



# Ascending price Vickrey auctions for general valuations<sup>☆</sup>

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## Abstract

Ascending price auctions involving a single price path and buyers paying their final bid price cannot achieve the Vickrey–Clarke–Groves (VCG) outcome in the combinatorial auctions setting. Using a notion called *universal competitive equilibrium* prices, shown to be necessary and sufficient to achieve the VCG outcome using ascending price auctions, we define a class of ascending price auctions in which buyers bid on a single price path. Truthful bidding by buyers is an ex post Nash equilibrium in such auctions. By giving discounts to buyers from the final price, the VCG outcome is achieved for general valuations.

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## 1. Introduction

Ascending price auctions are preferred over their sealed-bid counterparts in practical settings [10,9,25]. In the context of selling a single item, the ascending price English auction shares the economic efficiency of the sealed-bid second-price Vickrey auction [31] for private value models.

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The sealed-bid Vickrey–Clarke–Groves (VCG) mechanism [31,8,15] generalizes the Vickrey auction to combinatorial auctions [29,30] with multiple items and general (private) non-additive valuations and retains its ex post efficiency and dominant-strategy incentive-compatibility properties. Taken together, the economic properties of the VCG mechanism and the practical benefits of an ascending price auction have generated interest in designing efficient ascending price combinatorial auctions, achieving the outcome of the VCG mechanism. Several papers have addressed this issue for restricted valuation domains: for the one-to-one assignment problem by Demange et al. [13], for homogeneous items with non-increasing marginal valuations by Ausubel [1], for heterogeneous valuations with gross substitutes valuations by Ausubel and Milgrom [3] and de Vries et al. [11].

For a general private valuations model, i.e., with no externalities and free disposal but no other restrictions on valuations (such as requirement that items are substitutes of each other), there is a negative result due to de Vries et al. [11]. They show that gross substitutes valuations are almost the largest valuation domain for which an ascending price auction can achieve the VCG outcome. Of course, this negative result depends on how an ascending price auction is defined. These authors adopted a definition in which the auction should have a single price path (a sequence of increasing prices) and the buyers should pay the final price in this price path. Unlike an earlier definition of an ascending price auction, due to Gul and Stacchetti [16], they did not restrict prices to item prices but allowed a non-anonymous (i.e., personalized for every buyer) and non-linear (i.e., non-additive over items) price path.

To overcome this impossibility, one needs to relax the definition of an ascending price auction. One possible relaxation is to allow multiple price paths in an auction. For instance, in the restricted case of gross substitutes valuations, Ausubel [2] defines an auction that uses multiple price paths where the prices quoted on each path are anonymous and linear. Combining information from all price paths, Ausubel's auction is able to incrementally determine the VCG payments to be made by buyers upon termination. This idea is further generalized by de Vries et al. [11], who show that their auction can be run multiple times, once for every buyer, to calculate the VCG payments of buyers for general valuations.

The use of multiple price paths in these auctions requires each buyer to bid on price paths which are only used to calculate payment of a specific buyer and serve no other purpose. This is not appealing in practice because buyers have no incentive to participate in such price paths. Besides, introducing multiple price paths creates overhead for buyers to bid in an auction. It also has less transparency and simplicity than a single price path auction. For this reason, the following question merits research and is the focus of this paper:

Is there a relaxation of the traditional definition of ascending price auctions which maintains a single price path and still terminates with the VCG outcome for general valuation profiles in an ex post Nash equilibrium?

In pursuit of an answer to this question, we explore an alternative relaxation of the definition of ascending price auctions in de Vries et al. [11] that maintains a single price path. We allow the final payments made by each buyer to differ from the final clearing prices. In fact, this relaxation is already present in Ausubel's auctions [2,1]. The final payments made by each buyer in our auctions can be determined either as a one-time discount from the final clearing prices or dynamically during the auction. In this sense, one can consider that our auctions generalize Ausubel's single price path auction [1] from diminishing marginal values to arbitrary preferences. We believe that the use of a single price path together with incremental discounting makes for transparent and simple combinatorial auctions.

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