.0	137
70	70.0	110
71	71.0	83
72	72.0	56
73	73.0	29
74	74.0	2
75	75.0	0
76	76.0	0
77	77.0	0
78	78.0	0
79	79.0	0
80	80.0	0
81	81.0	0
82	82.0	0
83	83.0	0
84	84.0	0
85	85.0	0
86	86.0	0
87	87.0	0
88	88.0	0
89	89.0	0
90	90.0	0
91	91.0	0
92	92.0	0
93	93.0	0
94	94.0	0
95	95.0	0
96	96.0	0

M3F: Total Production Stage A, Predicted Total Production and Resulting (Spot) Price

Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price	Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price	Total Production Stage A	Predicted (NE) Aggregate Production	Predicted (NE) price
0	43.2	833	**33**	48.4	693	**66**	66.0	218
1	43.4	829	**34**	48.6	688	**67**	67.0	191
2	43.5	824	**35**	48.7	684	**68**	68.0	164
3	43.7	820	**36**	48.9	680	**69**	69.0	137
4	43.9	816	**37**	49.0	676	**70**	70.0	110
5	44.0	811	**38**	49.2	672	**71**	71.0	83
6	44.2	807	**39**	49.3	668	**72**	72.0	56
7	44.3	803	**40**	49.5	663	**73**	73.0	29
8	44.5	799	**41**	49.7	659	**74**	74.0	2
9	44.7	794	**42**	49.8	655	**75**	75.0	0
10	44.8	790	**43**	50.0	651	**76**	76.0	0
11	45.0	786	**44**	50.1	647	**77**	77.0	0
12	45.1	781	**45**	50.3	643	**78**	78.0	0
13	45.3	777	**46**	50.4	639	**79**	79.0	0
14	45.5	773	**47**	50.6	635	**80**	80.0	0
15	45.6	769	**48**	50.7	630	**81**	81.0	0
16	45.8	764	**49**	50.9	626	**82**	82.0	0
17	45.9	760	**50**	51.0	622	**83**	83.0	0
18	46.1	756	**51**	51.2	618	**84**	84.0	0
19	46.2	752	**52**	52.0	596	**85**	85.0	0
20	46.4	747	**53**	53.0	569	**86**	86.0	0
21	46.6	743	**54**	54.0	542	**87**	87.0	0
22	46.7	739	**55**	55.0	515	**88**	88.0	0
23	46.9	735	**56**	56.0	488	**89**	89.0	0
24	47.0	730	**57**	57.0	461	**90**	90.0	0
25	47.2	726	**58**	58.0	434	**91**	91.0	0
26	47.3	722	**59**	59.0	407	**92**	92.0	0
27	47.5	718	**60**	60.0	380	**93**	93.0	0
28	47.6	713	**61**	61.0	353	**94**	94.0	0
29	47.8	709	**62**	62.0	326	**95**	95.0	0
30	48.0	705	**63**	63.0	299	**96**	96.0	0
31	48.1	701	**64**	64.0	272			
32	48.3	697	**65**	65.0	245			

(NOT FOR PUBLICATION)

Appendix F: Consolidated instructions
The following "consolidated" instructions integrate the instructions of all treatments in "Structural versus Behavioral Remedies in the Deregulation of Electricity Markets: An Experimental Investigation Guided by Theory and Policy Concerns". The treatments are explained in detail in the manuscript and are here referred to in shorthand as:

- M2, M3, M4 – denoting simple producer markets (without traders), with convex cost functions,
- M2-zc – denoting a simple producer market (without traders), with zero cost function,
- M2F, M3F – denoting markets featuring producers and traders, with convex cost functions,
- M2F-zc – denoting a market featuring producers and traders, with zero cost function.

In the following "consolidated" instructions:

- standard font is the baseline text common to all treatments,
- bold standard font is also baseline text common to all treatments; it is simply highlighted,
- *Italics* identify text that is specific to a subset of the treatments; all text in italics is furthermore in [] because, separated by semicolon it is always specified for which subset of treatments the text in italics is relevant.
- Text between <> gives an action that the instructor should do.

Welcome to the experiment! Please turn off your mobile phones.

1. INTRODUCTION
You are about to participate in an economics experiment. The instructions are simple. If you follow them carefully, you can earn a substantial amount of money. Your earnings will be paid to you in cash at the end of the experiment. <show the money>

The currency in this experiment is called "Experimental Currency Units", or "ECU"s. At the end of the experiment, we will exchange ECUs for Czech Crowns. The exchange rate has been set in such a way that, on average earnings coincide with the predicted average earnings. (i.e., ca Czk 600-700 for a session of two hours). Your specific earnings will depend on your choices and the choices of the participants you will be paired with.

This experiment will take approximately *["100 ~ 120"; M2F, M2F-zc, M3F] ["80 ~ 90"; M2, M2-zc, M3, M4]* minutes. There are 25 paid rounds in this experiment.

A.1. General rules

If you have a question, raise your hand and one of the experimenters will come to your desk to answer it.

You are not allowed to communicate with other participants during the experiment. If you violate this rule, you will be asked to leave the experiment and will not be paid (not even your show-up fee).

["In the experiment it is possible to go bankrupt. In this case you have the option to invest your show-up fee. If you go bankrupt, and you do not want to invest your show-up fee, you will be asked to leave the experiment. In that case, you will be paid just your show-up fee. However, there are strategies that, if you use them, guarantee that you will not go bankrupt."; M2, M2F, M3, M3F, M4]

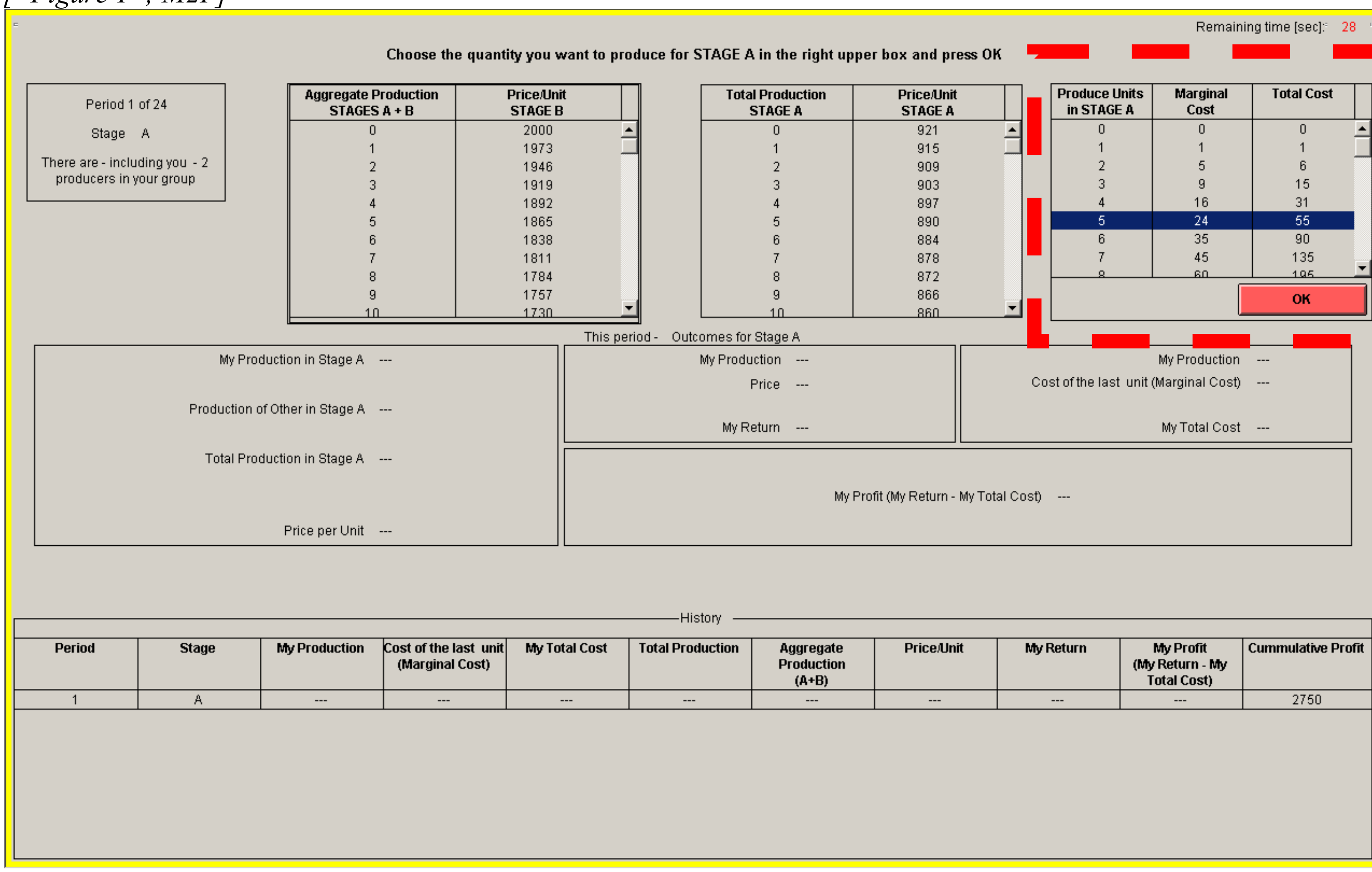
You will be a member of a group. Including you, there will be *["TWO"; M2, M2-zc, M2F, M2F-zc] ["THREE"; M3, M3F] ["FOUR"; M4]* participants in your group. Group membership is assigned randomly at the start of the experiment. Group membership is anonymous; you will not know who is in the group with you and *["the other person in your group will not"; M2, M2-zc, M2F, M2F-zc] ["none of your group members will"; M3,* *M3F, M4]* know that you are in his or her group. You will not interact with members of other groups. **Your group membership stays fixed for the experiment.**

A group defines the Producers in a market; as Producer you will produce a fictitious product and sell it on the market. At the beginning of the experiment, you receive a start capital of 2.750 ECU.

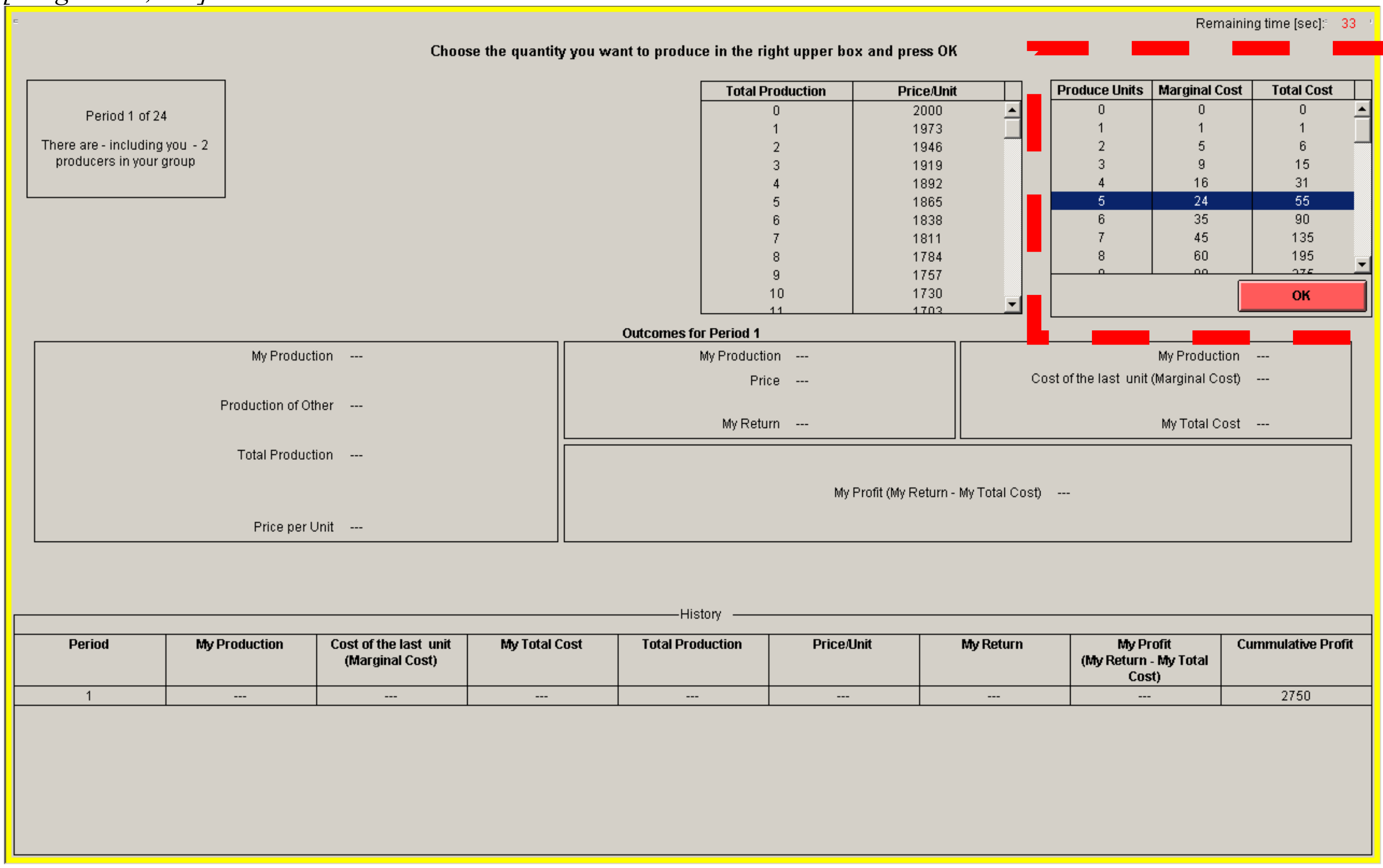
A.2. Description
[“Each of the 30 periods consists of two successive stages. The first of these is called Stage A and the second is called Stage B. We will first describe Stage A, then Stage B.

A.2.1. Stage A*”; M2F, M2F-zc, M3F]*
At the beginning of *[each of the 30 periods; M2, M2-zc, M3, M4] [Stage A; M2F, M2F-zc, M3F]* you have to decide how many units of a good to produce. You make your decision by clicking on the number of units listed in the Table and then clicking on the **OK button.** By clicking on the number of units, you highlight the whole row; for an example where a player chose to produce 5 units, see the marked Table in Figure 1.

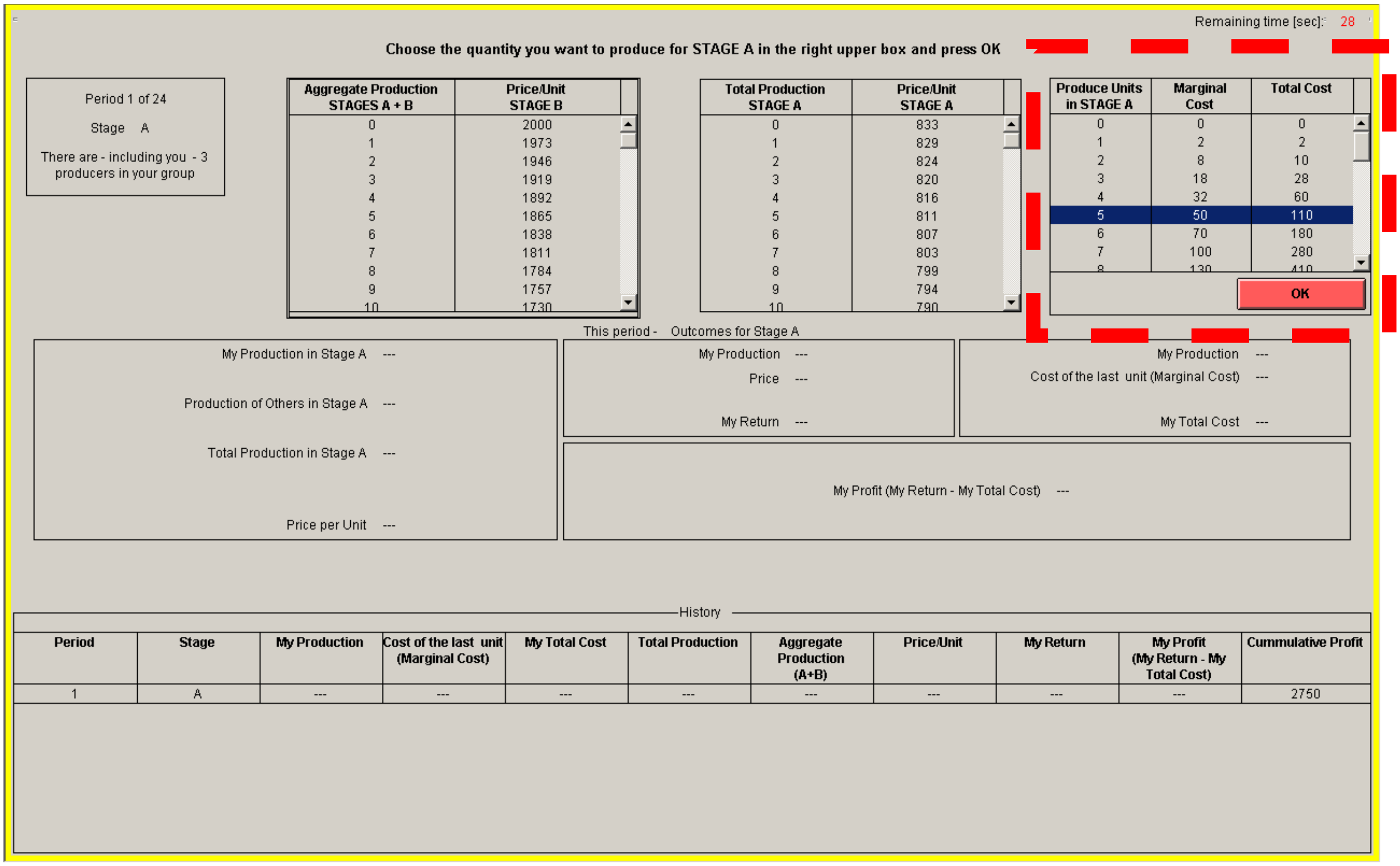
[“Figure 1”; M2F]



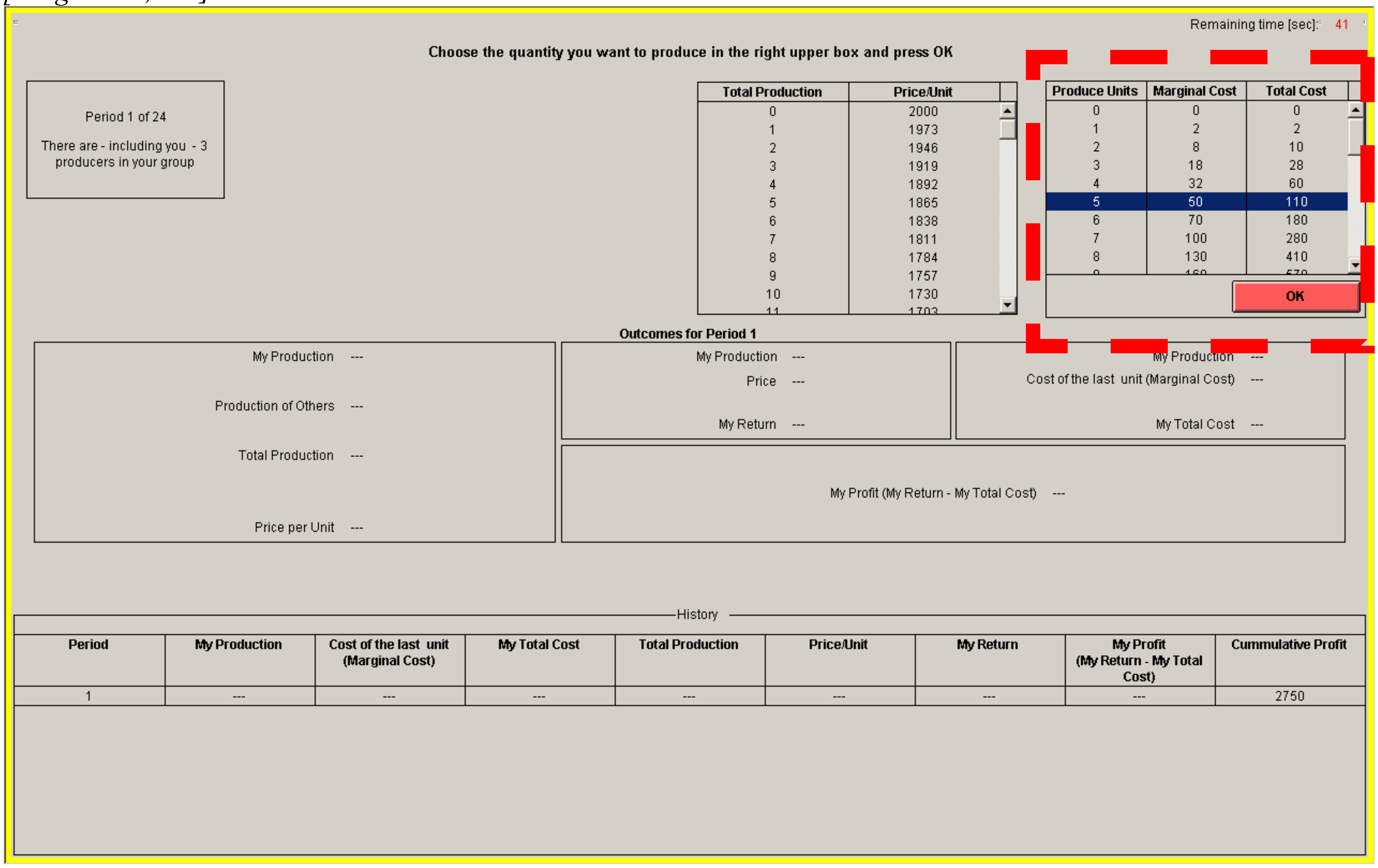
[“Figure 1”; M2]



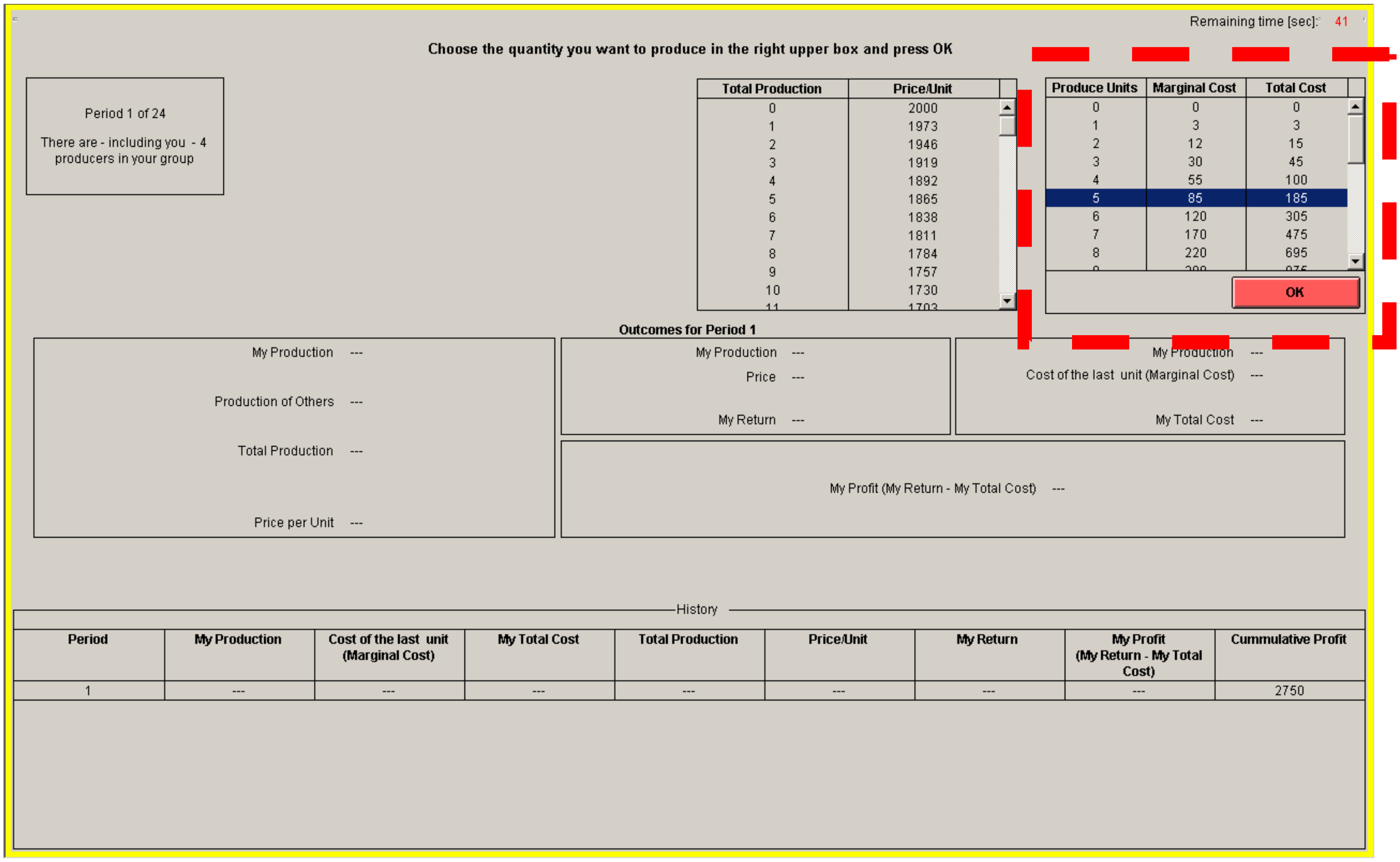
[“Figure 1”; M3F]


Remaining time [sec]: 28
Choose the quantity you want to produce for STAGE A in the right upper box and press OK
Period 1 of 24
Stage A
There are - including you - 3 producers in your group
Aggregate Production STAGES A + B | Price/Unit STAGE B
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
Total Production STAGE A | Price/Unit STAGE A
0 833
1 829
2 824
3 820
4 816
5 811
6 807
7 803
8 799
9 794
Produce Units in STAGE A | Marginal Cost | Total Cost
0 0 0
1 2 2
2 8 10
3 18 28
4 32 60
5 50 110
6 70 180
7 100 280
OK
This period - Outcomes for Stage A
My Production in Stage A ---
Production of Others in Stage A ---
Total Production in Stage A ---
Price per Unit ---
My Production ---
Price ---
My Return ---
My Production ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period | Stage | My Production | Cost of the last unit (Marginal Cost) | My Total Cost | Total Production | Aggregate Production (A+B) | Price/Unit | My Return | My Profit (My Return - My Total Cost) | Cummulative Profit
1 | A | --- | --- | --- | --- | --- | --- | --- | --- | 2750

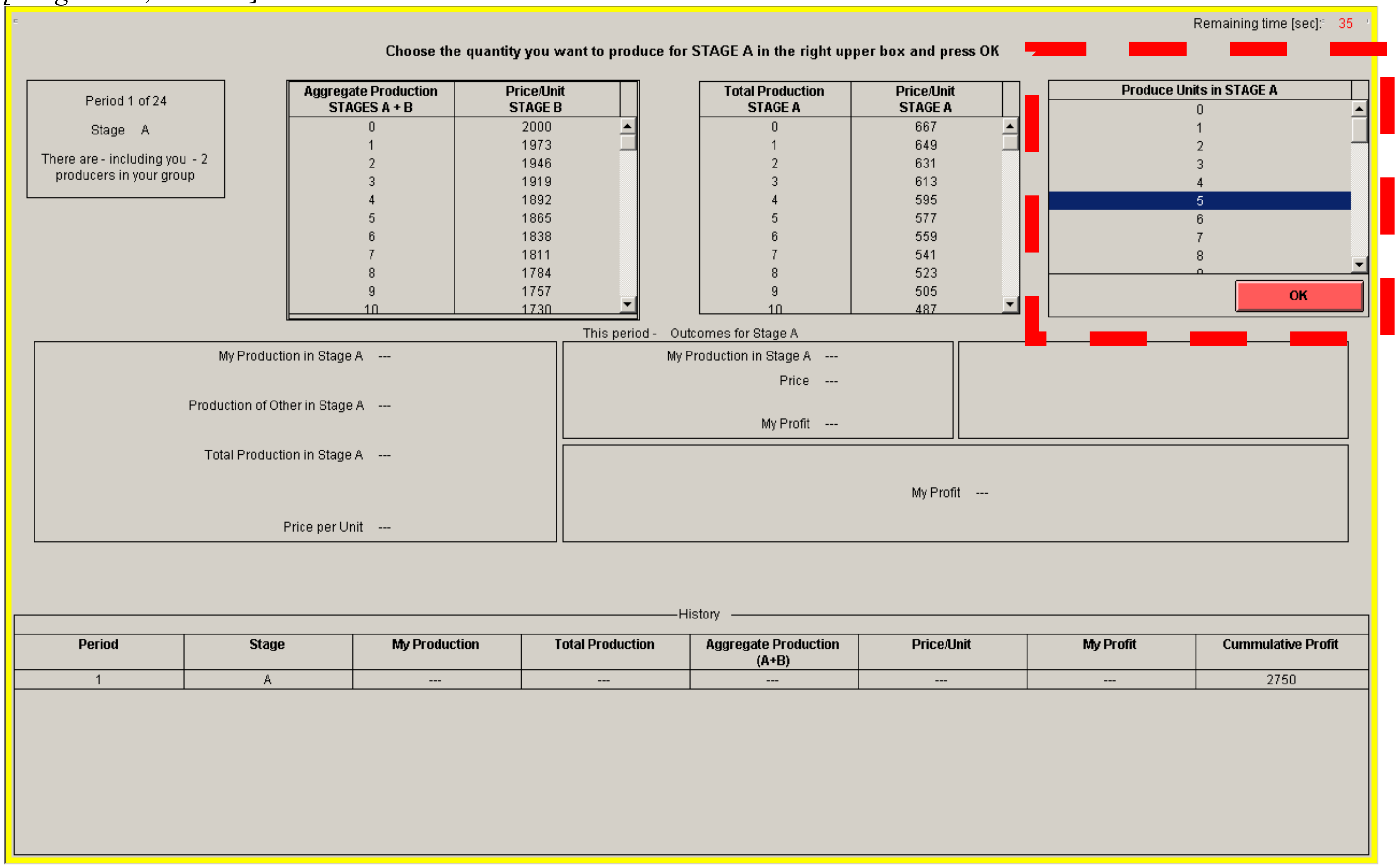
[“Figure 1”; M3]



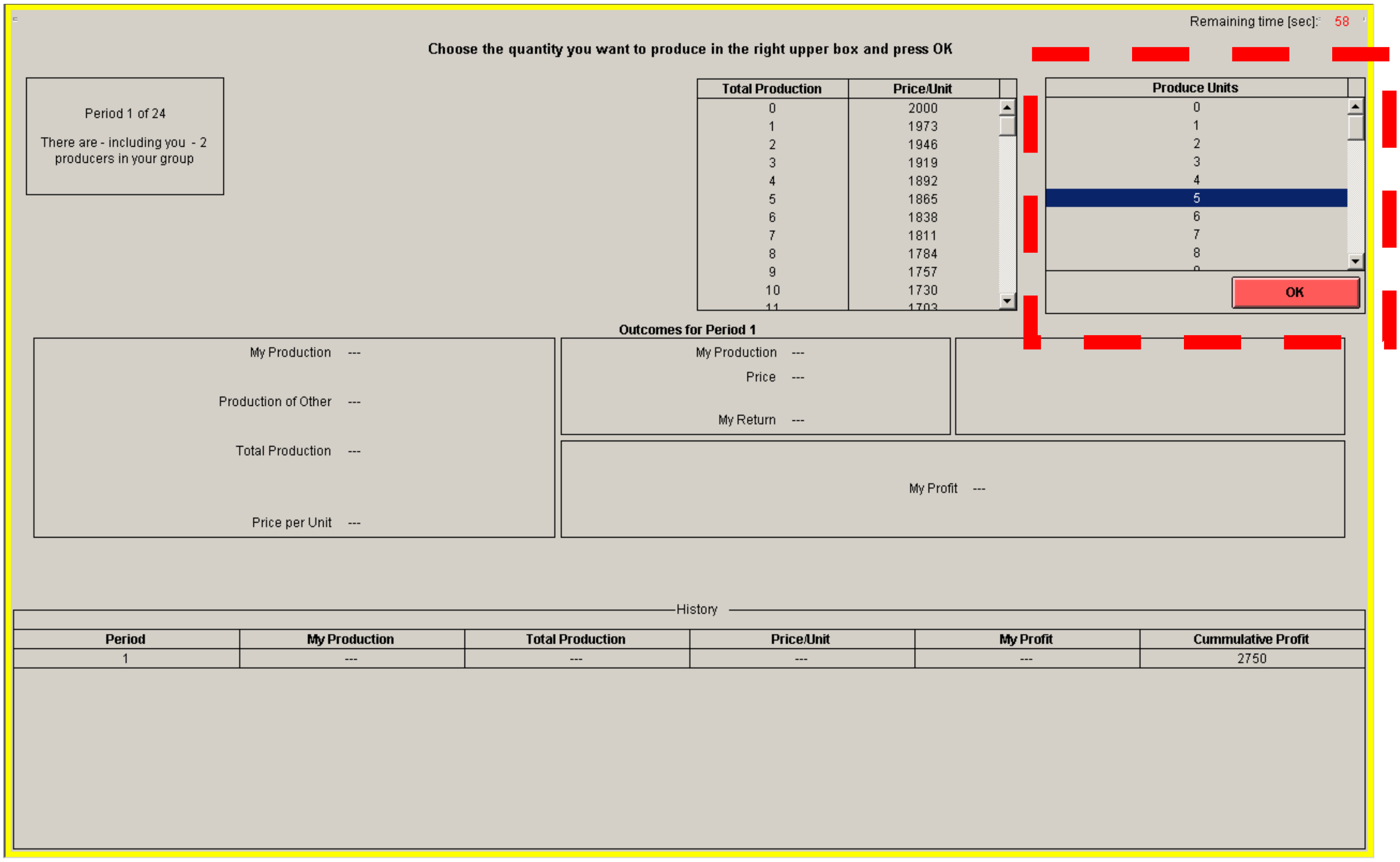
[“Figure 1”; M4]


Remaining time [sec]: 41
Choose the quantity you want to produce in the right upper box and press OK
Period 1 of 24
There are - including you - 4 producers in your group
Total Production
Price/Unit
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
10 1730
Produce Units
Marginal Cost
Total Cost
0 0 0
1 3 3
2 12 15
3 30 45
4 55 100
5 85 185
6 120 305
7 170 475
8 220 695
OK
Outcomes for Period 1
My Production ---
Production of Others ---
Total Production ---
Price per Unit ---
My Production ---
Price ---
My Return ---
My Production ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cummulative Profit
1 --- --- --- --- --- --- --- 2750

[“Figure 1”; M2F-zc]



[“Figure 1”; M2-zc]



To make your choice you have **one minute**; if you have not made a choice (and clicked on the OK button) then yet, the computer will assign you the default choice of zero. This is the standard procedure for all decisions in the experiment.

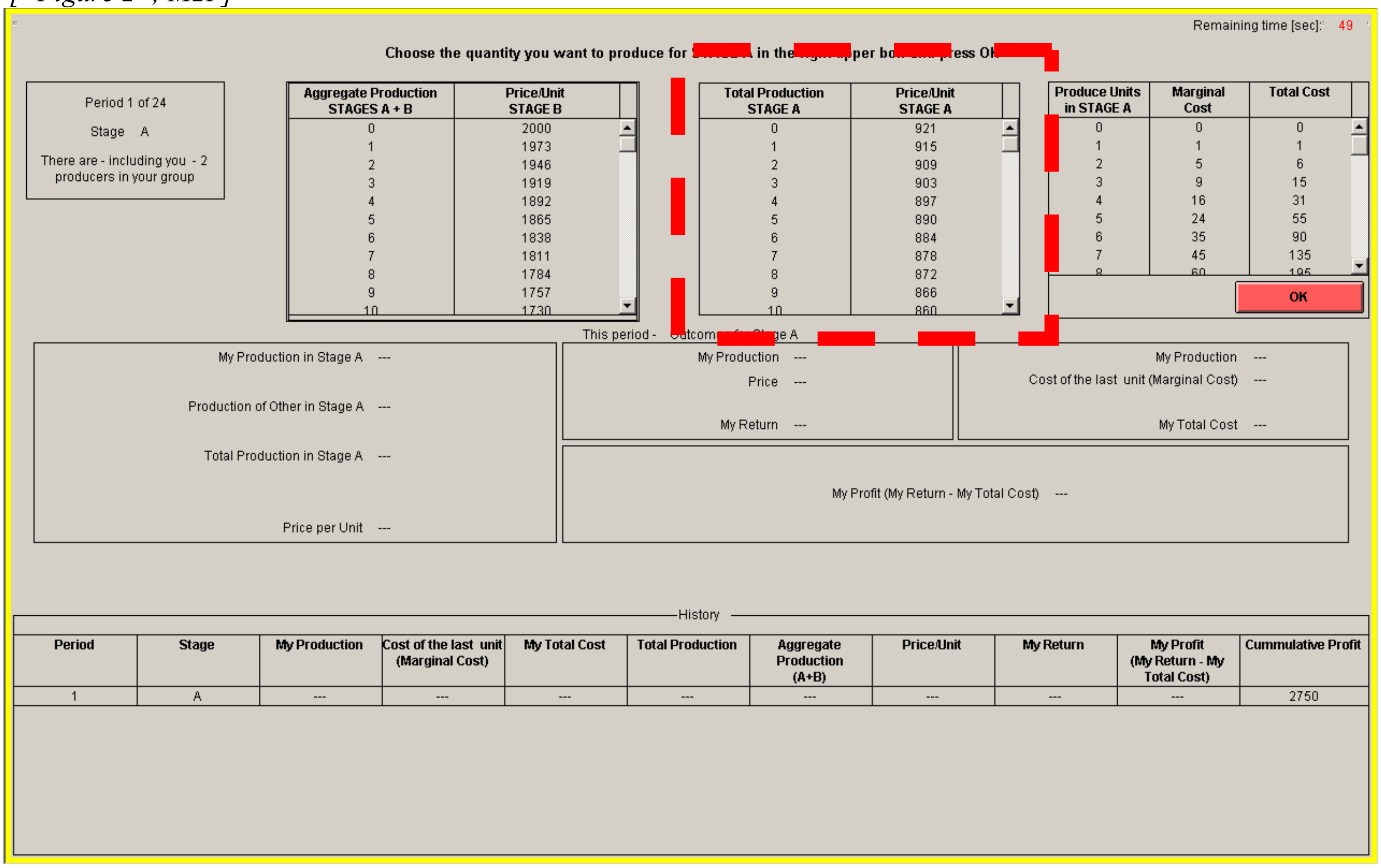
["Next to the number of the units of the good you might want to produce (Produce Units), you find the cost of each unit (Marginal Cost), and the Total Cost"; M2, M2F, M3, M3F, M4]
["Thus the cost of the 1st unit is 1, of the 2nd unit is 5, of the 3rd unit is 9, and so on." ; M2,M2F]
["Thus the cost of the 1st unit is 2, of the 2nd unit is 8, of the 3rd unit is 18, and so on." ; M3, M3F]
["Thus the cost of the 1st unit is 3, of the 2nd unit is 12, of the 3rd unit is 30, and so on."; M4]
["The total cost of units produced is equal to the sum of the marginal costs of units produced." ; M2,M2F, M3, M3F, M4]
["*Producing a total of 1 unit thus cost 1, a total of 2 units costs 6, a total of 3 units costs 15, and so on." ; M2,M2F]*
["*Producing a total of 1 unit thus cost 2, a total of 2 units costs 10, a total of 3 units costs 28, and so on." ; M3, M3F]*
["*Producing a total of 1 unit thus cost 3, a total of 2 units costs 15, a total of 3 units costs 45, and so on."; M4]*

The total number of units produced in *["the market"; M2, M2-zc, M3, M4] ["Stage A"; M2F, M2F-zc, M3F]* is called "Total Production."

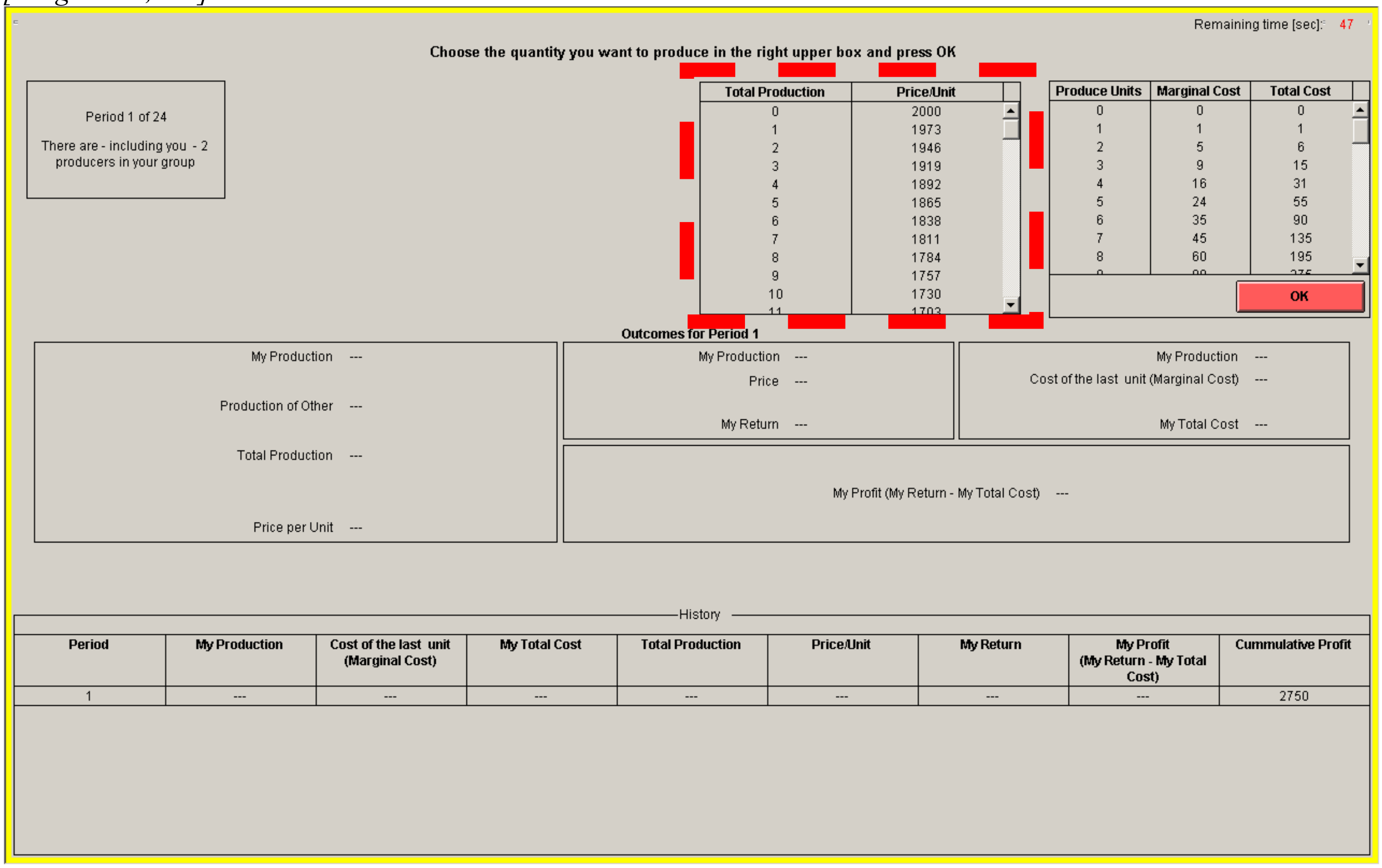
After all firms have made their decisions, the computer will calculate your profits for *["that period."; M2, M2-zc, M3, M4] ["Stage A."; M2F, M2F-zc, M3F] ["Your return will be equal to the number of units you produce times the market price; your profit will be equal to your return minus your total cost."; M2, M2F, M3, M3F, M4]["Your profit will be equal to the number of units you produce times the market price"; M2-zc,M2F-zc]*

The market price will depend on the total production in your market; the more units you and the other *[“Producer”; M2, M2-zc, M2F, M2F-zc] [“Producers”; M3, M3F, M4]* produced, the lower the price per unit will be. The precise relation you can find in the Table labeled [“***Total Production STAGE A and Resulting Price in STAGE A***”*; M2F, M2F-zc, M3F] [“**Total Production and Resulting Price**”; M2,M2-zc,M3,M4]*, that you find in the end of the instructions on page *[“97”;M2F][“98”;M2F-zc][“99”;M3F][“**Error! Bookmark not defined.**”; M2, M2-zc, M3, M4*. **It is also shown on your screen on top in the middle**. In the example, see the marked Table in Figure 2.

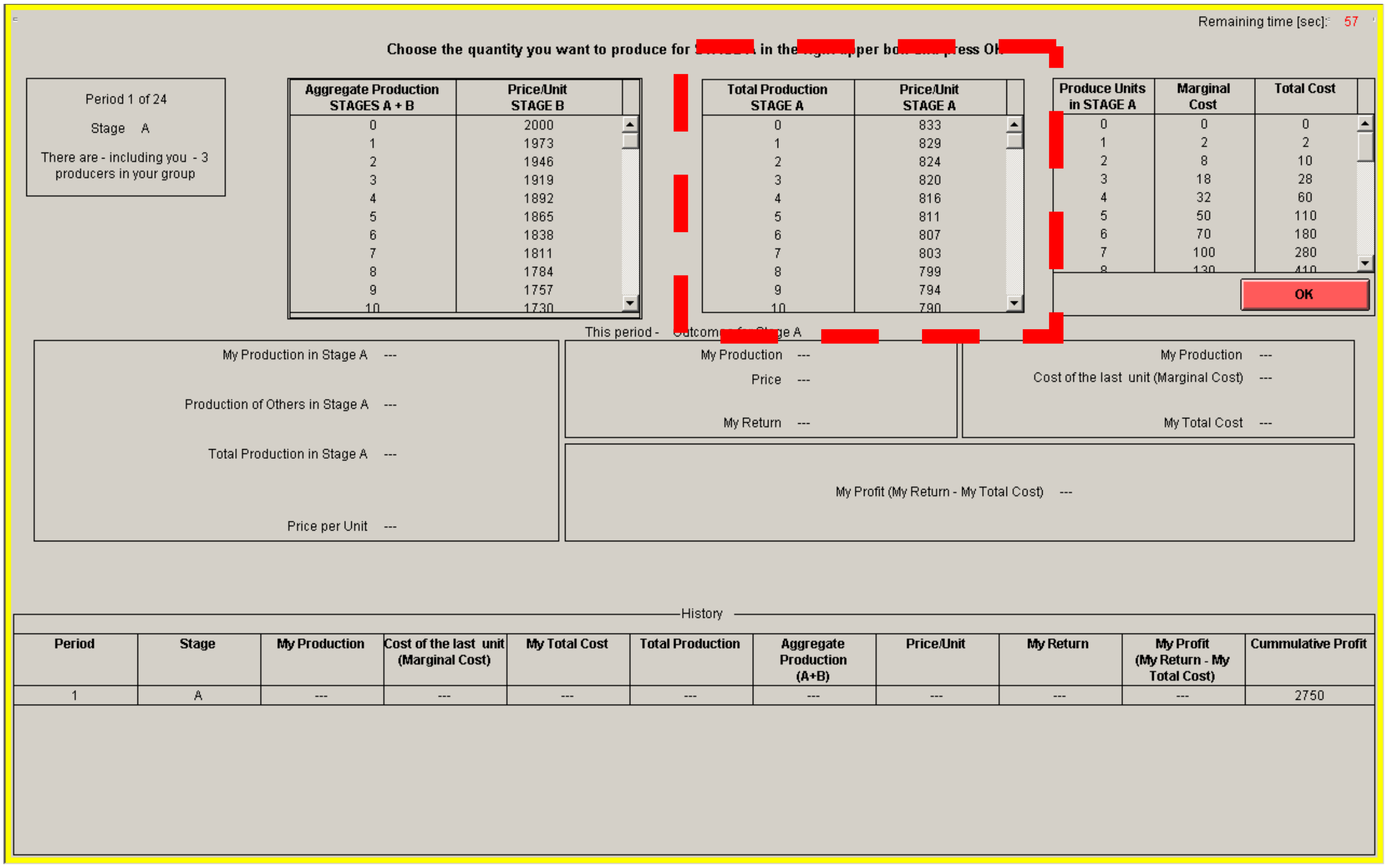
[“Figure 2”; M2F]



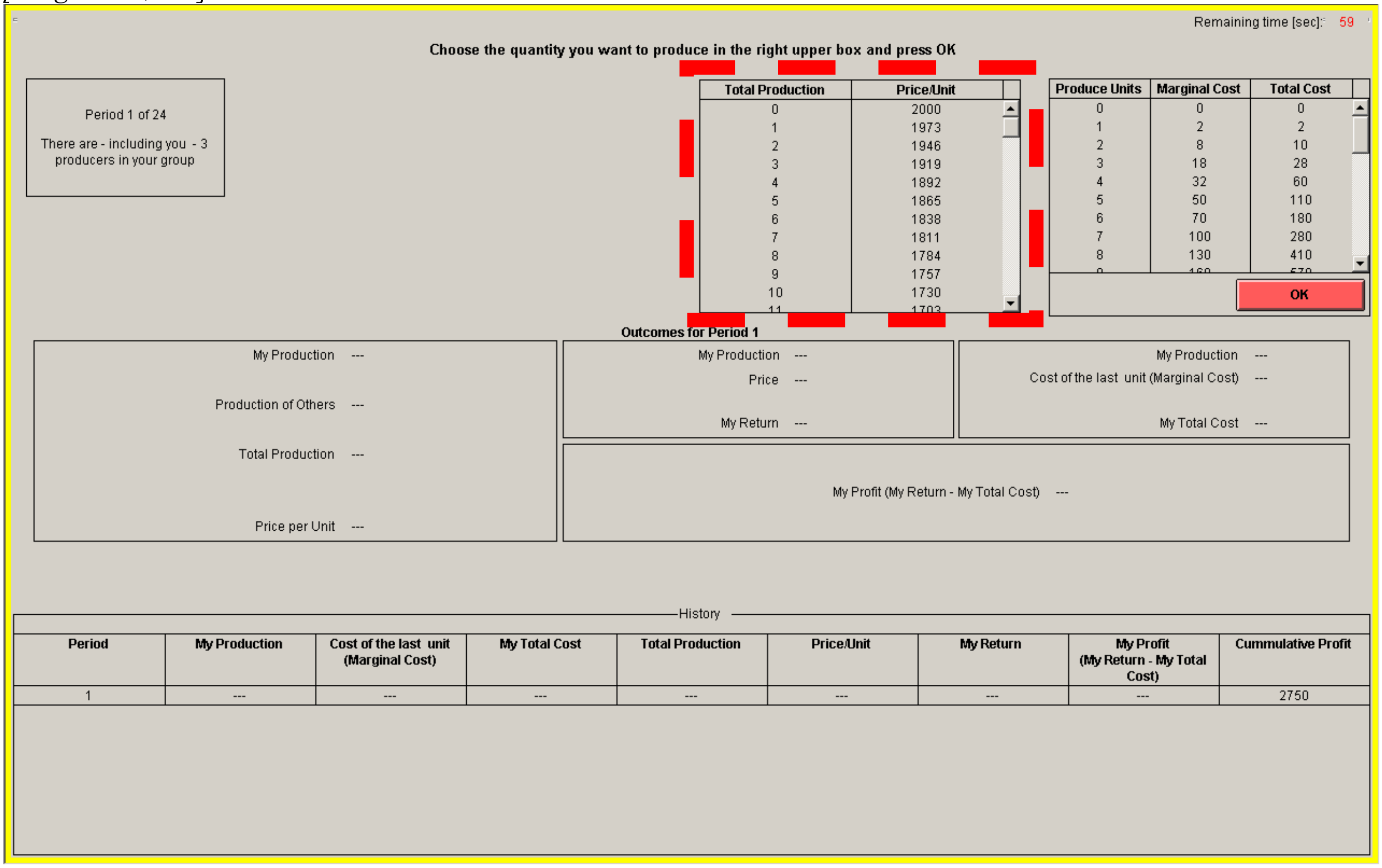
[“Figure 2”; M2]



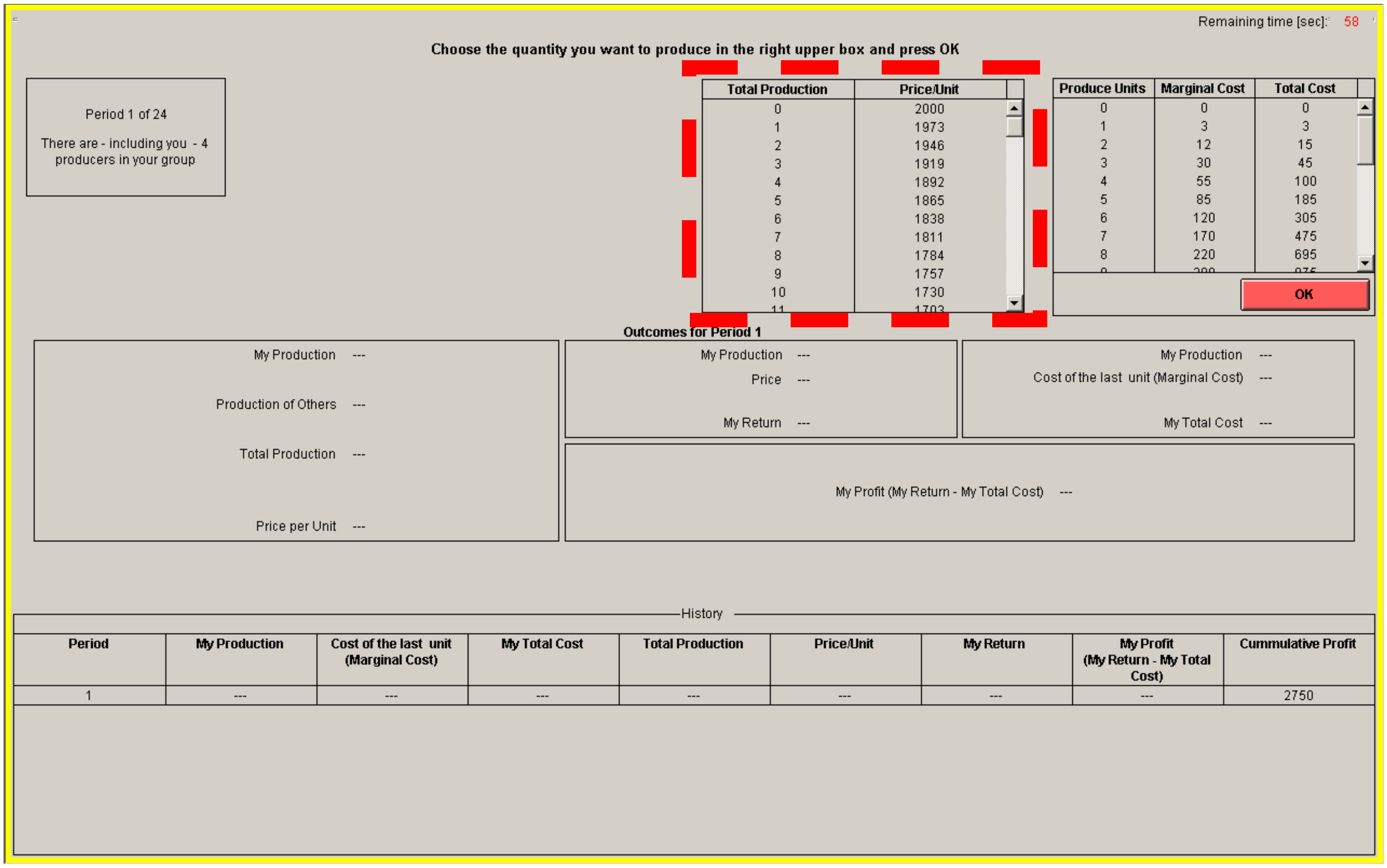
[“Figure 2”; M3F]


Remaining time [sec]: 57
Choose the quantity you want to produce for
Period 1 of 24
Stage A
There are - including you - 3 producers in your group
Aggregate Production STAGES A + B
Price/Unit STAGE B
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
Total Production STAGE A
Price/Unit STAGE A
0 833
1 829
2 824
3 820
4 816
5 811
6 807
7 803
8 799
9 794
Produce Units in STAGE A
Marginal Cost
Total Cost
0 0 0
1 2 2
2 8 10
3 18 28
4 32 60
5 50 110
6 70 180
7 100 280
OK
This period -
My Production in Stage A ---
Production of Others in Stage A ---
Total Production in Stage A ---
Price per Unit ---
My Production ---
Price ---
My Return ---
My Production ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period
Stage
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Aggregate Production (A+B)
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cummulative Profit
1 A --- --- --- --- --- --- --- --- 2750

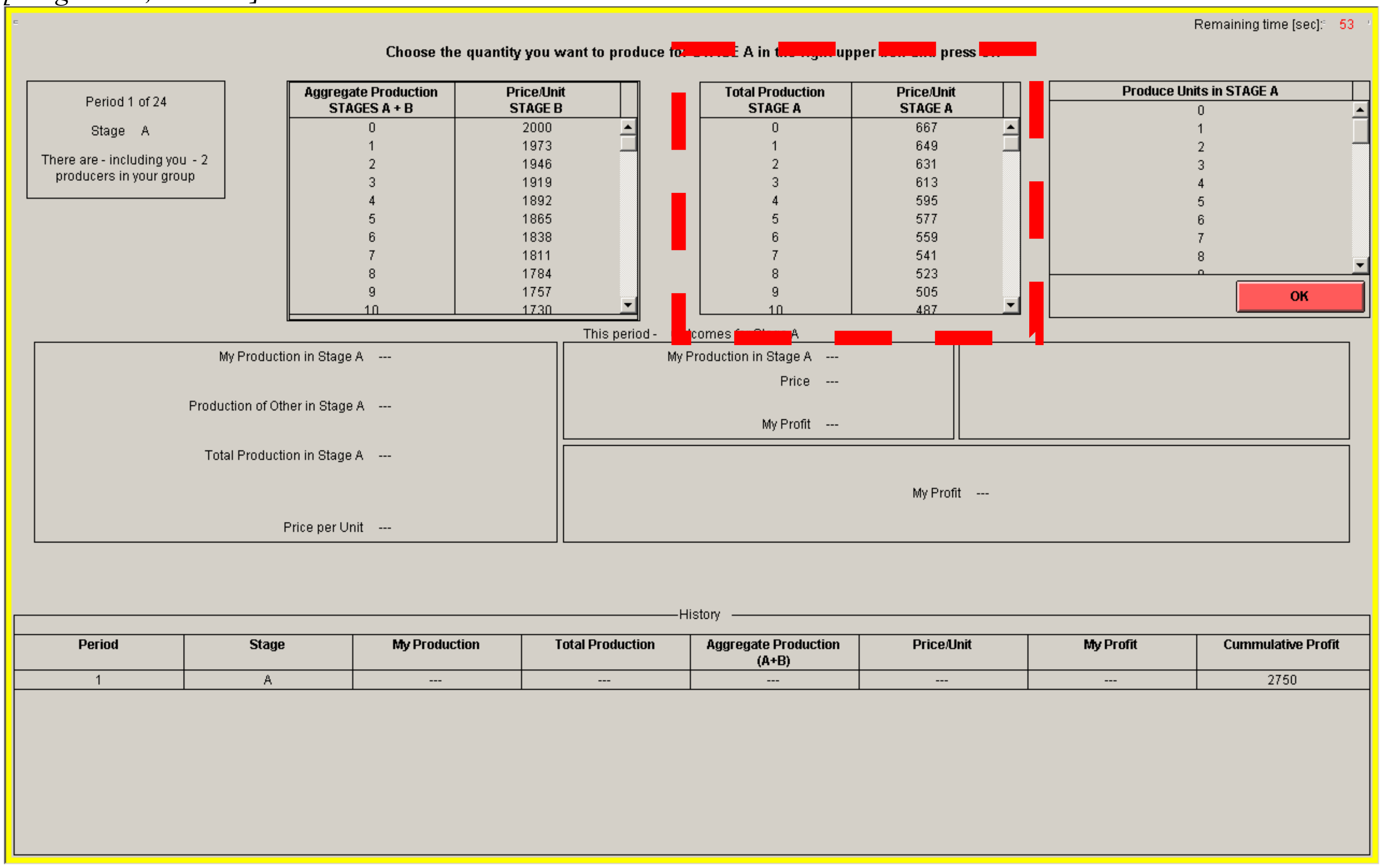
[“Figure 2”; M3]



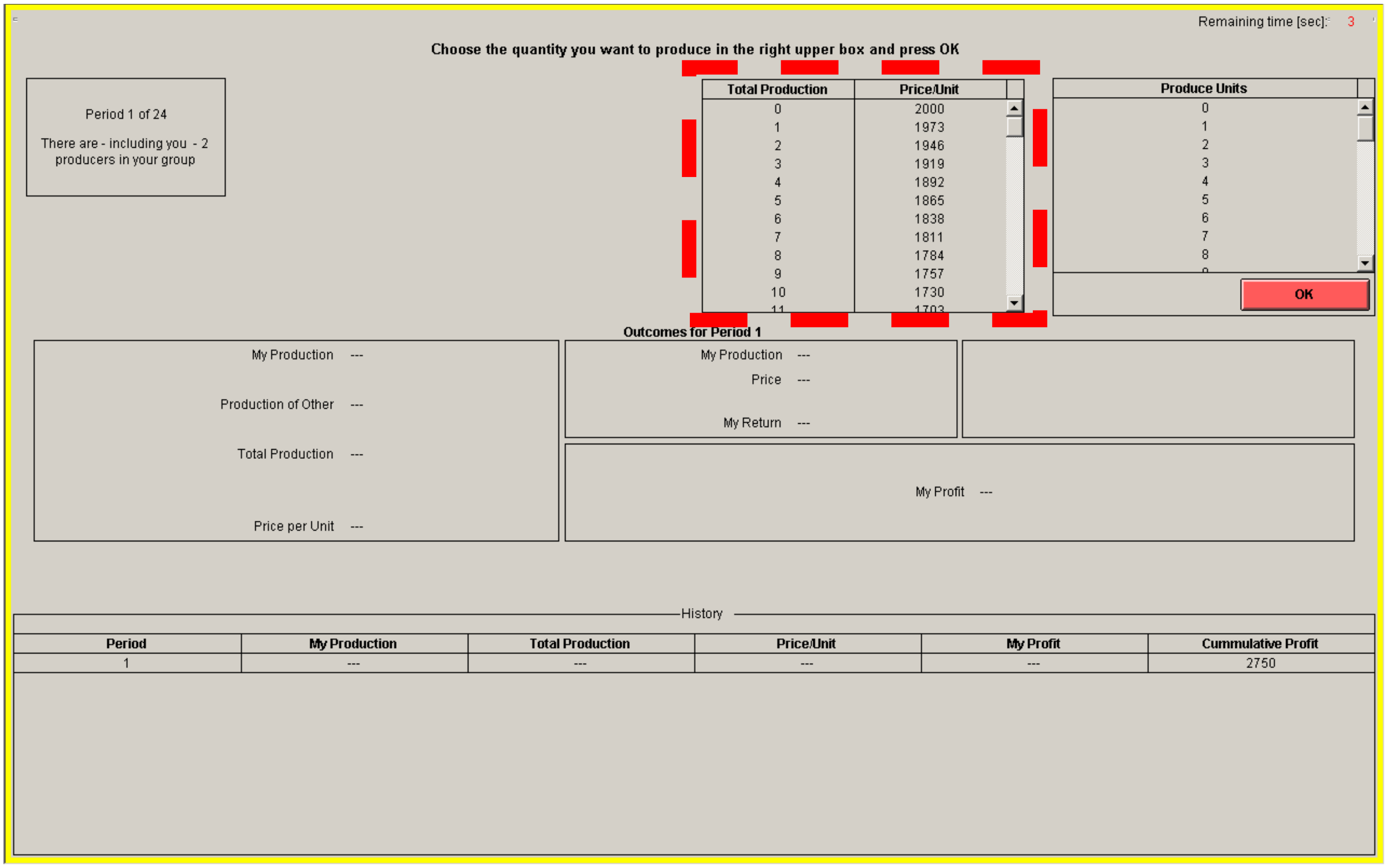
[“Figure 2”; M4]


Remaining time [sec]: 58
Choose the quantity you want to produce in the right upper box and press OK
Period 1 of 24
There are - including you - 4 producers in your group
Total Production
Price/Unit
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
10 1730
Produce Units
Marginal Cost
Total Cost
0 0 0
1 3 3
2 12 15
3 30 45
4 55 100
5 85 185
6 120 305
7 170 475
8 220 695
OK
Outcomes for Period 1
My Production ---
Production of Others ---
Total Production ---
Price per Unit ---
My Production ---
Price ---
My Return ---
My Production ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cummulative Profit
1 --- --- --- --- --- --- --- 2750

[“Figure 2”; M2F-zc]



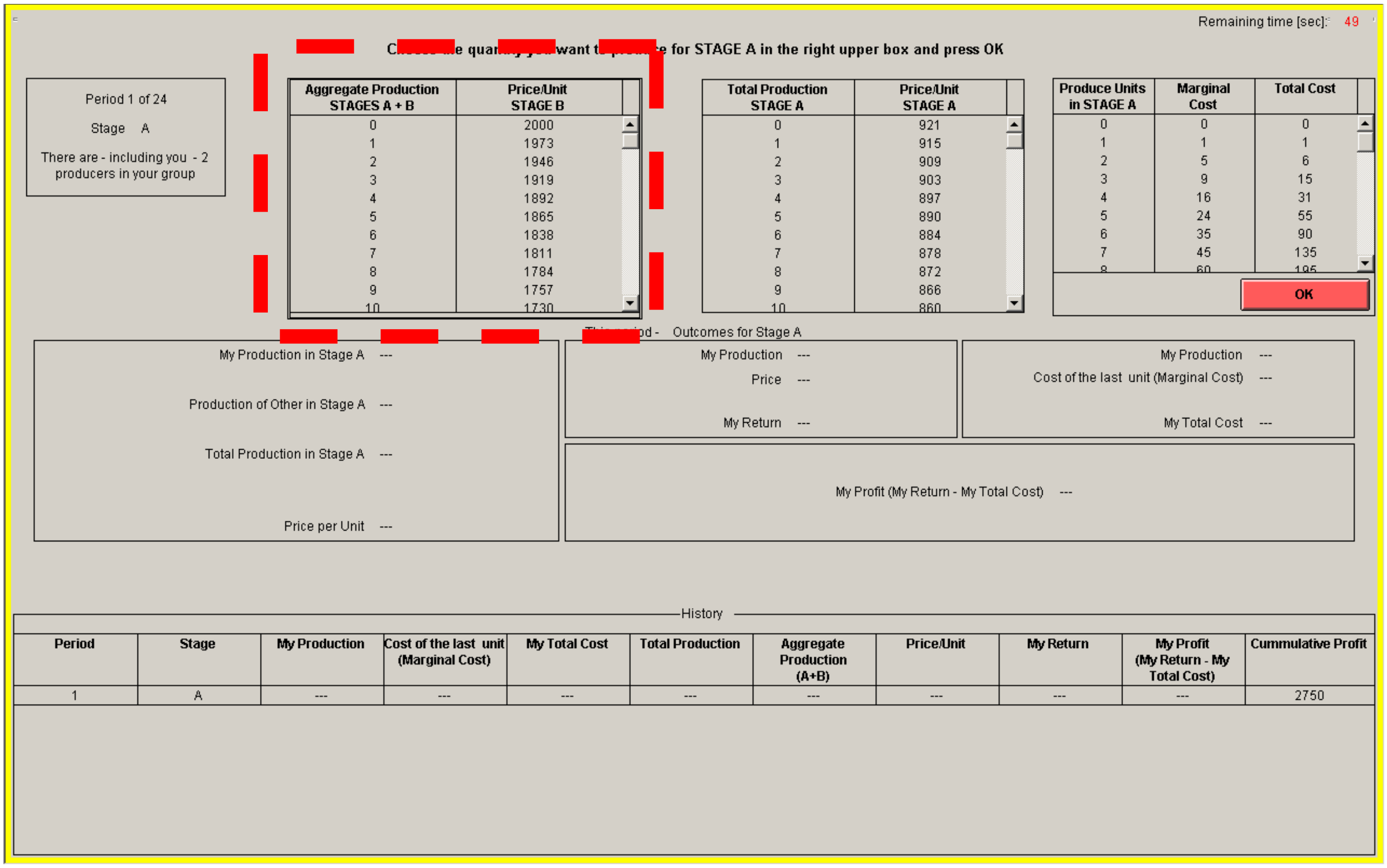
[“Figure 2”; M2-zc]



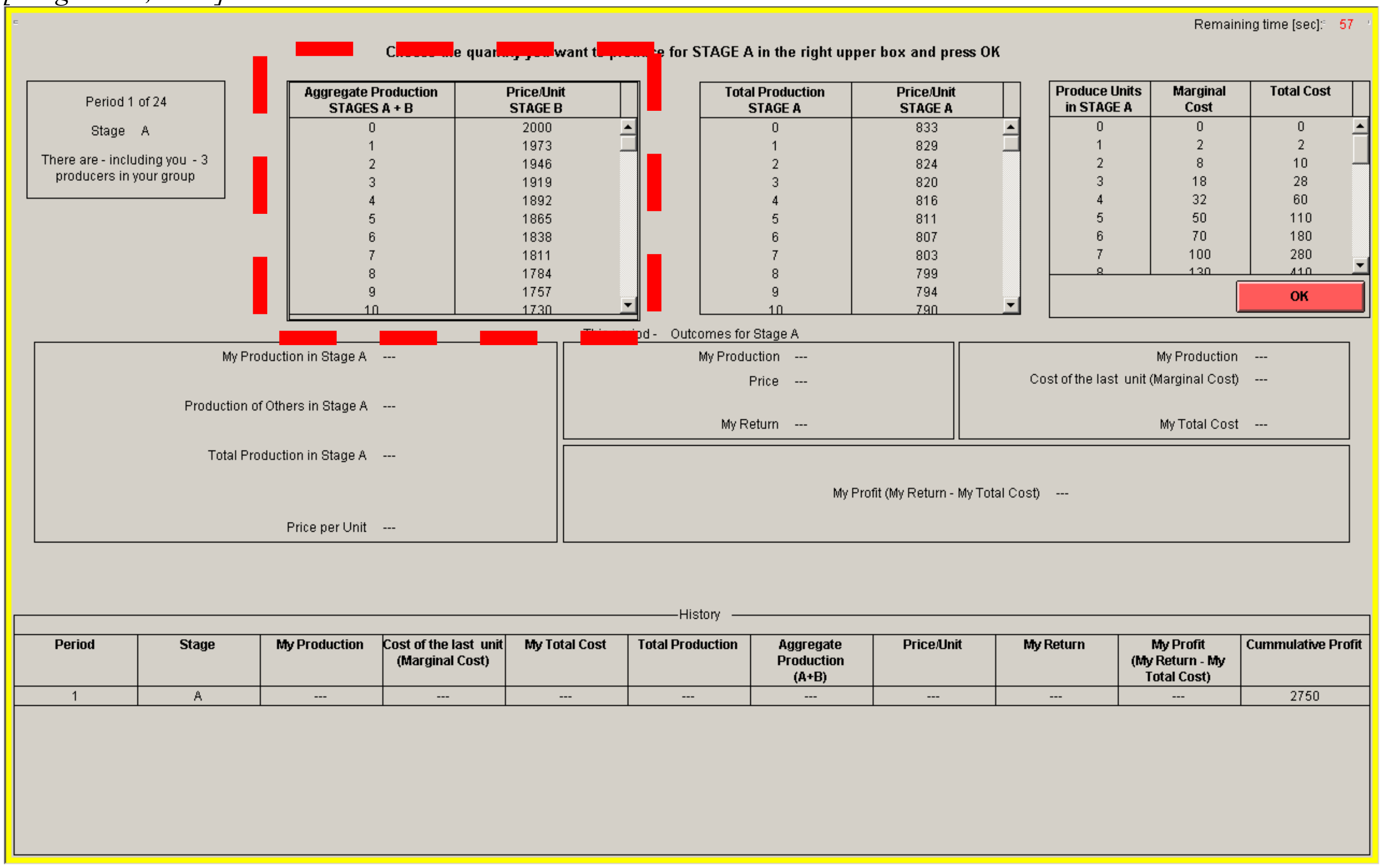
This Table gives you the market price in ECU. Thus, in the example in Figure 2, if total production was zero (that is, if no firm in the market produced anything at all), then the price per unit would be *["921"; M2F]* *["*667*"; M2F-zc] ["833"; M3F] ["2000"; M2,M2-zc, M3, M4]* ECU.

["On the upper left of the screen is a Table that shows the Market price in Stage B, given the total production in Stage A and Stage B together. ***The sum of the total production in Stage A and B is called "the Aggregate Production".*** *In the example, see the marked Table in Figure 3. This Table is relevant for the market price in Stage B."; M2F, M2F-zc, M3F]*

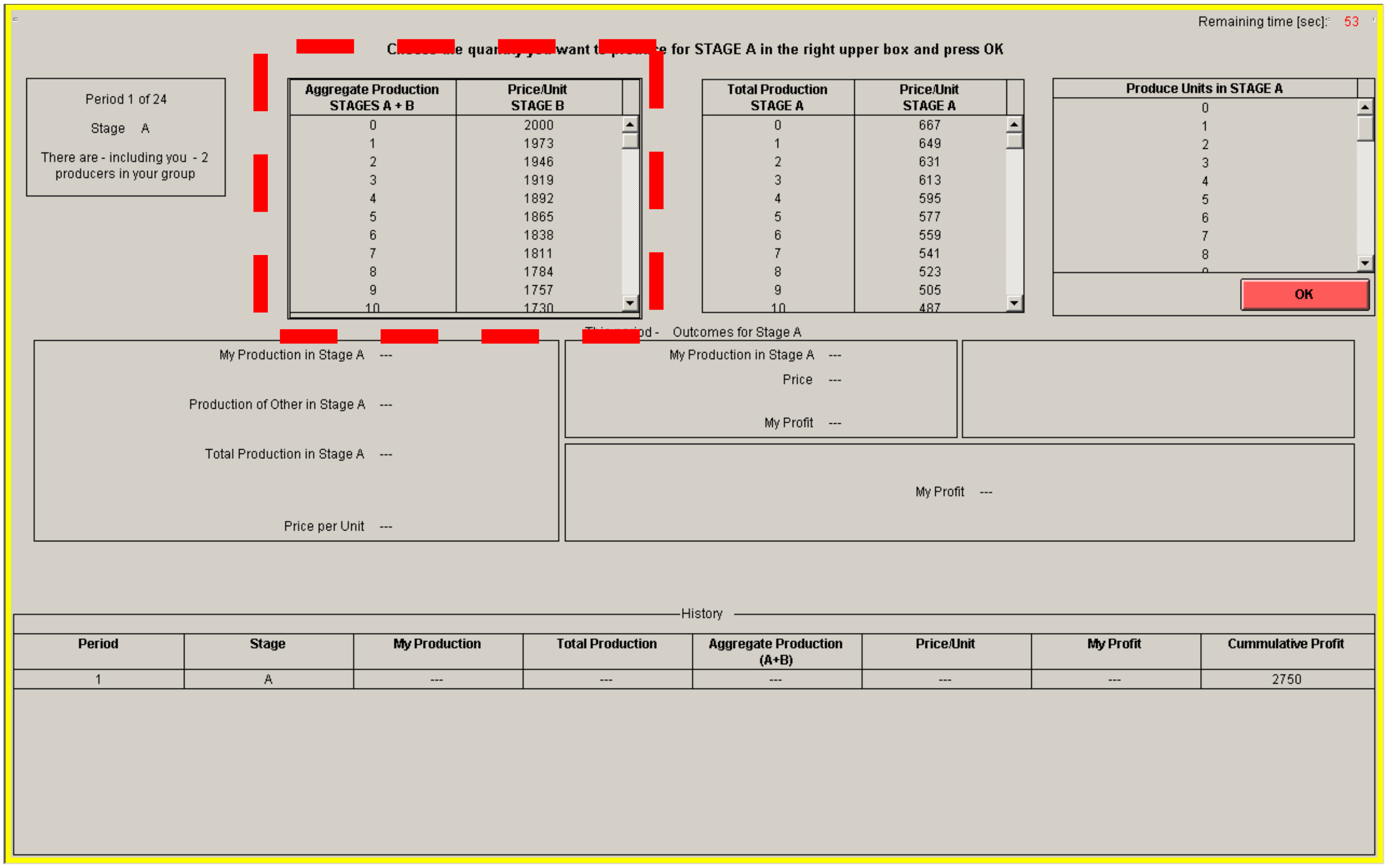
["Figure 3"; M2F]


Remaining time [sec]: 49
for STAGE A in the right upper box and press OK
Period 1 of 24
Stage A
There are - including you - 2 producers in your group
Aggregate Production STAGES A + B
Price/Unit STAGE B
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
Total Production STAGE A
Price/Unit STAGE A
0 921
1 915
2 909
3 903
4 897
5 890
6 884
7 878
8 872
9 866
Produce Units in STAGE A
Marginal Cost
Total Cost
0 0 0
1 1 1
2 5 6
3 9 15
4 16 31
5 24 55
6 35 90
7 45 135
OK
Outcomes for Stage A
My Production in Stage A ---
Production of Other in Stage A ---
Total Production in Stage A ---
Price per Unit ---
My Production ---
Price ---
My Return ---
My Production ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period | Stage | My Production | Cost of the last unit (Marginal Cost) | My Total Cost | Total Production | Aggregate Production (A+B) | Price/Unit | My Return | My Profit (My Return - My Total Cost) | Cummulative Profit
1 | A | --- | --- | --- | --- | --- | --- | --- | --- | 2750

[“Figure 3”; M3F]



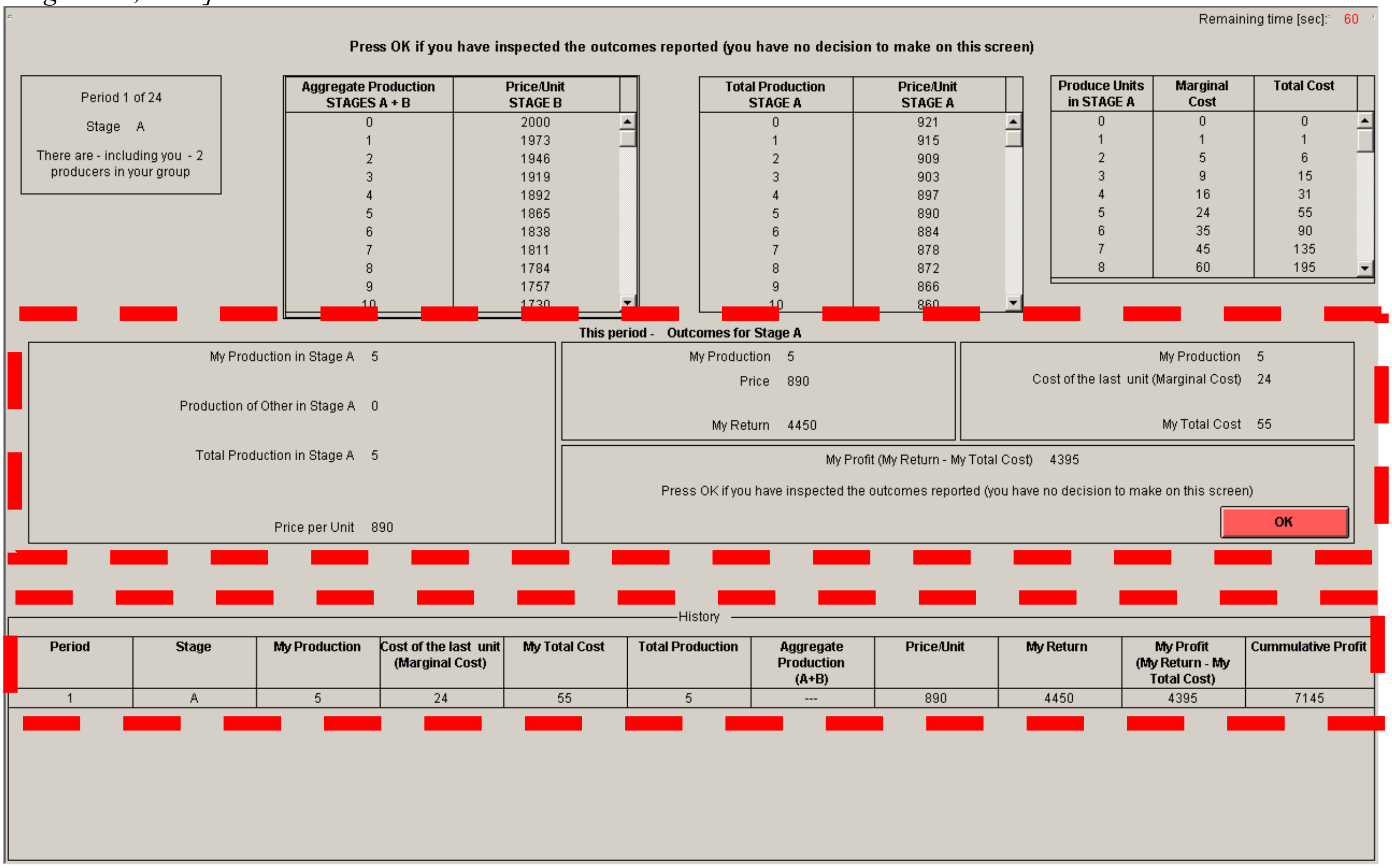
[“Figure 3”; M2F-zc]



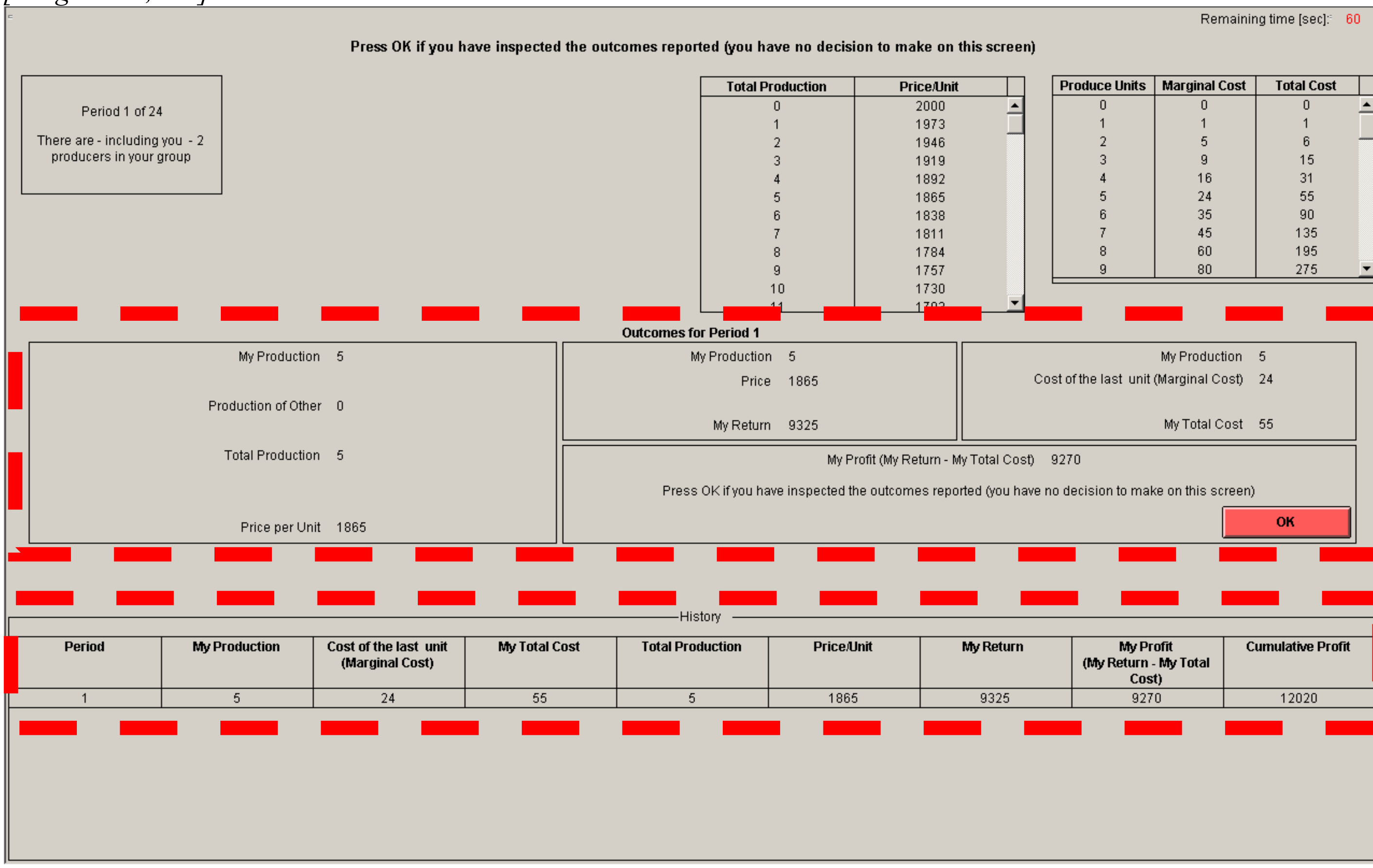
At the end of *[“each period”; M2, M2-zc, M3, M4][“Stage A”; M2F, M2F-zc, M3F]* you will see a “Results Screen.” The Results Screen will show the outcomes for *[“that period”; M2, M2-zc, M3, M4] [“Stage A”; M2F, M2F-zc, M3F]* , displayed in the middle of your screen. You have **one minute** to inspect the outcomes (this is the standard time you have for inspecting results).

The example in Figure *[“4”; M2F, M2F-zc, M3F] [“3”; M2,M2-zc, M3, M4]* illustrates the display of the results in the middle box. All results are also written in the History box, displayed in the lower part of your screen (the marked box below in Figure *[“4”; M2F, M2F-zc, M3F] [“3”; M2, M2-zc, M3, M4]*).

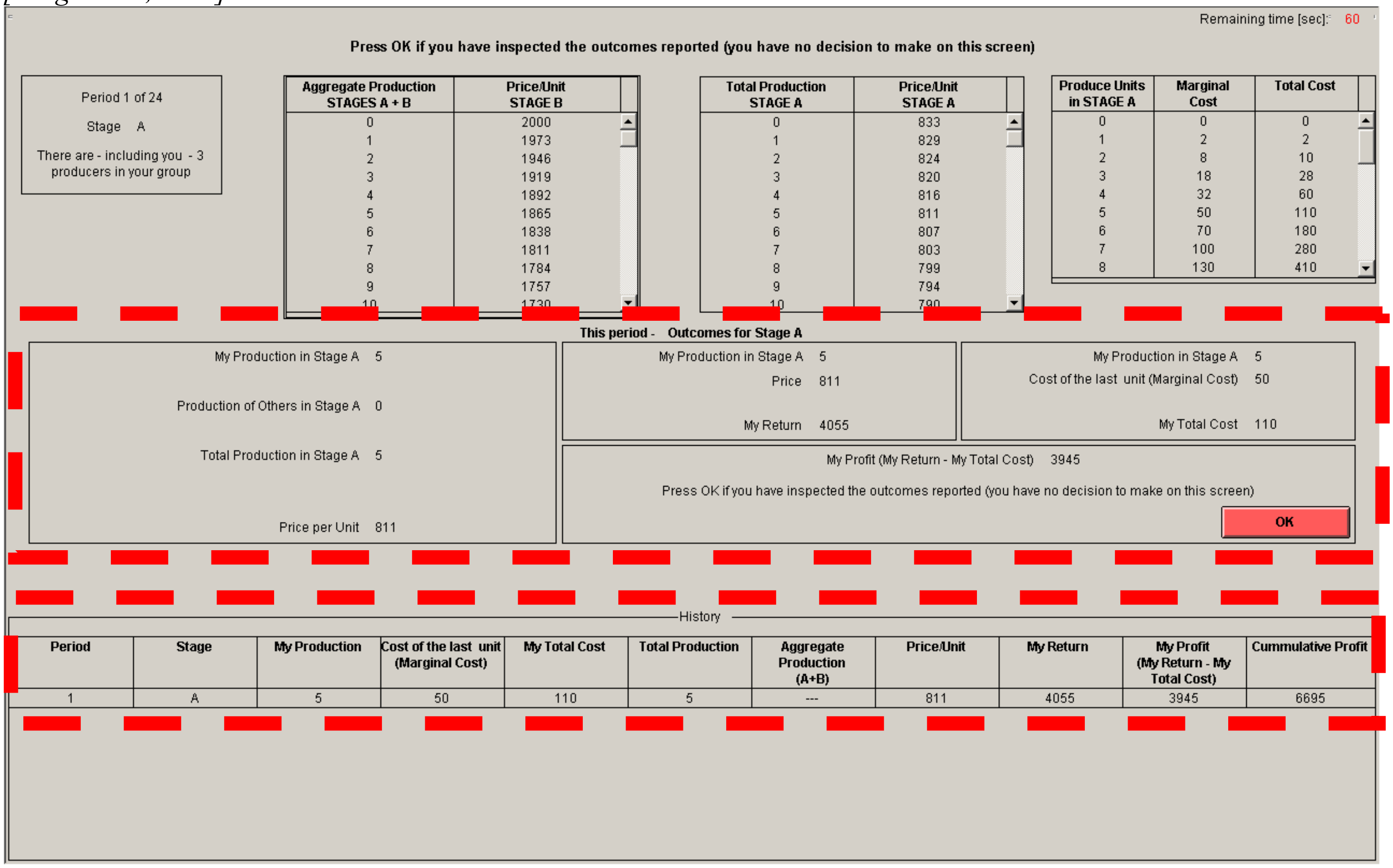
"Figure 4"; M2F]


Remaining time [sec]: 60
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
Period 1 of 24
Stage A
There are - including you - 2 producers in your group
Aggregate Production STAGES A + B
Price/Unit STAGE B
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
Total Production STAGE A
Price/Unit STAGE A
0 921
1 915
2 909
3 903
4 897
5 890
6 884
7 878
8 872
9 866
Produce Units in STAGE A
Marginal Cost
Total Cost
0 0 0
1 1 1
2 5 6
3 9 15
4 16 31
5 24 55
6 35 90
7 45 135
8 60 195
This period - Outcomes for Stage A
My Production in Stage A 5
Production of Other in Stage A 0
Total Production in Stage A 5
Price per Unit 890
My Production 5
Price 890
My Return 4450
My Production 5
Cost of the last unit (Marginal Cost) 24
My Total Cost 55
My Profit (My Return - My Total Cost) 4395
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
OK
History
Period
Stage
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Aggregate Production (A+B)
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cummulative Profit
1 A 5 24 55 5 --- 890 4450 4395 7145

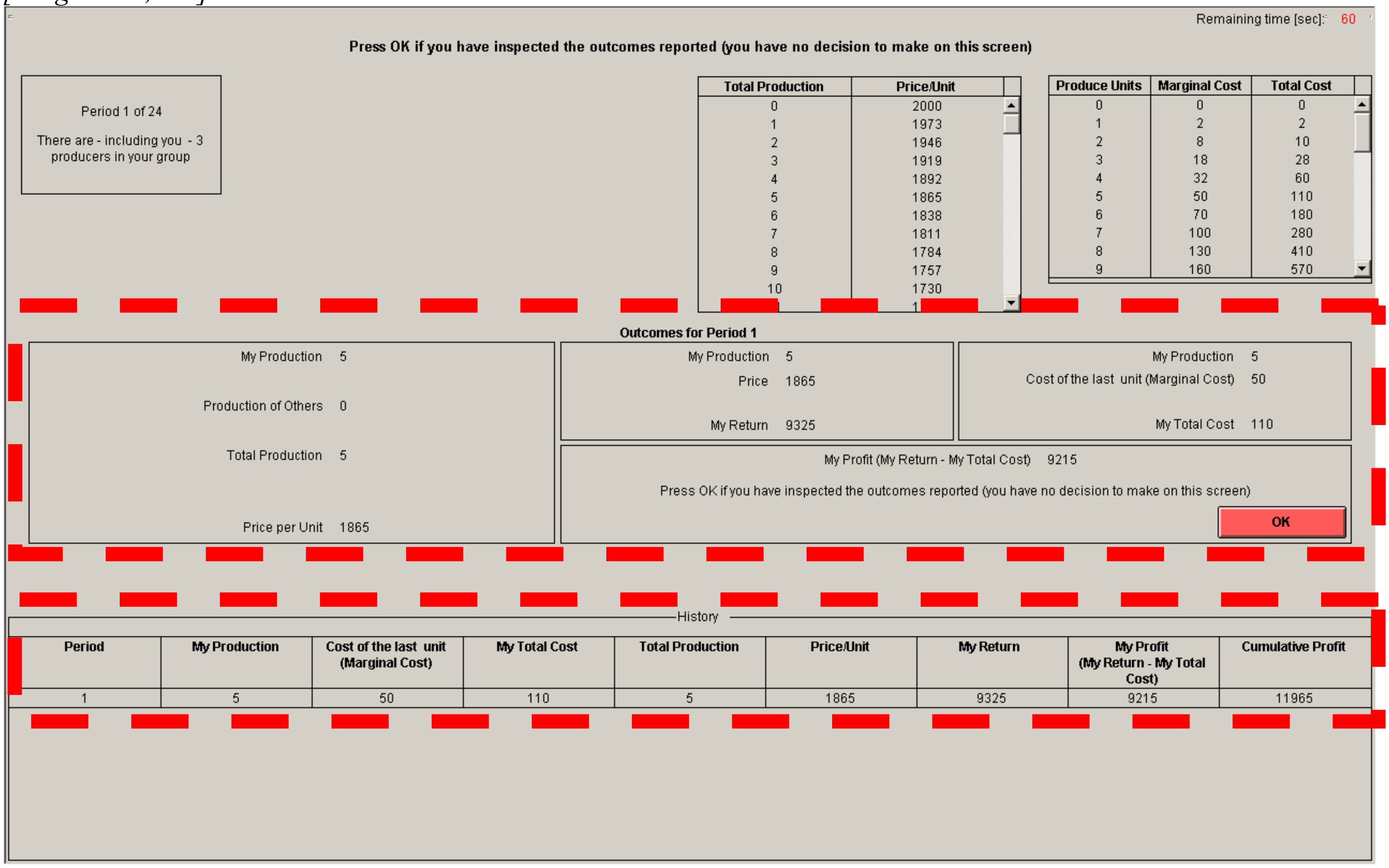
[“Figure 3”; M2]


Remaining time [sec]: 60
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
Period 1 of 24
There are - including you - 2 producers in your group
Total Production | Price/Unit
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
10 1730
Produce Units | Marginal Cost | Total Cost
0 0 0
1 1 1
2 5 6
3 9 15
4 16 31
5 24 55
6 35 90
7 45 135
8 60 195
9 80 275
Outcomes for Period 1
My Production 5
Production of Other 0
Total Production 5
Price per Unit 1865
My Production 5
Price 1865
My Return 9325
My Production 5
Cost of the last unit (Marginal Cost) 24
My Total Cost 55
My Profit (My Return - My Total Cost) 9270
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
OK
History
Period | My Production | Cost of the last unit (Marginal Cost) | My Total Cost | Total Production | Price/Unit | My Return | My Profit (My Return - My Total Cost) | Cumulative Profit
1 | 5 | 24 | 55 | 5 | 1865 | 9325 | 9270 | 12020

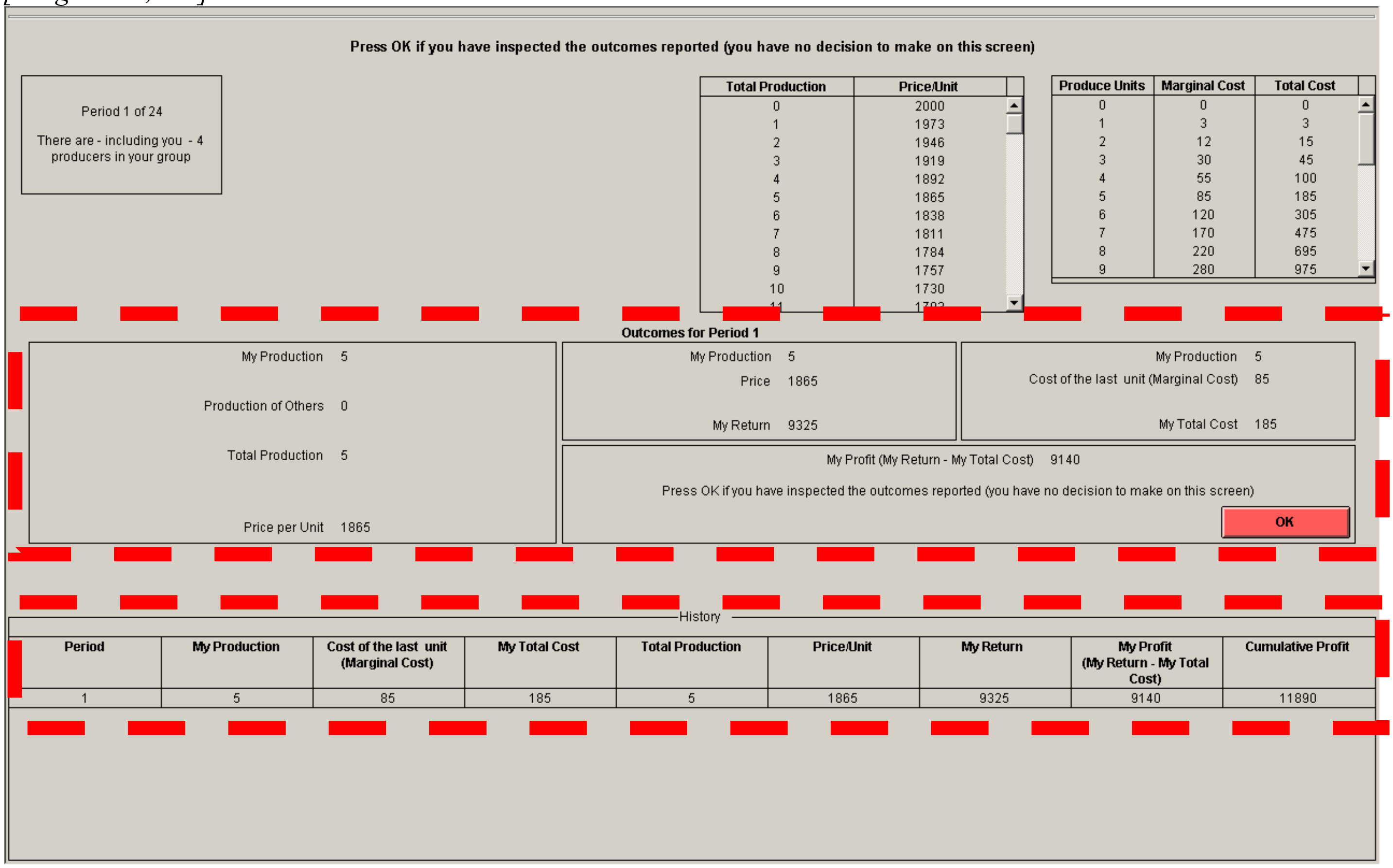
[“Figure 4”; M3F]


Remaining time [sec]: 60
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
Period 1 of 24
Stage A
There are - including you - 3 producers in your group
Aggregate Production STAGES A + B
Price/Unit STAGE B
0 1 2 3 4 5 6 7 8 9 10
2000 1973 1946 1919 1892 1865 1838 1811 1784 1757 1730
Total Production STAGE A
Price/Unit STAGE A
0 1 2 3 4 5 6 7 8 9 10
833 829 824 820 816 811 807 803 799 794 790
Produce Units in STAGE A
Marginal Cost
Total Cost
0 1 2 3 4 5 6 7 8
0 2 8 18 32 50 70 100 130
0 2 10 28 60 110 180 280 410
This period - Outcomes for Stage A
My Production in Stage A 5
Production of Others in Stage A 0
Total Production in Stage A 5
Price per Unit 811
My Production in Stage A 5
Price 811
My Return 4055
My Production in Stage A 5
Cost of the last unit (Marginal Cost) 50
My Total Cost 110
My Profit (My Return - My Total Cost) 3945
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
OK
History
Period | Stage | My Production | Cost of the last unit (Marginal Cost) | My Total Cost | Total Production | Aggregate Production (A+B) | Price/Unit | My Return | My Profit (My Return - My Total Cost) | Cummulative Profit
1 | A | 5 | 50 | 110 | 5 | --- | 811 | 4055 | 3945 | 6695

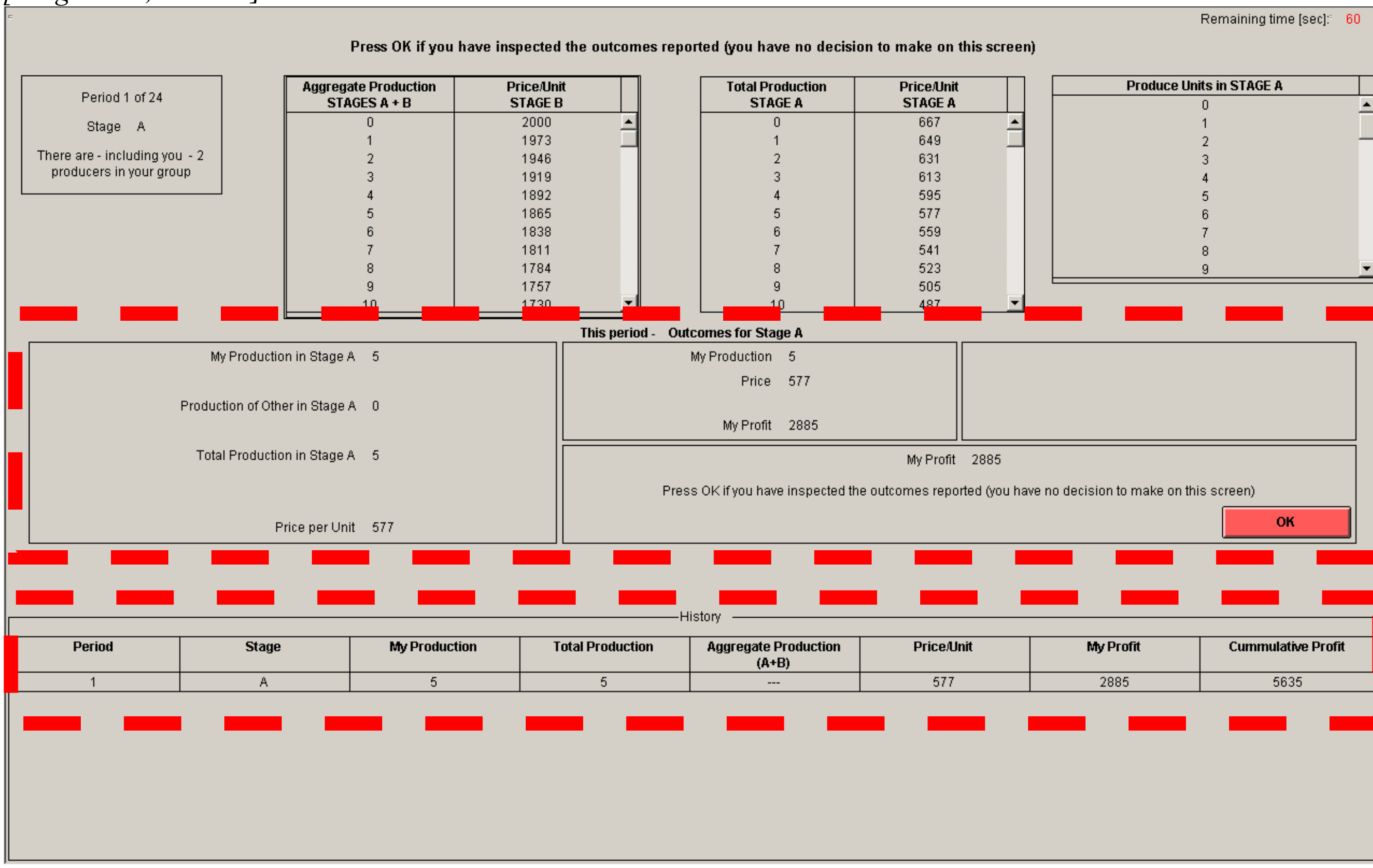
[“Figure 3”; M3]


Remaining time [sec]: 60
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
Period 1 of 24
There are - including you - 3 producers in your group
Total Production | Price/Unit
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
10 1730
Produce Units | Marginal Cost | Total Cost
0 0 0
1 2 2
2 8 10
3 18 28
4 32 60
5 50 110
6 70 180
7 100 280
8 130 410
9 160 570
Outcomes for Period 1
My Production 5
Production of Others 0
Total Production 5
Price per Unit 1865
My Production 5
Price 1865
My Return 9325
My Production 5
Cost of the last unit (Marginal Cost) 50
My Total Cost 110
My Profit (My Return - My Total Cost) 9215
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
OK
History
Period | My Production | Cost of the last unit (Marginal Cost) | My Total Cost | Total Production | Price/Unit | My Return | My Profit (My Return - My Total Cost) | Cumulative Profit
1 5 50 110 5 1865 9325 9215 11965

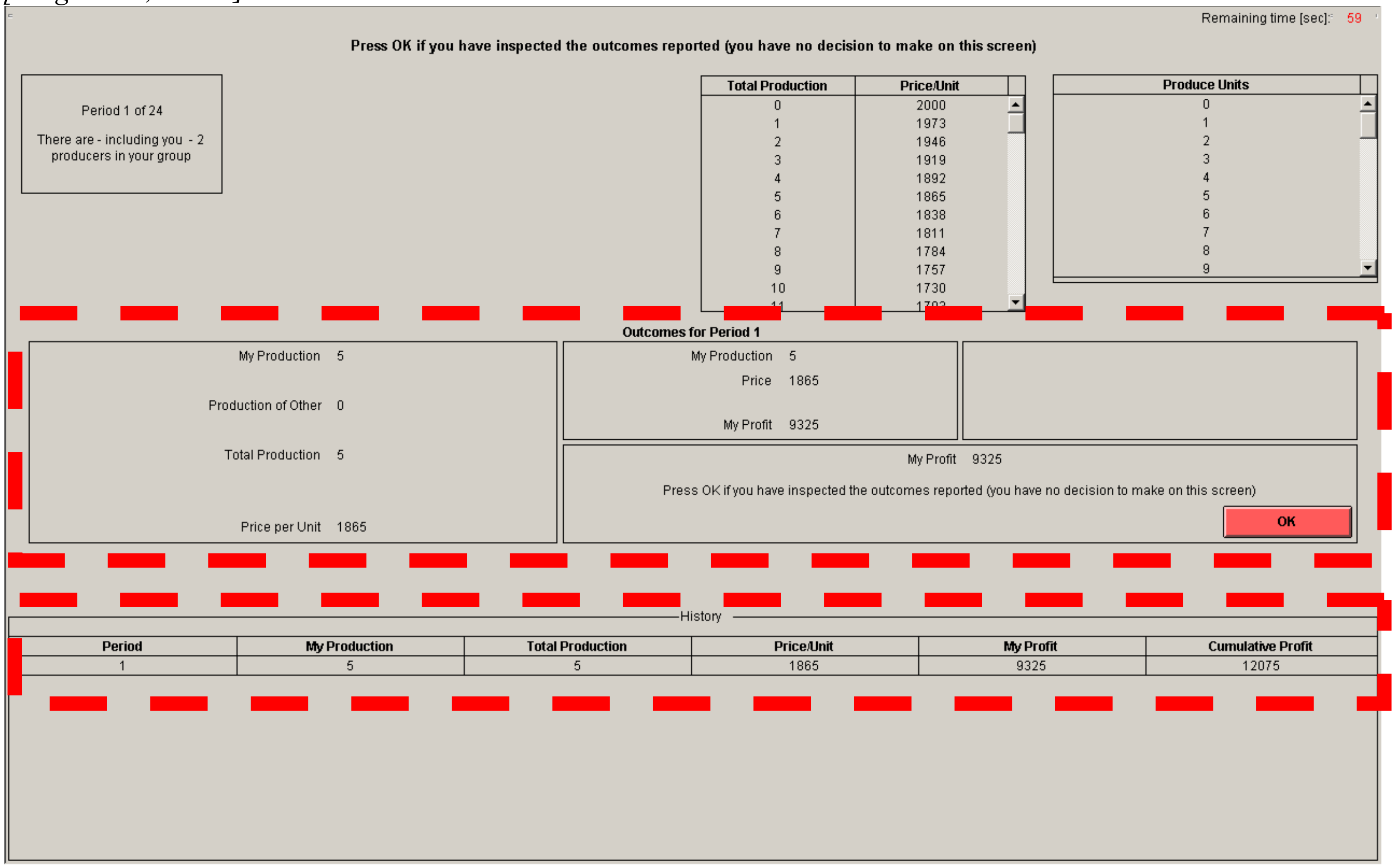
[“Figure 3”; M4]


Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
Period 1 of 24
There are - including you - 4 producers in your group
Total Production
Price/Unit
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
10 1730
Produce Units
Marginal Cost
Total Cost
0 0 0
1 3 3
2 12 15
3 30 45
4 55 100
5 85 185
6 120 305
7 170 475
8 220 695
9 280 975
Outcomes for Period 1
My Production 5
Production of Others 0
Total Production 5
Price per Unit 1865
My Production 5
Price 1865
My Return 9325
My Production 5
Cost of the last unit (Marginal Cost) 85
My Total Cost 185
My Profit (My Return - My Total Cost) 9140
Press OK if you have inspected the outcomes reported (you have no decision to make on this screen)
OK
History
Period
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cumulative Profit
1 5 85 185 5 1865 9325 9140 11890

[“Figure 4”; M2F-zc]



[“Figure 3”; M2-zc]



[From here on only M2F, M2F-zc, M3F]

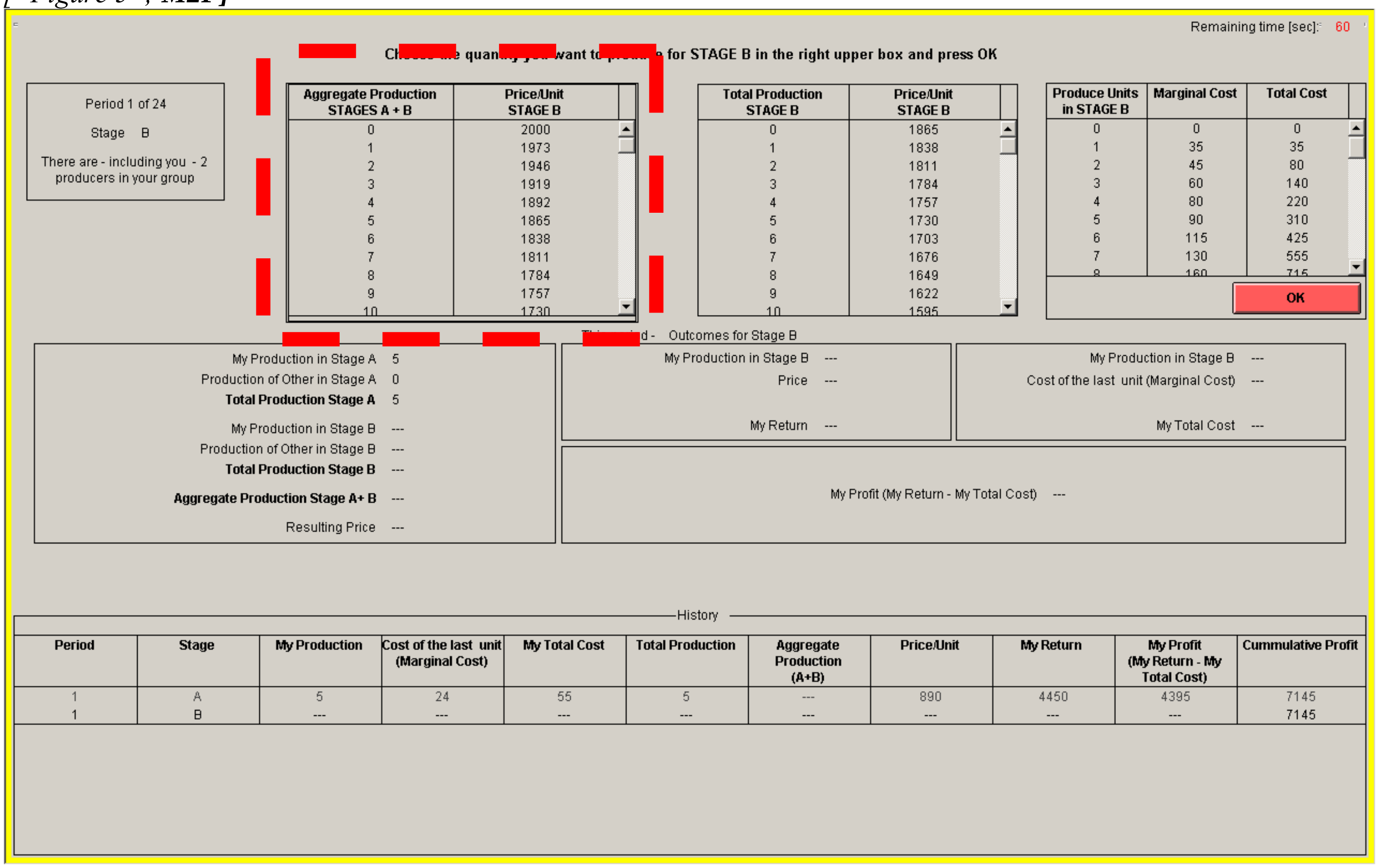
A.2.2. Stage B

Stage B is, in principle, identical to Stage A, but with one important exception. The way the price per unit is computed in Stage B differs in two ways from the way it was computed in Stage A.

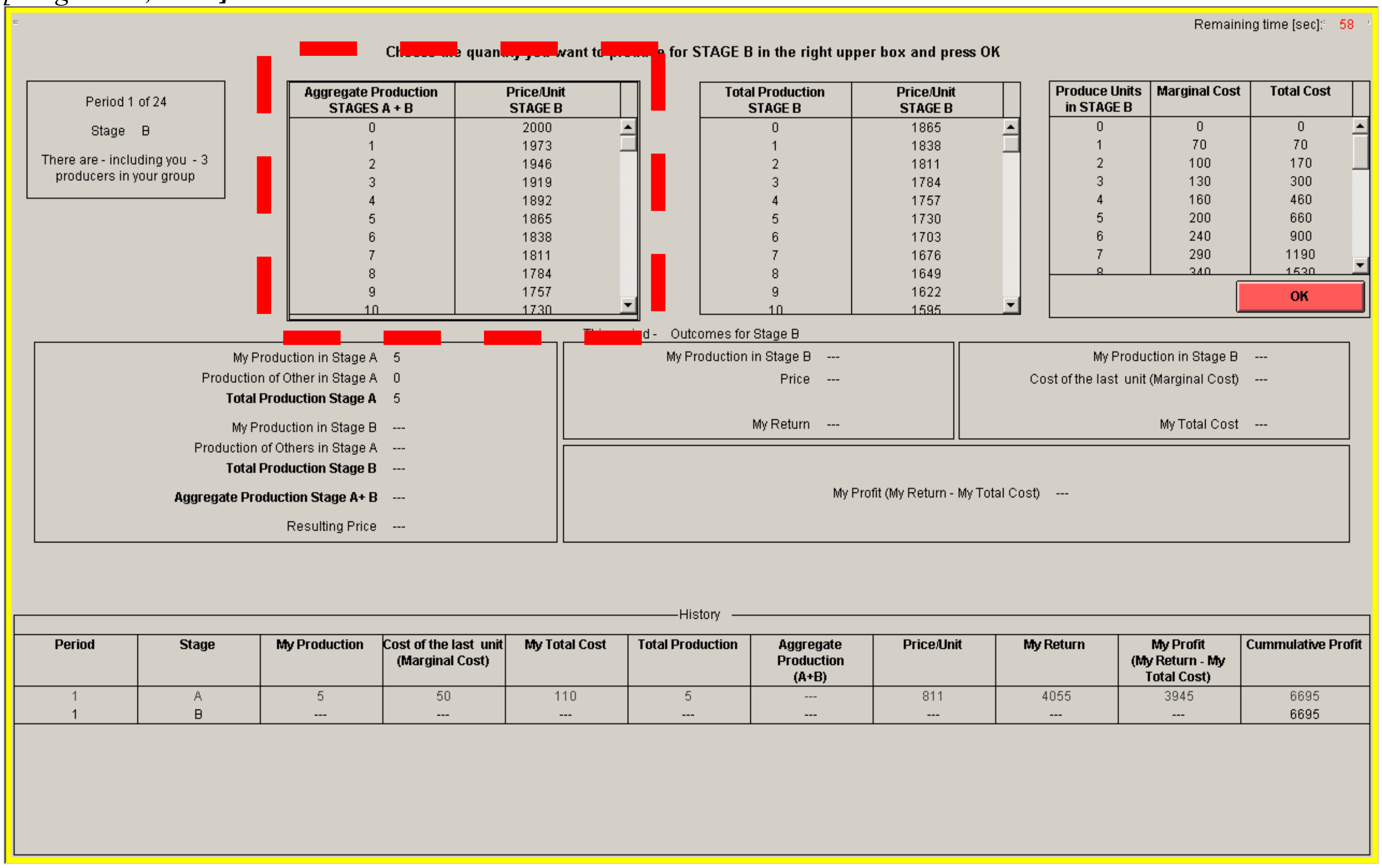
Firstly, the price per unit in Stage B depends on the **aggregate production**; the sum of the total production in Stage A and Stage B. The higher aggregate production is, the lower the price per unit will be.

Secondly, a different Table will be used for calculating the price per unit: the Table labeled "**Aggregate Production STAGES A + B and Resulting Price in Stage B**". The Table shows the price per unit, given the aggregate production of Stage A and Stage B together. You can find this Table in the end of the instructions on page 100. **It is also shown on your screen on top on the left side**. In the example, see Figure 5.

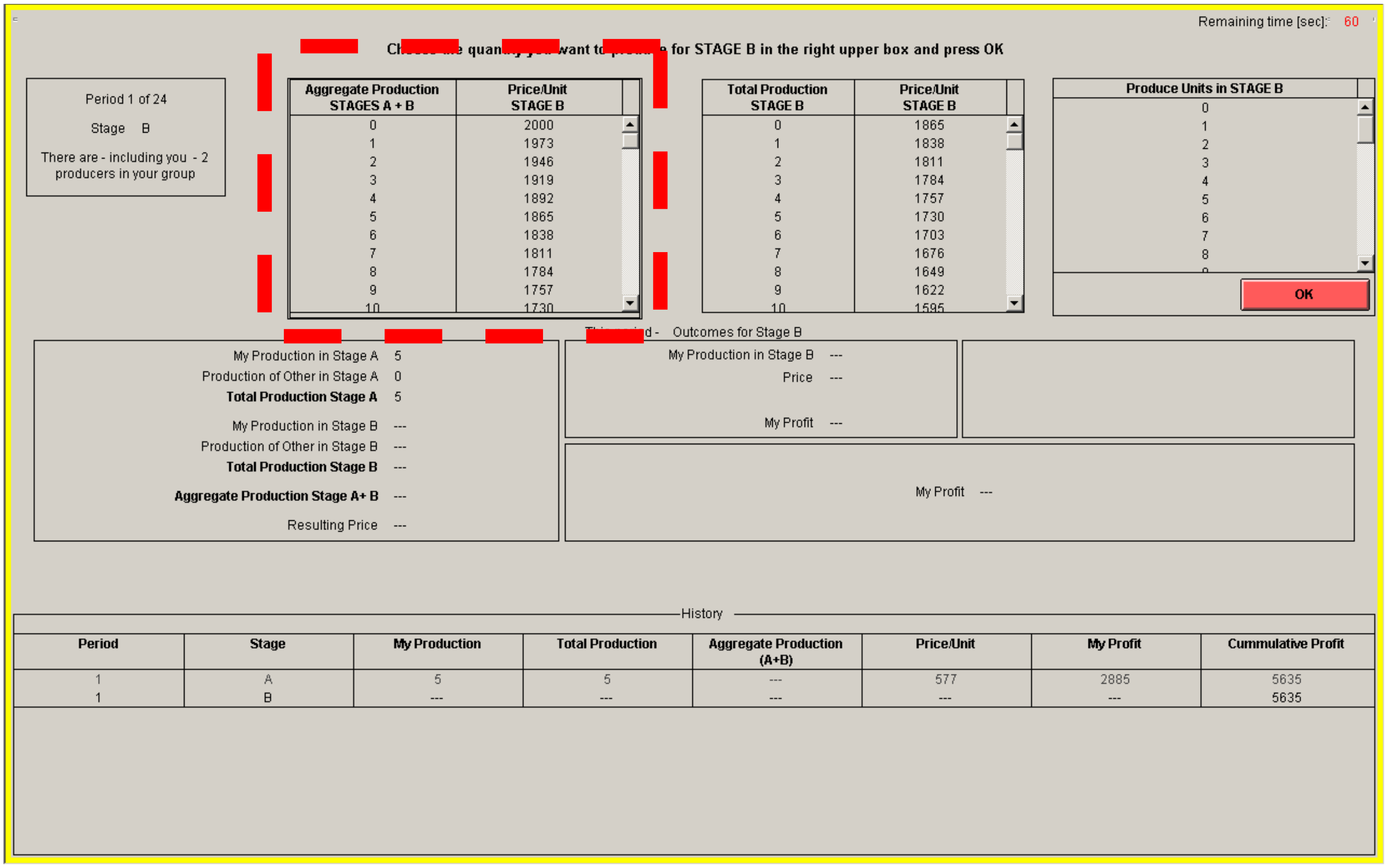
*["Figure 5"; **M2F]***



[“Figure 5”; ***M3F]***

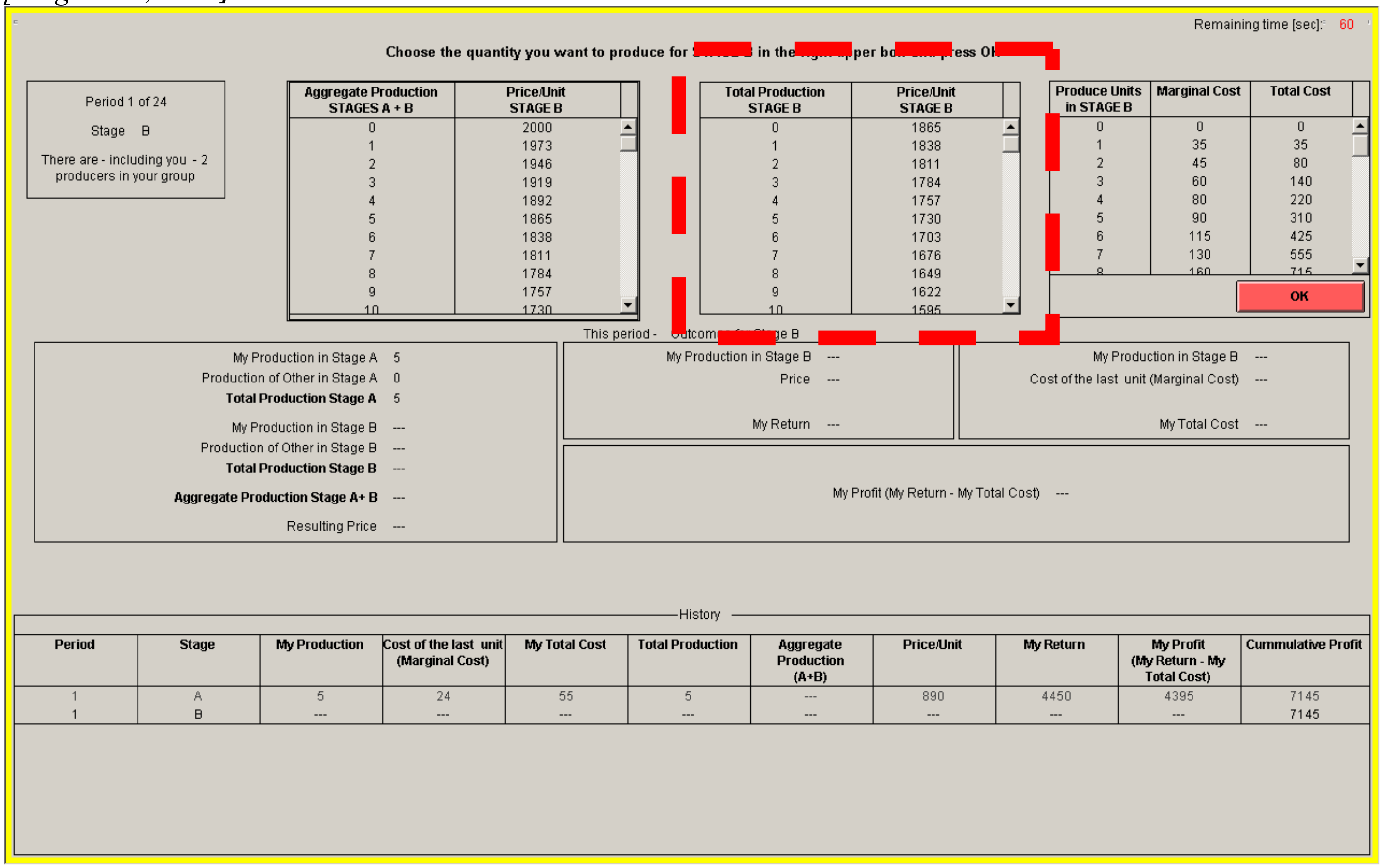


[“Figure 5”; ***M2F-zc]***

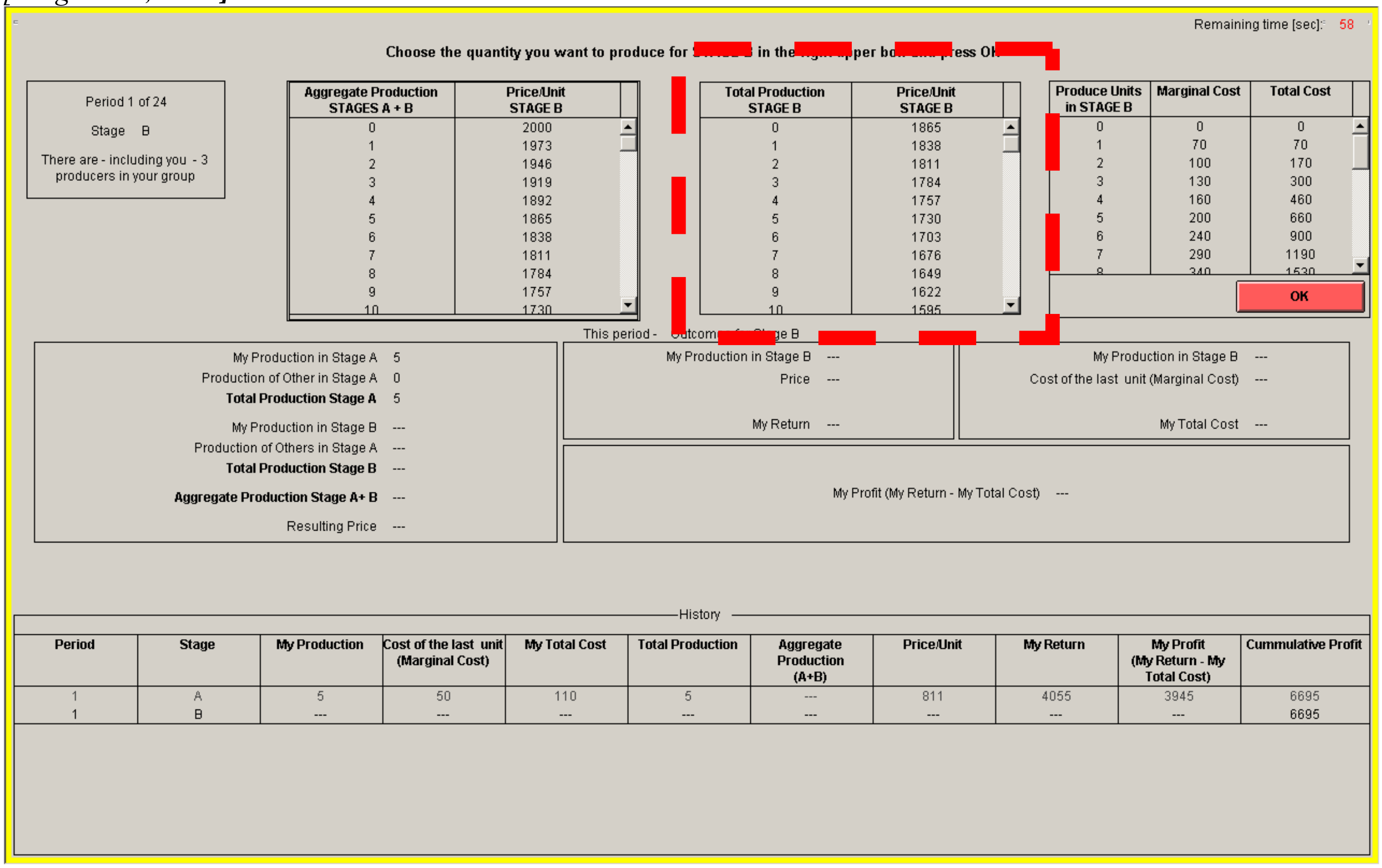


To make it easier for you to decide how many units to produce in Stage B, the screen shows the Table "**Total Production Stage B**" on top and in the middle of the screen. See the marked Table in Figure 6. This Table basically gives the same information as the Table "Aggregate Production STAGES A +B" on the left, but automatically uses the total production in Stage A to calculate prices.

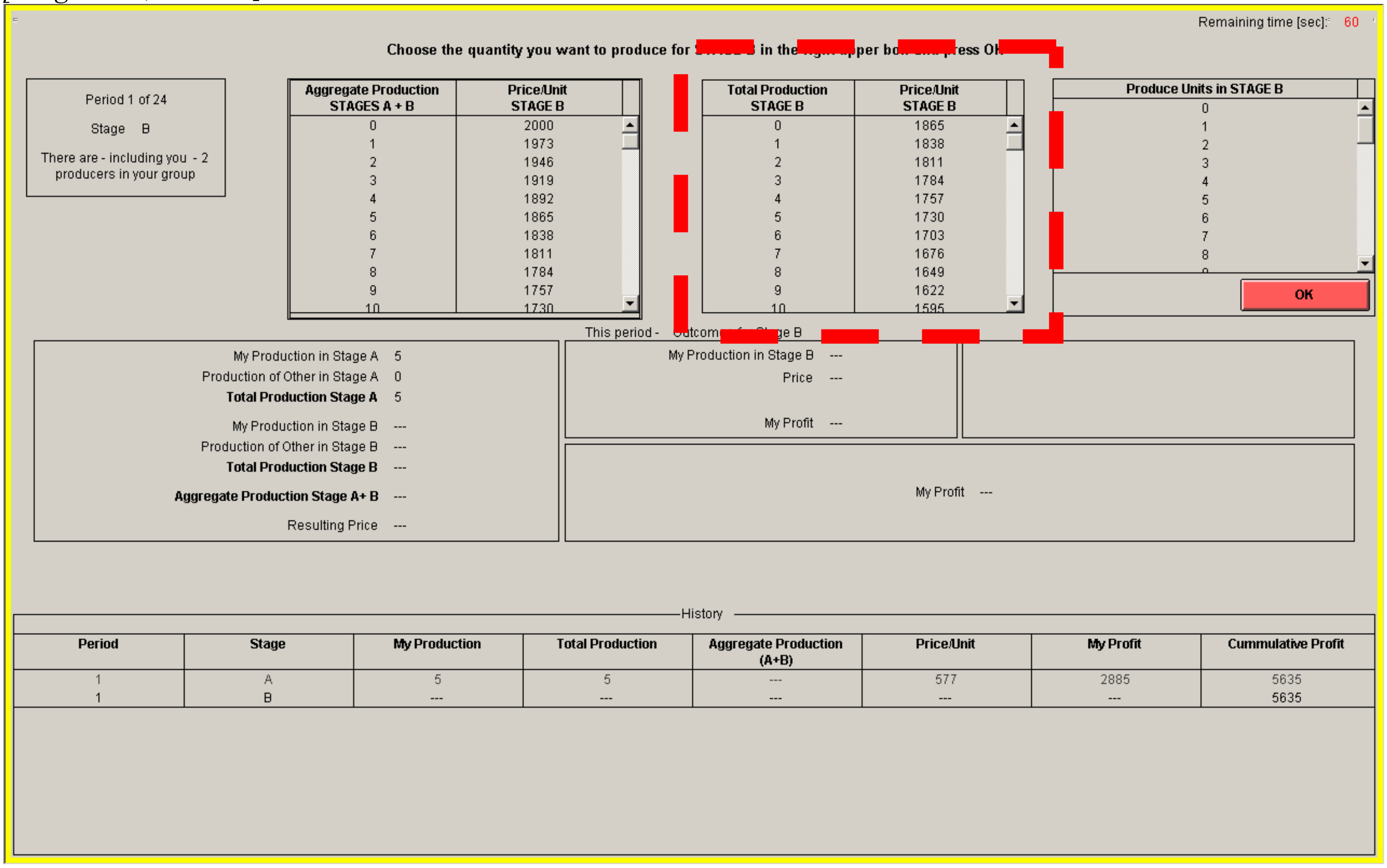
[“Figure 6”; ***M2F]***


Remaining time [sec]: 60
Choose the quantity you want to produce for
Period 1 of 24
Stage B
There are - including you - 2 producers in your group
Aggregate Production STAGES A + B
Price/Unit STAGE B
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
Total Production STAGE B
Price/Unit STAGE B
0 1865
1 1838
2 1811
3 1784
4 1757
5 1730
6 1703
7 1676
8 1649
9 1622
Produce Units in STAGE B
Marginal Cost
Total Cost
0 0 0
1 35 35
2 45 80
3 60 140
4 80 220
5 90 310
6 115 425
7 130 555
OK
This period -
My Production in Stage A 5
Production of Other in Stage A 0
Total Production Stage A 5
My Production in Stage B ---
Production of Other in Stage B ---
Total Production Stage B ---
Aggregate Production Stage A+ B ---
Resulting Price ---
My Production in Stage B ---
Price ---
My Return ---
My Production in Stage B ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period | Stage | My Production | Cost of the last unit (Marginal Cost) | My Total Cost | Total Production | Aggregate Production (A+B) | Price/Unit | My Return | My Profit (My Return - My Total Cost) | Cummulative Profit
1 | A | 5 | 24 | 55 | 5 | --- | 890 | 4450 | 4395 | 7145
1 | B | --- | --- | --- | --- | --- | --- | --- | --- | 7145

[“Figure 6”; ***M3F]***

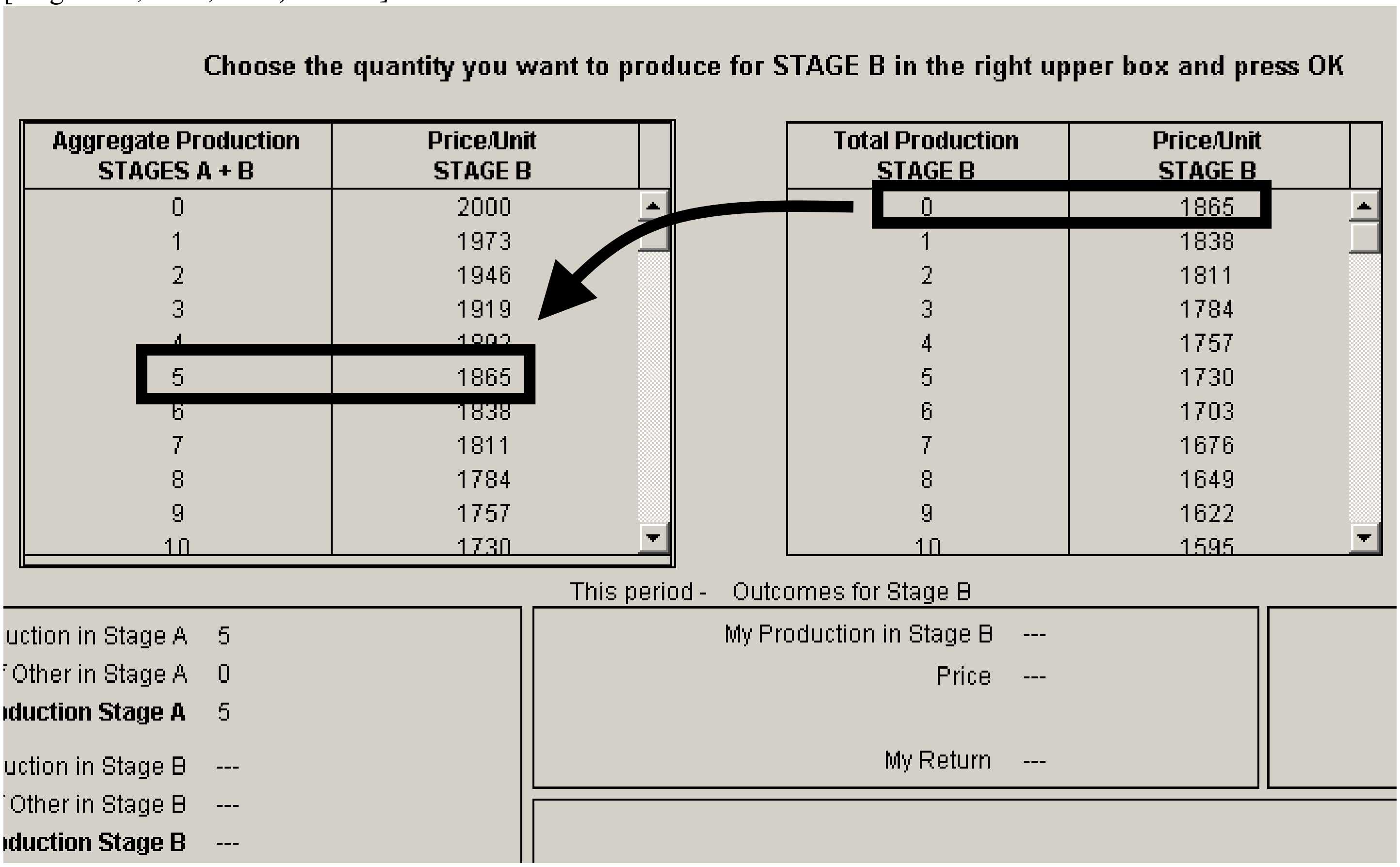

Remaining time [sec]: 58
Period 1 of 24
Stage B
There are - including you - 3 producers in your group
Aggregate Production STAGES A + B
Price/Unit STAGE B
0 2000
1 1973
2 1946
3 1919
4 1892
5 1865
6 1838
7 1811
8 1784
9 1757
Total Production STAGE B
Price/Unit STAGE B
0 1865
1 1838
2 1811
3 1784
4 1757
5 1730
6 1703
7 1676
8 1649
9 1622
Produce Units in STAGE B
Marginal Cost
Total Cost
0 0 0
1 70 70
2 100 170
3 130 300
4 160 460
5 200 660
6 240 900
7 290 1190
OK
My Production in Stage A 5
Production of Other in Stage A 0
Total Production Stage A 5
My Production in Stage B ---
Production of Others in Stage A ---
Total Production Stage B ---
Aggregate Production Stage A+ B ---
Resulting Price ---
My Production in Stage B ---
Price ---
My Return ---
My Production in Stage B ---
Cost of the last unit (Marginal Cost) ---
My Total Cost ---
My Profit (My Return - My Total Cost) ---
History
Period
Stage
My Production
Cost of the last unit (Marginal Cost)
My Total Cost
Total Production
Aggregate Production (A+B)
Price/Unit
My Return
My Profit (My Return - My Total Cost)
Cummulative Profit
1 A 5 50 110 5 --- 811 4055 3945 6695
1 B --- --- --- --- --- --- --- --- 6695

[“Figure 6”; ***M2F-zc]***



In the example in Figure 6 the total production in Stage A was 5 units. Thus if the total production in Stage B is 0, then the aggregate production of Stages A and B together is 5. Figure 7 shows a close-up of the Tables for this example. As you can see, **the Table “Aggregate Production” on the left shows the same prices as the Table “Total Production Stage B” on the right**, but prices are assigned to production levels that are 5 units higher; an upwards shift. In each round **the upward shift will be equal to the total production in Stage A** (which was 5 in this example).

[“Figure 7*”; M2F, M3F, M2F-zc]*



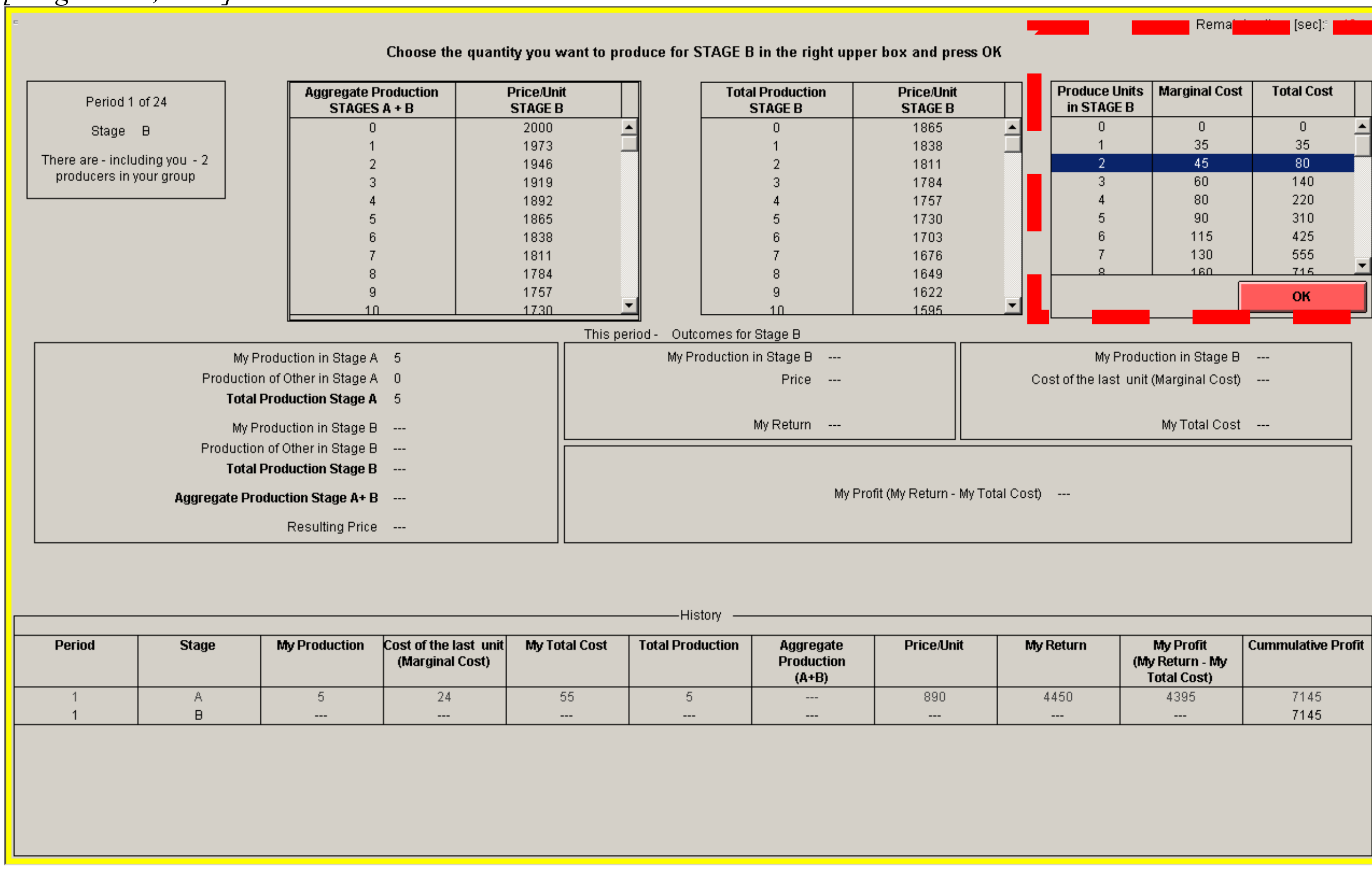
[“Your return will be equal to the number of units you produce times the market price; your profit will be equal to your return minus your total cost.”; M2F, M3F][“Your profit will be equal to the number of units you produce times the market price”; M2F-zc]

You choose the number of units in the same box in the upper right part of the screen as in Stage A. The marked box in Figure 8 shows the number of units to produce in Stage B. *[“Next to this number are the marginal cost and the total cost.*

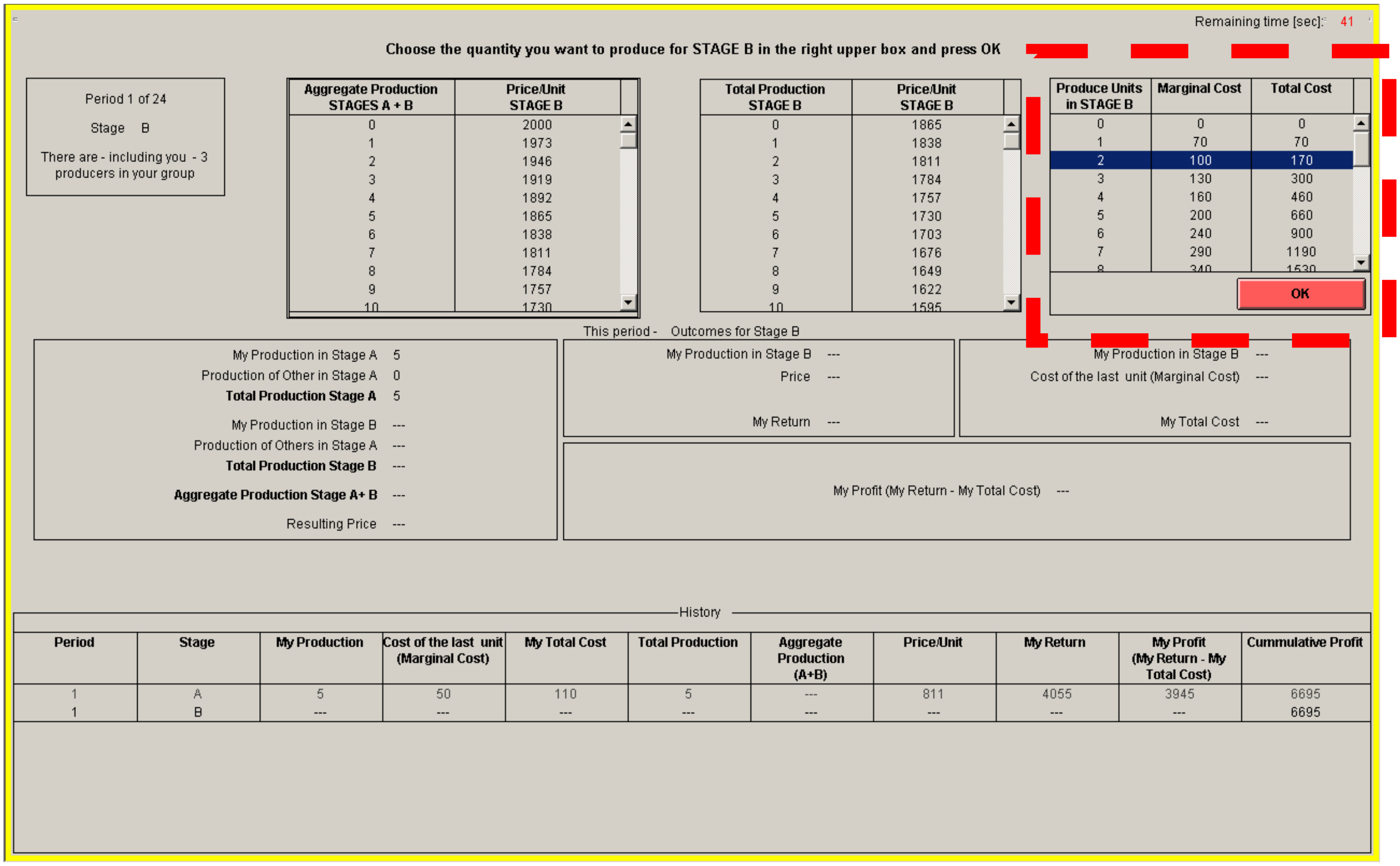
Suppose, as in the example in Figure 8, you sold 5 units in Stage A and that in Stage B you want to sell an additional 2 units. You then select 2 units as in the example in Figure 8.”; M2F, M3F]

[“Your total cost are then equal to the marginal cost of the first unit (35) and the marginal cost of the 2nd *unit (45), which is equal to 80 (35 + 45).”; M2F]*
[“Your total cost are then equal to the marginal cost of the first unit (70) and the marginal cost of the 2nd *unit (100), which is equal to 170 (70 + 100).”; M3F]*

[“Figure 8 ”; M2F]



[“Figure 8 ”; M3F]



Remaining time [sec]: 41

Choose the quantity you want to produce for STAGE B in the right upper box and press OK

Period 1 of 24

Stage B

There are - including you - 3 producers in your group

Aggregate Production STAGES A + B	Price/Unit STAGE B
0	2000
1	1973
2	1946
3	1919
4	1892
5	1865
6	1838
7	1811
8	1784
9	1757
10	1730

Total Production STAGE B	Price/Unit STAGE B
0	1865
1	1838
2	1811
3	1784
4	1757
5	1730
6	1703
7	1676
8	1649
9	1622
10	1595

Produce Units in STAGE B	Marginal Cost	Total Cost
0	0	0
1	70	70
2	100	170
3	130	300
4	160	460
5	200	660
6	240	900
7	290	1190
8	340	1530

OK

This period - Outcomes for Stage B

My Production in Stage A 5
Production of Other in Stage A 0
Total Production Stage A 5

My Production in Stage B ---
Production of Others in Stage A ---
Total Production Stage B ---

Aggregate Production Stage A+ B ---

Resulting Price ---

My Production in Stage B ---
Price ---

My Return ---

My Production in Stage B ---
Cost of the last unit (Marginal Cost) ---

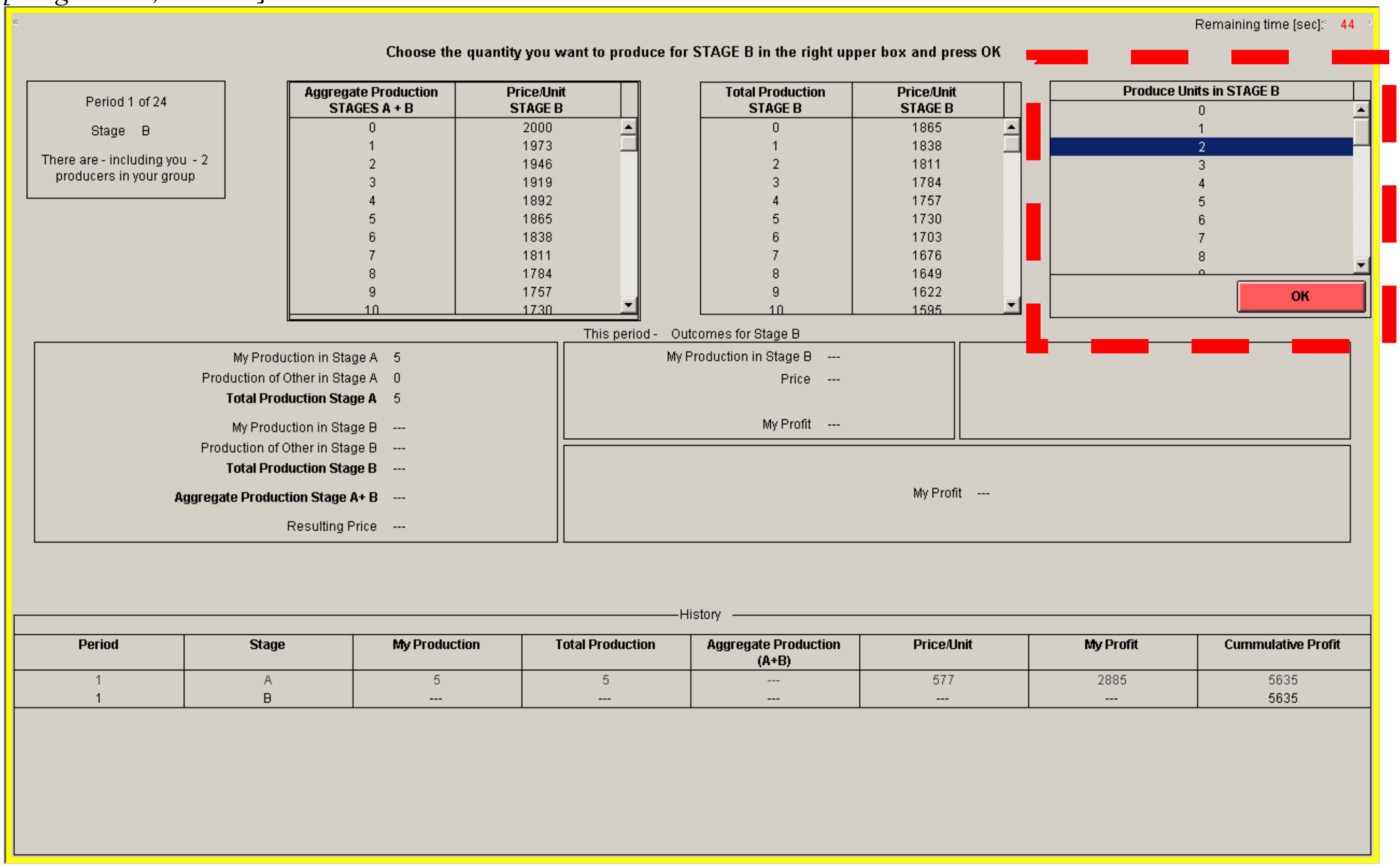
My Total Cost ---

My Profit (My Return - My Total Cost) ---

History

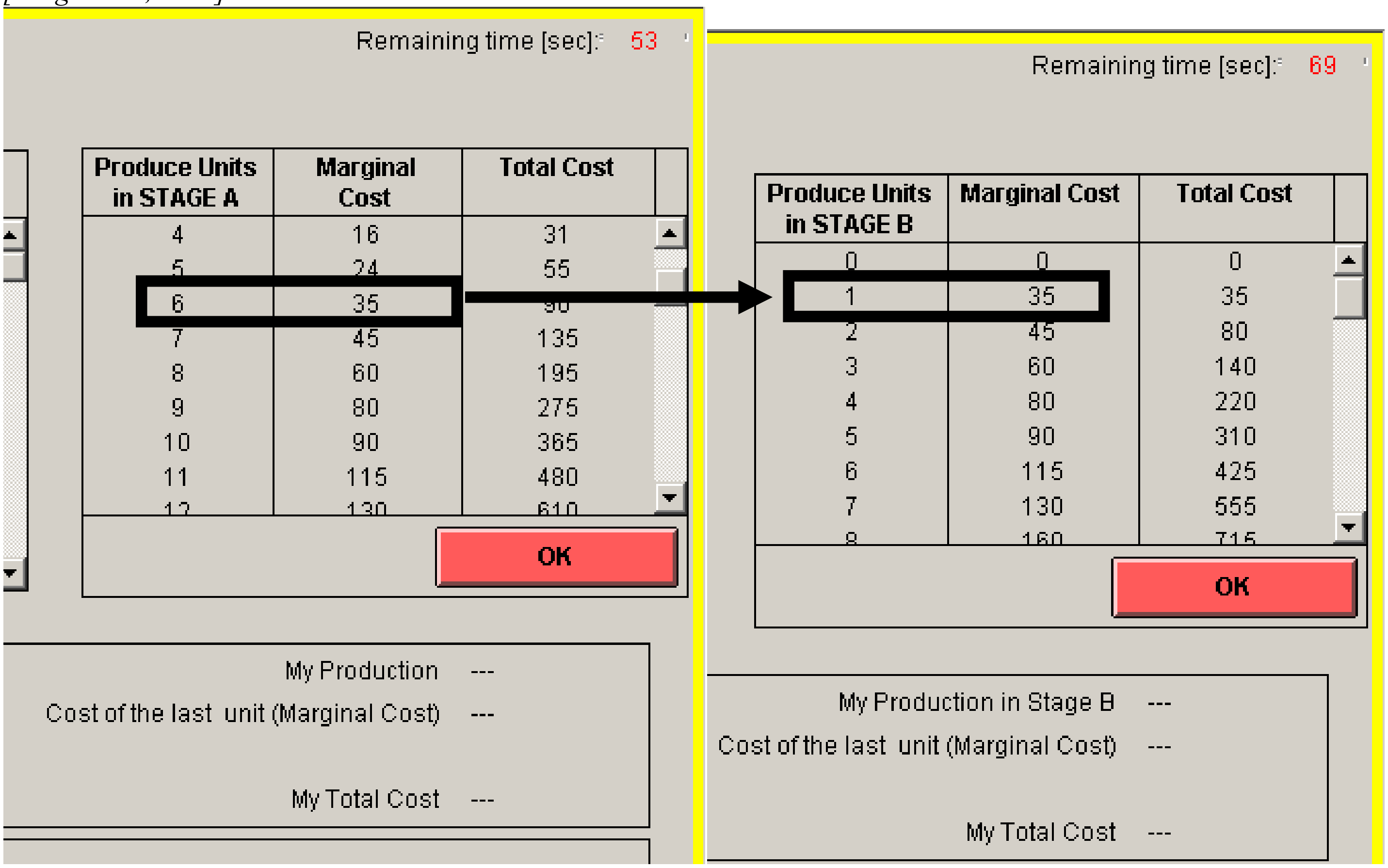
Period	Stage	My Production	Cost of the last unit (Marginal Cost)	My Total Cost	Total Production	Aggregate Production (A+B)	Price/Unit	My Return	My Profit (My Return - My Total Cost)	Cummulative Profit
1	A	5	50	110	5	---	811	4055	3945	6695
1	B	---	---	---	---	---	---	---	---	6695

[“Figure 8 ”; M2F-zc]

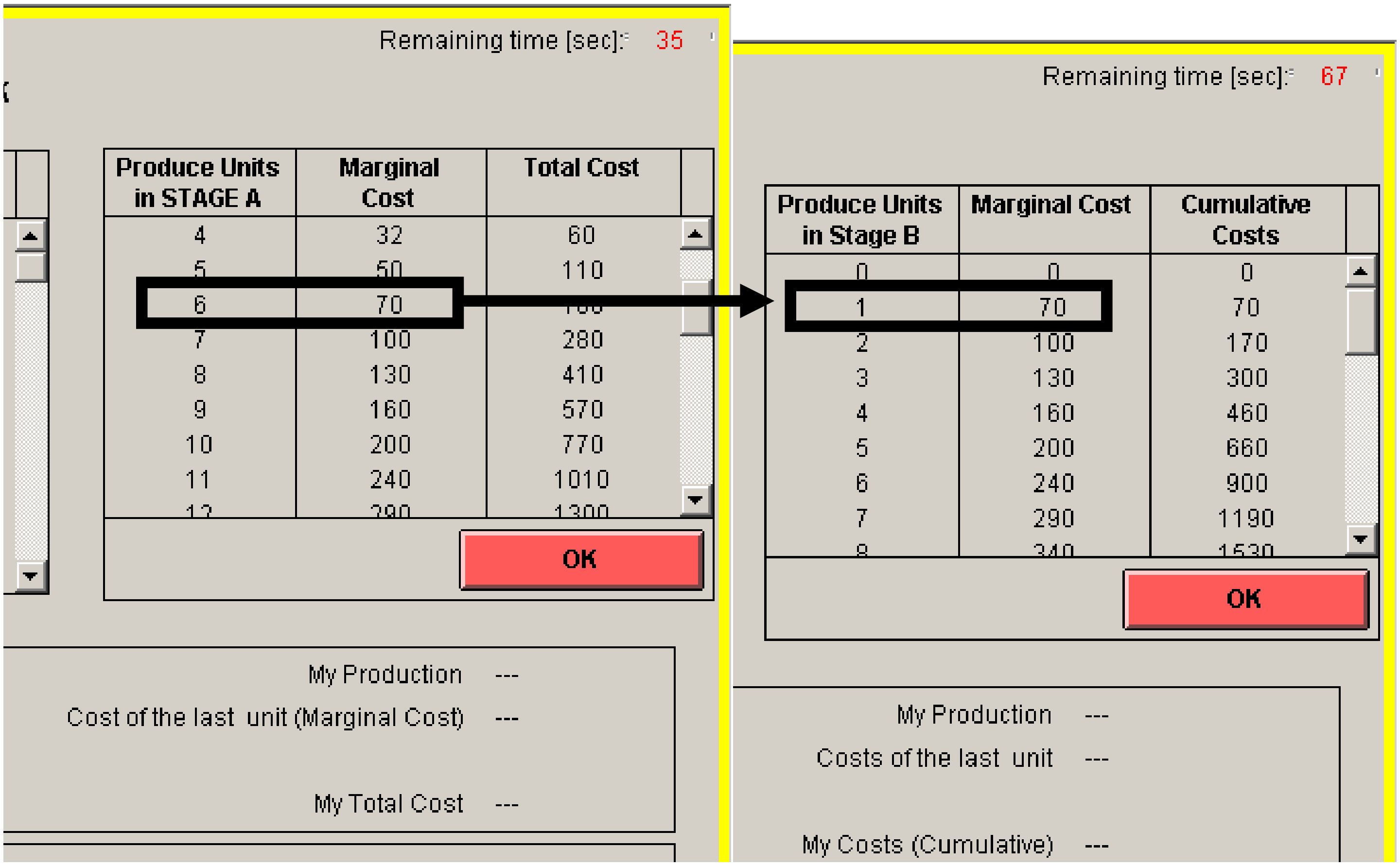


[“Note that the marginal costs in Stage B are the same ones as in Stage A, but we start counting from the number of units that were produced in Stage A. In the example in Figure 9 the producer produced 5 units in Stage A. On the right side are shown his marginal costs in Stage A, on the left his marginal costs in Stage B. In Stage B, the marginal cost of the 1^{st} unit is equal to that of the 6^{th} unit in Stage A, of the 2^{nd} unit to that of the 7^{th} unit in Stage A, of the 3^{rd} unit to that of the 8^{th} unit in Stage A, and so forth (a shift equal to the production in Stage A, which is 5).”; M2F, M3F]

[“Figure 9”; M2F]



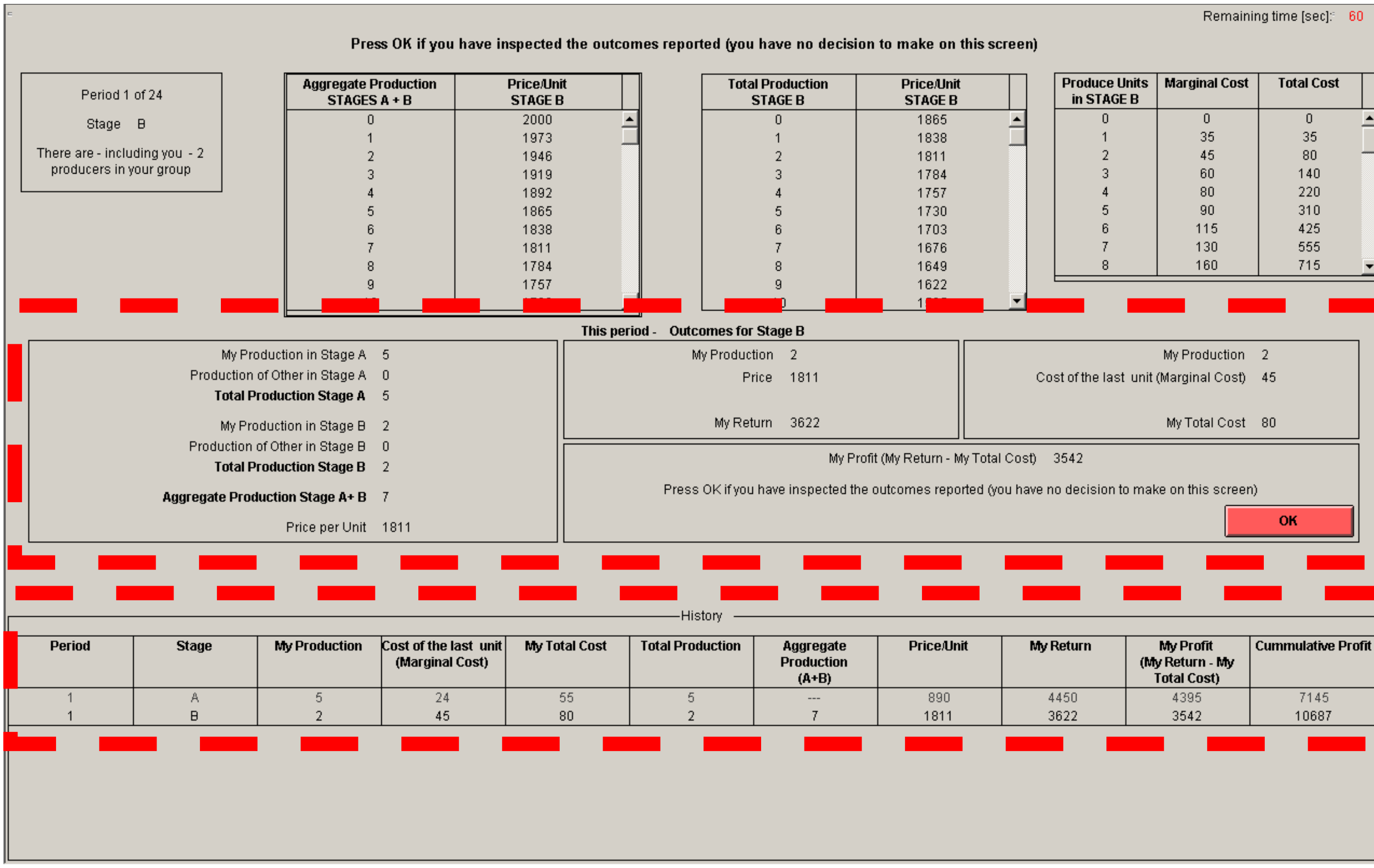
[“Figure 9”; M3F]



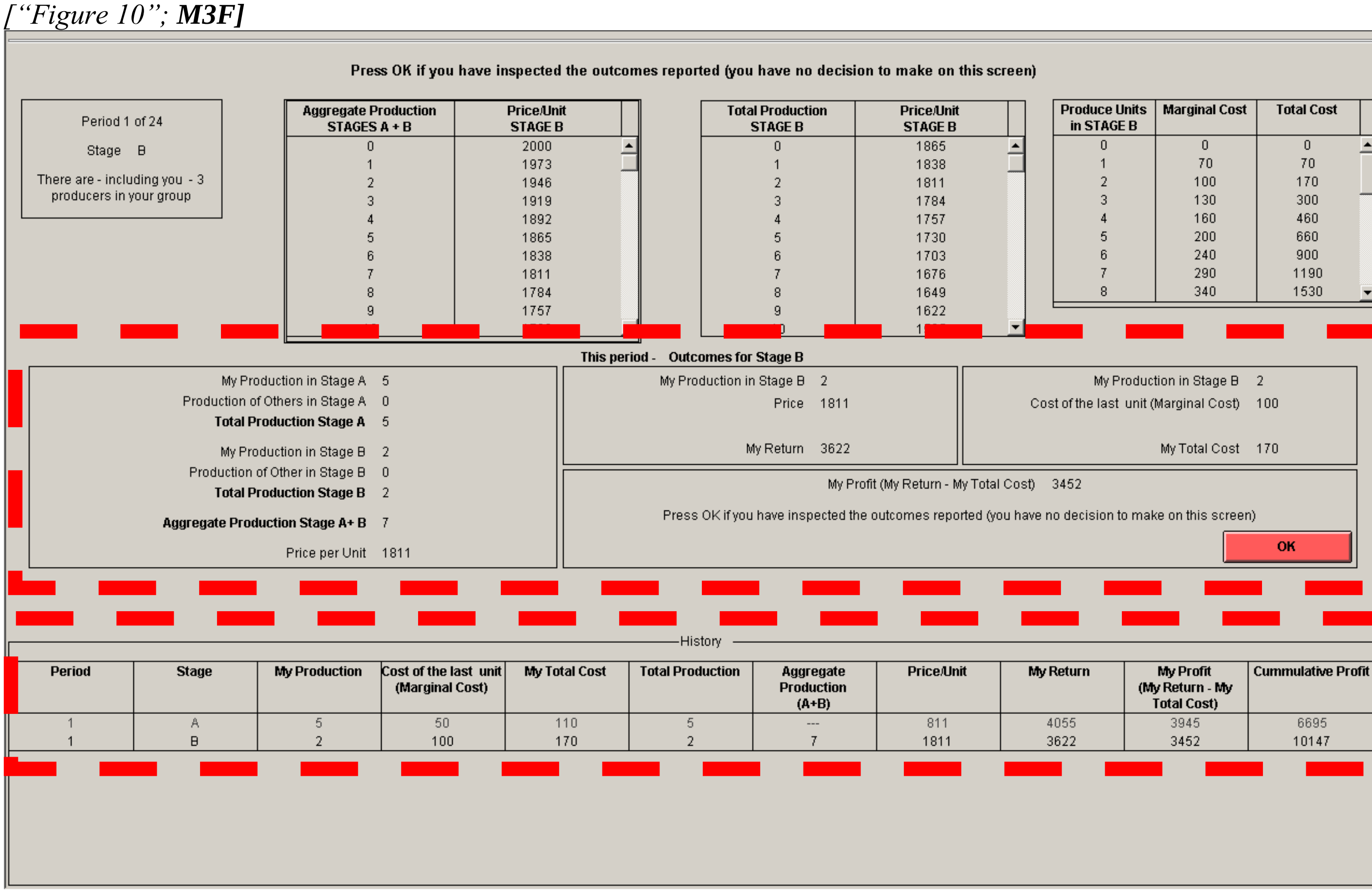
At the end of Stage B, you will again see a Results Screen showing similar information as the Results Screen described above. The Results Screen will show the outcomes for that period, displayed in the middle of your screen. You have **one minute** to inspect the outcomes.

The example in Figure *[“10”; M2F, M3F] [“9”; M2F-zc]* illustrates the display of the results in the middle box. You can also find all results in the History box, displayed in the lower part of your screen (the lower marked box in Figure *[“10”; M2F, M3F] [“9”; M2F-zc]*).

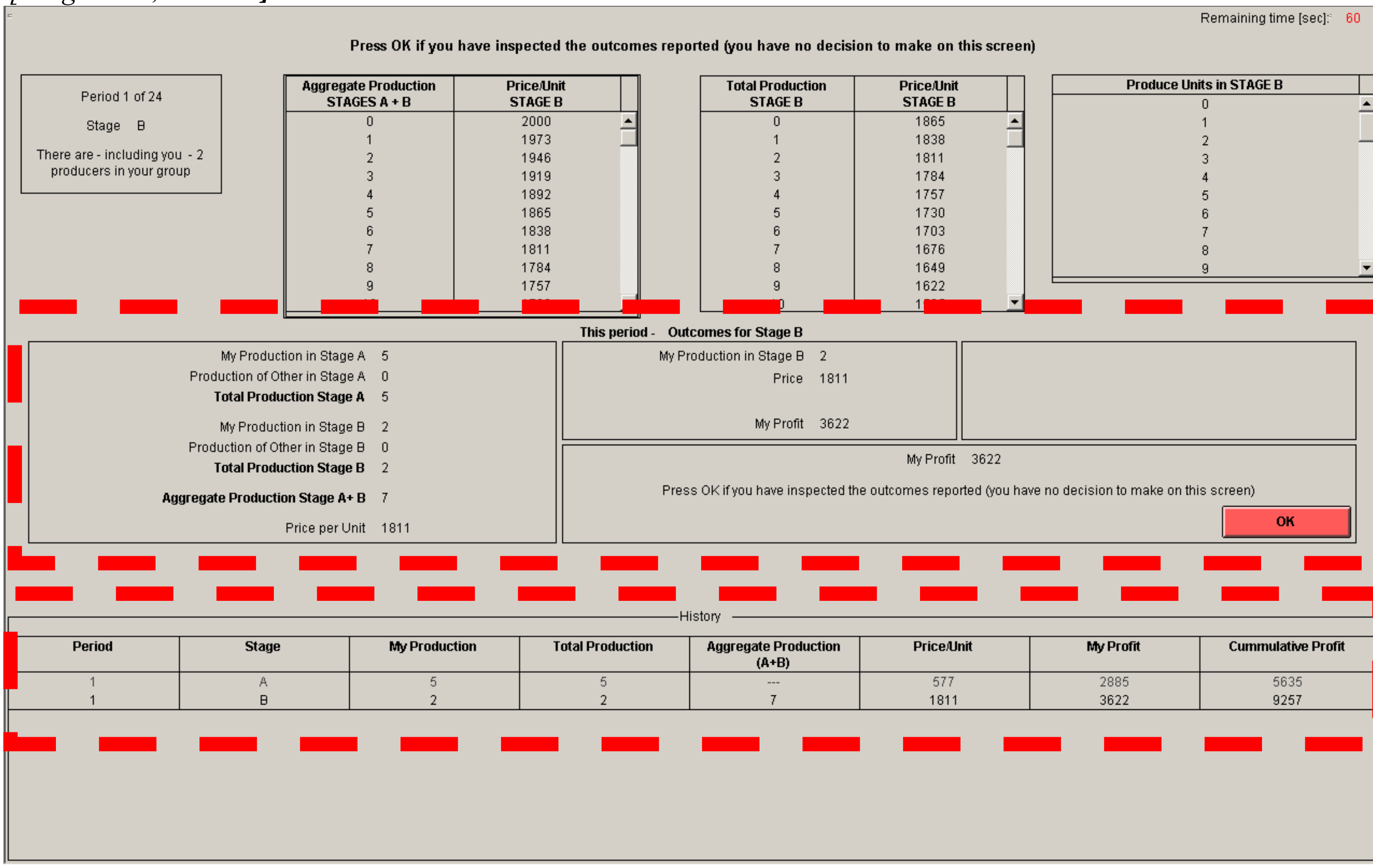
[“Figure 10”; ***M2F]***



[“Figure 10”; **M3F]**



[“Figure 9”; ***M2F-zc]***



[“Do you have any questions? The better you understand the setup, the better you will be able to make good decisions that increase your earnings.”;M2, M2-zc, M2F, M2F-zc, M3, M3F, M4]

[Only for M2F, M2F-zc, M3F]
The following questions serve to test your understanding of the key relationships in the decision task. Write down your answers. Use the Tables in the back of the instructions.

1. In round 1 total production in Stage A is 22 and the total production in B is 10

What is the price per unit in Stage A?	
What is the price per unit in Stage B?	

Answers:
1. In round 1 total production in Stage A is 22 and the total production in B is 10

What is the price per unit in Stage A?	***788; M2F*** ***271;M2F-zc*** ***739; M3F***
What is the price per unit in Stage B?	***1136; M2F, M2F-zc, M3F***

[End only for M2,F, M2F-zc, M3F]

[Only for M2,F, M3F]

2. In round 1 a Producer produces 3 units in Stage A, and then 7 units in Stage B.

What is the cost of the last unit (marginal cost) for the Producer in Stage A	
What is the cost of the last unit (marginal cost) for the Producer in Stage B	
What is the total cost of the Producer in round 1?	

Answers:
2. In round 1 a Producer produces 3 units in Stage A, and then 7 units in Stage B.

What is the cost of the last unit (marginal cost) for the Producer in Stage A	***9; M2F*** ***18; M3, M3F*** ***30; M4***
What is the cost of the last unit (marginal cost) for the Producer in Stage B	***90; M2, M2F*** ***200; M3, M3F*** ***345; M4***
What is the total cost of the Producer in round 1?	***365; M2F*** ***770; M3, M3F*** ***1320; M4***

[M2, M2F only]

Production Costs

Units Produced	Marginal Costs	Total Costs
1	1	1
2	5	6
3	9	15
4	16	31
5	24	55
6	35	90
7	45	135
8	60	195
9	80	275
10	90	365
11	115	480
12	130	610
13	160	770
14	180	950
15	210	1160
16	230	1390
17	260	1650
18	300	1950
19	330	2280
20	360	2640
21	410	3050
22	430	3480
23	490	3970
24	520	4490

Units produced	Marginal Costs	Total Costs
25	560	5050
26	620	5670
27	660	6330
28	710	f40
29	760	7800
30	810	8610
31	870	9480
32	920	10400
33	1000	11400
34	1050	12450
35	1100	13550
36	1150	14700
37	1230	15930
38	1320	17250
39	1350	18600
40	1450	20050
41	1500	21550
42	1600	23150
43	1650	24800
44	1750	26550
45	1800	28350
46	1900	30250
47	2000	32250
48	2050	34300

[M3, M3F only]

Production Costs

Units Produced	Marginal Costs	Total Costs
0	0	0
1	2	2
2	8	10
3	18	28
4	32	60
5	50	110
6	70	180
7	100	280
8	130	410
9	160	570
10	200	770
11	240	1010
12	290	1300
13	340	1640
14	390	2030
15	450	2480
16	510	2990
17	580	3570
18	650	4220
19	720	4940
20	800	5740
21	880	6620
22	970	7590
23	1060	8650
24	1150	9800
25	1250	11050
26	1350	12400
27	1450	13850
28	1600	15450
29	1650	17100
30	1800	18900
31	1950	20850
32	2050	22900

[M4 only]

Production Costs

Units produced	Marginal Costs	Total Costs
0	0	0
1	3	3
2	12	15
3	30	45
4	55	100
5	85	185
6	120	305
7	170	475
8	220	695
9	280	975
10	345	1320
11	420	1740
12	500	2240
13	590	2830
14	690	3520
15	790	4310
16	890	5200
17	1010	6210
18	1140	7350
19	1270	8620
20	1380	10000
21	1550	11550
22	1700	13250
23	1900	15150
24	2000	17150

[M2F only]

Total Production STAGE A and Resulting Price in STAGE A

Total production STAGE A	Price/unit STAGE A	Total production STAGE A	Price/unit STAGE A	Total production STAGE A	Price/unit STAGE A
0	921	**33**	723	**66**	218
1	915	**34**	717	**67**	191
2	909	**35**	711	**68**	164
3	903	**36**	705	**69**	137
4	897	**37**	699	**70**	110
5	890	**38**	693	**71**	83
6	884	**39**	688	**72**	56
7	878	**40**	682	**73**	29
8	872	**41**	676	**74**	2
9	866	**42**	670	**75**	0
10	860	**43**	664	**76**	0
11	854	**44**	659	**77**	0
12	848	**45**	653	**78**	0
13	842	**46**	647	**79**	0
14	836	**47**	641	**80**	0
15	830	**48**	636	**81**	0
16	824	**49**	630	**82**	0
17	818	**50**	624	**83**	0
18	812	**51**	619	**84**	0
19	806	**52**	596	**85**	0
20	800	**53**	569	**86**	0
21	794	**54**	542	**87**	0
22	788	**55**	515	**88**	0
23	782	**56**	488	**89**	0
24	776	**57**	461	**90**	0
25	770	**58**	434	**91**	0
26	764	**59**	407	**92**	0
27	758	**60**	380	**93**	0
28	752	**61**	353	**94**	0
29	746	**62**	326	**95**	0
30	740	**63**	299	**96**	0
31	734	**64**	272		
32	728	**65**	245		

[M2F-zc only]

Total Production STAGE A and Resulting Price in STAGE A

Total production STAGE A	Price/unit STAGE A	Total production STAGE A	Price/unit STAGE A	Total production STAGE A	Price/unit STAGE A
0	667	**33**	73	**66**	0
1	649	**34**	55	**67**	0
2	631	**35**	37	**68**	0
3	613	**36**	19	**69**	0
4	595	**37**	1	**70**	0
5	577	**38**	0	**71**	0
6	559	**39**	0	**72**	0
7	541	**40**	0	**73**	0
8	523	**41**	0	**74**	0
9	505	**42**	0	**75**	0
10	487	**43**	0	**76**	0
11	469	**44**	0	**77**	0
12	451	**45**	0	**78**	0
13	433	**46**	0	**79**	0
14	415	**47**	0	**80**	0
15	397	**48**	0	**81**	0
16	379	**49**	0	**82**	0
17	361	**50**	0	**83**	0
18	343	**51**	0	**84**	0
19	325	**52**	0	**85**	0
20	307	**53**	0	**86**	0
21	289	**54**	0	**87**	0
22	271	**55**	0	**88**	0
23	253	**56**	0	**89**	0
24	235	**57**	0	**90**	0
25	217	**58**	0	**91**	0
26	199	**59**	0	**92**	0
27	181	**60**	0	**93**	0
28	163	**61**	0	**94**	0
29	145	**62**	0	**95**	0
30	127	**63**	0	**96**	0
31	109	**64**	0		
32	91	**65**	0		

[M3F only]

Total Production Stage A and Resulting Price in Stage A

Total Production Stage A	Predicted (NE) price	Total Production Stage A	Predicted (NE) price	Total Production Stage A	Predicted (NE) price
0	833	33	693	66	218
1	829	34	688	67	191
2	824	35	684	68	164
3	820	36	680	69	137
4	816	37	676	70	110
5	811	38	672	71	83
6	807	39	668	72	56
7	803	40	663	73	29
8	799	41	659	74	2
9	794	42	655	75	0
10	790	43	651	76	0
11	786	44	647	77	0
12	781	45	643	78	0
13	777	46	639	79	0
14	773	47	635	80	0
15	769	48	630	81	0
16	764	49	626	82	0
17	760	50	622	83	0
18	756	51	618	84	0
19	752	52	596	85	0
20	747	53	569	86	0
21	743	54	542	87	0
22	739	55	515	88	0
23	735	56	488	89	0
24	730	57	461	90	0
25	726	58	434	91	0
26	722	59	407	92	0
27	718	60	380	93	0
28	713	61	353	94	0
29	709	62	326	95	0
30	705	63	299	96	0
31	701	64	272		
32	697	65	245		

[M2F, M2F-zc, M3F only]

Aggregate Production STAGES A + B and Resulting Price in Stage B

Aggregate Production Stage A+ B	Price/Unit STAGE B	Aggregate Production Stage A+ B	Price/Unit STAGE B	Aggregate Production Stage A+ B	Price/Unit STAGE B
0	2000	33	1109	66	218
1	1973	34	1082	67	191
2	1946	35	1055	68	164
3	1919	36	1028	69	137
4	1892	37	1001	70	110
5	1865	38	974	71	83
6	1838	39	947	72	56
7	1811	40	920	73	29
8	1784	41	893	74	2
9	1757	42	866	75	0
10	1730	43	839	76	0
11	1703	44	812	77	0
12	1676	45	785	78	0
13	1649	46	758	79	0
14	1622	47	731	80	0
15	1595	48	704	81	0
16	1568	49	677	82	0
17	1541	50	650	83	0
18	1514	51	623	84	0
19	1487	52	596	85	0
20	1460	53	569	86	0
21	1433	54	542	87	0
22	1406	55	515	88	0
23	1379	56	488	89	0
24	1352	57	461	90	0
25	1325	58	434	91	0
26	1298	59	407	92	0
27	1271	60	380	93	0
28	1244	61	353	94	0
29	1217	62	326	95	0
30	1190	63	299	96	0
31	1163	64	272		
32	1136	65	245		

[M2, M2-zc, M3, M4 only]

Total Production and Resulting Price

Production	Price/Unit
0	2000
1	1973
2	1946
3	1919
4	1892
5	1865
6	1838
7	1811
8	1784
9	1757
10	1730
11	1703
12	1676
13	1649
14	1622
15	1595
16	1568
17	1541
18	1514
19	1487
20	1460
21	1433
22	1406
23	1379
24	1352
25	1325
26	1298
27	1271
28	1244
29	1217
30	1190
31	1163
32	1136

Production	Price/Unit
33	1109
34	1082
35	1055
36	1028
37	1001
38	974
39	947
40	920
41	893
42	866
43	839
44	812
45	785
46	758
47	731
48	704
49	677
50	650
51	623
52	596
53	569
54	542
55	515
56	488
57	461
58	434
59	407
60	380
61	353
62	326
63	299
64	272
65	245

Production	Price/Unit
66	218
67	191
68	164
69	137
70	110
71	83
72	56
73	29
74	2
75	0
76	0
77	0
78	0
79	0
80	0
81	0
82	0
83	0
84	0
85	0
86	0
87	0
88	0
89	0
90	0
91	0
92	0
93	0
94	0
95	0
96	0